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## WORKSHOP 2003

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These are the Proceedings of the Tenth Annual university-wide seminar WORKSHOP 2003 which took place at the Czech Technical University in Prague from 10th to 12th February, 2003.

The aim of the seminar is to present and discuss the latest results obtained by researchers especially at the Czech Technical University in Prague and at collaborating institutions.

The organizing committee has selected a total of 563 contributions divided into 15 different areas of interest:

- **Part A:**
  - mathematics
  - physics
  - informatics and automation engineering
  - electronics and instrumentation
  - materials engineering
- **Part B:**
  - mechanics and thermodynamics
  - mechanical engineering
  - production systems and technology
  - energetics and power engineering
  - nuclear engineering
  - chemistry
  - biomedical engineering
  - civil engineering
  - architecture and town planning
  - transportation, logistics, economy, management



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# CONTENTS

## 1. MATHEMATICS

Online Preparatory Course in Mathematics ..... 22
*J. Černý, M. Kočandrlová, I. Křivková*

A Combined Type of Examinations in Basic Courses of Mathematics ..... 24
*F. Bubeník*

Center of Active Learning ..... 26
*J. Černý*

Mathematical Properties of Fuzzy Logics ..... 28
*R. Horčík*

Online Course on Numerical Mathematics ..... 30
*Z. Šibrava, A. Wohlmuthová, P. Kučera, O. Zindulka, M. Ludvíková*

Numerical Solution of Nonlinear Problems from Fluid Dynamics ..... 32
*P. Sváček*

Development of the External Interpolation Module for Microsoft Excel ..... 34
*I. Linkeová*

Project of using webMathematica on CTU ..... 36
*L. Prskavec, L. Musil, O. Matička*

Constructive Geometry Teaching Innovation for Study Program Geodesy and Cartography ..... 38
*H. Dvořáková, J. Dvořák, J. Hnojil*

Numerical Solution of Incompressible Viscous Flows through Channels ..... 40
*V. Prokop, K. Kozel, R. Keslerová*

Finite Element Solution of 2D Flow Problem in a Channel with Singularities ..... 42
*P. Burda, J. Novotný, B. Sousedík, M. Jelínek*

Reconstruction from Many Images ..... 44
*D. Martinec, T. Pajdla*

Mixed-hybrid Discrete Fracture Network Model of the Flow through a Rock Massif: Numerical Analysis of the Developed Model and its Calibration ..... 46
*M. Vohralík, J. Maryška, O. Severýn*

Some Applications of Differential Equations in Mechanics ..... 48
*P. Kučera, M. Beneš*

## 2. PHYSICS

Improvement of Physics Teaching Based on Student Laboratory Work at Faculty of Transportation Sciences ..... 52
*Z. Malá, D. Nováková*

Physics Experiments in Optics and Optoelectronics at CTU ..... 54
*D. Nováková, Z. Malá, R. Novák, J. Pospíšil, V. Vacek*

The Innovation of Physics Teaching at Faculty of Transportation Sciences CTU ..... 56
*Z. Malá, D. Nováková*

Radiation Damage in YAlO3:Ce and YAlO3:Ce, Zr Scintilators ..... 58
*J. Mareš, J. Pejchal, M. Nikl, V. Múčka, M. Pospíšil, R. Silber*

Spin Correlations of Top-Antitop Quarks Produced in Proton-Proton and Antiproton-Proton Interactions at 14 TeV and 2 TeV ..... 60
*K. Smolek*

Non Thermal Plasma Technologies for VOC Decomposition ..... 62
*S. Pekárek*

Visualization of High Current Discharges at Atmospheric Pressure ..... 64
*P. Barvíř, J. Kravárik, P. Kubeš*

Signal Processing of Time - Depending Signals of Periodically Working Machines ..... 66
*I. Bláhová, O. Jiříček, M. Brothánek*

Detection of Neutrons at PF-1000 Facility ..... 68
*P. Kubeš, J. Kravárik, P. Barvíř, D. Klír, M. Scholz, K. Tomaszewski*

Modelling of GaAs Stress-strain Curves and Photoplastic Effect ..... 70
*R. Lohonka, J. Kratochvíl, G. Vanderschaeve*

Modelling of Plastic Zone around Vickers Indent. Analytical Approach. ..... 72
*R. Lohonka, G. Vanderschaeve, J. Kratochvíl, C. Levade*

Mathematical Methods in the Physics of Microworld ..... 74
*J. Tolar, Č. Burdík, M. Havlíček, L. Hlavatý, G. Chadzitaskos, E. Pelantová, I. Jex, M. Beneš, V. Svoboda, P. Šťovíček*

Double Beta Decay Experiment NEMO3 - Current Status and Czech Contribution ..... 76
*L. Vála, I. Štekl*

Acoustic Emission Study of Cleavage Initiation in Notched Tensile Specimens of Low-alloy Steel ..... 78
*P. Haušild, M. Karlík, F. Chmelík*

Algorithms for Phase Evaluation in Interferometric Measurement Techniques ..... 80
*J. Novák*

Analysis of Evaluation Process in Interferometric Technique for Deformation Measurement ..... 82
*J. Novák*

Low Frequency Waves in Plasma Fibers with Gravitational Field ..... 84
*V. Kaizr*

Analysis of Force Fields of Power Redistributed Optical Beams ..... 86
*A. Mikš, J. Novák*

Approximation of Wavefronts in Optical Testing Techniques ..... 88
*A. Mikš, J. Novák*

Modern Optical Techniques for Testing of Quality of Optical Elements ..... 90
*A. Mikš, J. Novák*

Solid-state Saturable Absorbers for Neodymium Lasers ..... 92
*A. Dombrovský, V. Kubeček*

Photovoltaic Properties of Fe:LiNbO3 ..... 94
*M. Bodnár, P. Hříbek*

Modification of Polymer Layers by Atmospheric Pressure Corona Discharge ..... 96
*J. Koller, L. Aubrecht*

Discharge Tube with Virtual Cathode ..... 98
*L. Seidelmann, L. Aubrecht*

A Study of the Cooling Facility in Preparation for the ATLAS Inner Detector Testing ..... 100
*V. Vacek*

Numerical Simulation of Plasma Fibers Energy Losses ..... 102
*D. Břeň, V. Kaizr*

Interactive Physics via Java Applets (FEE CTU) ..... 104
*P. Kulhánek, K. Řezáč, D. Břeň, J. Pašek, M. Žáček, V. Kaizr*

Determination of Thermophysical Properties of HFC Refrigerants by Molecular Simulations ..... 106
*R. Budinský, V. Vacek, M. Lísal*

Study of Theoretical Models of the Pinches with Helicity Structure ..... 108
*M. Žáček*

Study of DLC Thin Films Prepared on Si and Metal Substrates ..... 110
*D. Palamarčuk, J. Gurovič, F. Černý, M. Zoriy*

Mechanism of Subgrains Formation in Metals Induced by Creep ..... 112
*J. Kratochvíl, R. Sedláček*

The Model of Dislocation Structure Formation Based on the Theory of Continuous Distribution of Dislocations ..... 114
*J. Kratochvíl*

Simulations of Femtosecond X-Ray Emission from Aluminum Targets Irradiated by Short Laser Pulses ..... 116
*J. Limpouch, V. Bína, O. Klimo, L. Drška, M. Šiňor*

Laser Interferometry in Ultrasonic Physics ..... 118
*Z. Šlegrová, R. Bálek*

Ablation of Materials by a Single Pulse of Soft X-Rays Emitted from Laser-Produced Plasmas ..... 120
*R. Viskup, L. Juha, J. Krása*

Shallow Traps Energies in SrTiO3 Crystals Doped with Manganese ..... 122
*Z. Bryknar, P. Ptáček, Z. Potůček*

New Passivation Materials Power Semiconductors ..... 124
*S. Vacková, J. Gurovič, J. Vobecký, F. Černý, A. Macková, D. Kolesnikov*

Sound Quality Evaluation of Areo-acoustic Devices ..... 126
*R. Jurč*

Influence of Temperature Gradient on the Function of CdTe gamma Detectors ..... 128
*S. Vacková, T. Horažďovský, O. Majlingová, V. Gorodinskij, K. Žďánský, K. Vacek*

CEDOS – Center for Diffractive Optical Structures ..... 130
*P. Fiala, I. Richter, M. Škereň, J. Kratochvil, D. Najdek, M. Květoň*

Multi-focus Diffractive Optical Elements ..... 132
*M. Škereň, P. Fiala, I. Richter*

Realisation of Selected Optical Transformations ..... 134
*J. Kratochvil, P. Fiala, I. Richter*

Maxwell‘s Demon Attracts Attention Again ..... 136
*J. Jelen*

Laboratory Exercises in Vacuum Technology ..... 138
*R. Novák, T. Kubart, T. Polcar*

Ultrasonic System for Identification of Fluids in Closed Containers ..... 140
*R. Bálek, Z. Šlegrová*

Powder Neutron Diffraction Study of Ceramic Synthesis of the Pr(1-x)Na(x)MnO(3) ..... 142
*M. Dlouhá, S. Vratislav, Z. Jirák*

The Study of x-T phase Diagram of Rb(1-x)(NH(4))(x)I Mixed Crystals
by Neutron Scattering ..... 144
*M. Dlouhá, S. Vratislav, L. Smirnov*

Spectrophotometer Calibration Using Common Thungsten Bulb Light Source ..... 146
*P. Sněhota*

XUV Spectroscopic Measurement on Carbon Fibre Z-Pinch ..... 148
*D. Klír, J. Kravárik, P. Kubeš*

Passively Mode-Locked Diode Pumped Nd:YAG Lasers ..... 150
*V. Kubeček, A. Dombrovský, K. Zvoníček, J. Diels, A. Stintz*

Bidirectional Operation of Diode Pumped Nd:YVO4 Laser with Ring Resonator ..... 152
*K. Zvoníček, V. Kubeček*

Corona Discharge Interferometric Study ..... 154
*J. Píchal*

Luminescence of Defects in Undoped Crystals of Incipient Ferroelectrics KTaO3 ..... 156
*Z. Potůček, Z. Bryknar*

Generation of Ozone by Electrical Discharges ..... 158
*J. Rosenkranz, S. Pekárek*

Modelling of Magnetron Magnetic Systems ..... 160
*T. Kubart, R. Novák*

Implementation of IIR filters in ANC Controllers ..... 162
*O. Jiříček, M. Brothánek*

Application of Local ANC in Passanger Seat ..... 164
*O. Jiříček, M. Brothánek*

High Energy Radiation Delivery by Hollow Waveguides in Mid-infrared Spectral Region ..... 166
*M. Němec, H. Jelínková, J. Šulc, P. Černý, Mitsunobu Miyagi, Katsumasa Iwai, Yukio Abeb, Yi-Wei Shi, Yuji Matsuura*

Interactive Physics via Java Applets ..... 168
*M. Šiňor, L. Drška*

Using Point Source Array for Modeling of Oblique Wave Impact on Liquid-Solid Interface ..... 170
*M. Šiňor, M. Landa*

Stimulated Raman Scattering in Crystals Nd:SrWO4 and SrMoO4 in Picosecond Region: Comparative Study ..... 172
*P. Černý, H. Jelínková, J. Šulc, M. Doroschenko, P. Zverev, A. Komiakova, V. Skornjakov, T. Basiev*

Nd:SrWO4 Raman Laser ..... 174
*J. Šulc, M. Doroschenko, V. Skornjakov, H. Jelínková, P. Černý, P. Zverev, T. Basiev*

Difference Schemes for Conservation Laws and Hydrodynamics Modelling in Plasma Physics ..... 176
*R. Liska, L. Drška, Z. Jeriová, M. Kuchařík, J. Limpouch, M. Šiňor, P. Váchal*

Application of an X-Ray Fluorescence Method for Analysis of Inks and Pigments in Medieval Manuscripts ..... 178
*T. Čechák, L. Musílek, T. Trojek, J. Šimečková*

Temporal Variability of Several Radon Charakteristics of the Soil ..... 180
*A. Ridziková*

Transient Absorption of a Bichromophore ..... 182
*M. Dvořák, C. Grimm, J. Zerbst, J. Schroeder, V. Fidler*

Bichromophoric Molecule with Vibrational Probe – Computational Study ..... 184
*P. Špulák, M. Michl, V. Fidler*

## 3. INFORMATICS & AUTOMATION ENGINEERING

Simulated Enterprise Integrated System (SEIS) ..... 188
*M. Ota, I. Jelínek*

Some Theoretical Problems of Plate Digital Terrain Model Construction ..... 190
*L. Vaníčková, T. Vaníček*

Rule Extraction Using Artificial Neural Networks ..... 192
*M. Jakob*

Implementation of Information Databases DNEP into the Information System of the CTU ..... 194
*E. Šmídová, K. Lejčková, M. Přeučil, B. Říha, M. Tocháček, P. Komárek, L. Pavlík*

Arrangement of Access Networks and Properties of Subscriber Lines ..... 196
*J. Hrad*

Presentation of Results in Impulse Noise and Education ..... 198
*T. Zeman*

Simulation of Natural Environment in Virtual Reality ..... 200
*J. Chludil, J. Žára*

Optimized Mobile Robot Path Planning Methods ..... 202
*J. Pavlíček, L. Přeučil*

Simultaneous Localization and Map Building for Intelligent Mobile Robotics ..... 204
*R. Mázl, L. Přeučil*

Next Generation Network ..... 206
*J. Baloun, V. Lojík*

Depth-of-Field Rendering for Point-Based Object ..... 208
*J. Křivánek*

BR(1) Scheme for Fault-Tolerant Multicast ..... 210
*V. Dynda*

Implementation of Standardized Processing of Personal Data ..... 212
*P. Zácha, P. Vandrovec, I. Březina*

Extension of Parametric Design in Knowledge Modelling ..... 214
*M. Štefan, M. Valášek*

Generalization of Min Cut Graph Algorithm for Concurrent Engineering ..... 216
*M. Štefan*

Interaktivní tvorba a prohlížení grafické informace nevidomými uživateli ..... 218
*Z. Míkovec, P. Slavík*

Efficiency of Distributed Object Interface ..... 220
*J. Lukeš*

Intelligent Hypermedia ..... 222
*P. Štengl*

Distributed Shared Memory: Home Based Consistency Protocol ..... 224
*V. Jonáš*

The Study of the Properties of Independent (Decentralized) and Centralized Control of Redundant Parallel Robots ..... 226
*K. Belda, J. Böhm, M. Valášek*

Data-Mining and Decision-Support Systems Integration ..... 228
*J. Kléma, F. Železný*

Computational Stereoscopic Vision ..... 230
*J. Kostková, R. Šára*

360x360 Omnidirectional Camera ..... 232
*B. Mičušík, T. Pajdla*

Convergence of the Expectation Minimization Algorithm for the Conditionally Independent Model to the Global Maximum ..... 234
*V. Franc*

Formal Parallel Translation Directed by Parallel LLP(q,k) Parser ..... 236
*L. Vagner, B. Melichar*

Dynamic Generation of Test Sequences for Reactive Systems ..... 238
*T. Hlavatý, L. Přeučil*

Non-central Cameras for 3D Reconstruction ..... 240
*H. Bakstein, T. Pajdla*

Wavelet-Based Rate Scalable Image Coding ..... 242
*Farag Elnagahy, B. Šimák*

Wavelet-Based Rate Scalable Video Coding ..... 244
*Farag Elnagahy*

Influence of Network QoS Characteristics on MPEG Video Transmission ..... 246
*J. Vojtěch, S. Ubik*

System of Autonomous Cooperating Agents for Disaster Reconstruction ..... 248
*J. Vokřínek*

Peer-to-Peer Search Engine ..... 250
*A. Morávek, I. Jelínek*

Can Video Data Stream Improve the Audio Signal? ..... 252
*M. Brát, M. Šnorek*

Aldebaran ..... 254
*J. Pašek, D. Břeň*

Methods of the Image Quality Assessment ..... 256
*J. Dušek, K. Roubík*

Development of Study Materials for On-line Distance Learning ..... 258
*P. Soukup, M. Huml, M. Čábelka*

Multi-agent Systems in Virtual Organizations ..... 260
*A. Říha*

Modeling of Agents' Rational Reasoning on TAC (Trading Agent Competition) ..... 262
*J. Hodík*

Data Acquisition and Pre-processing for Vehicle Gearbox Diagnostics ..... 264
*P. Večeř, R. Šmíd, M. Kreidl*

Discrete Approximation of Linear Models with Delays in States and in Inputs ..... 266
*M. Hofreiter*

Tuning and Evaluating TCP End-to-End Performance in LFN Networks....268
*P. Cimbál*

The Lossless Data Compression....270
*M. Bouzek*

Formal Description of Design in Visual Prolog....272
*Z. Šilar, I. Jelínek*

The Scientific Image Data Optical Processing....274
*P. Páta*

Mobile Multimedia Collaboration and Annotation within the EU Project MUMMY....276
*M. Klíma, Z. Míkovec, P. Slavík*

Data Mining – Automatic Data Preprocessing....278
*P. Aubrecht*

Detection and Tracking of Moving Objects in Jittered Images....280
*M. Jiřina, J. Vařečka, D. Ptáček*

Face Detection from Discriminative Regions....282
*P. Bílek*

Usage of the Optimal Normal Basis in the Elliptic Curve Cryptosystems....284
*T. Vaněk*

Pattern Matching in Compressed Text....286
*J. Lahoda, B. Melichar*

Local Affine Frames for Object Recognition....288
*Š. Obdržálek*

Common Subsequence Automaton....290
*Z. Troníček*

A Simulation of Supervisory Human Operator Cognitive Processes....292
*L. Janků, M. Šorf, V. Křemen, M. Fejtová*

Distributed Computer of Space Facility - Software architecture....294
*J. Zděnek*

Teachers‘ Training for New Programming Courses in Structured Study....296
*J. Kolář, K. Müller, M. Bloch*

Planar Circuits for MW and MMW Technology....298
*J. Zehentner, J. Macháč*

SIP, Firewall and NAT....300
*J. Růžička*

Genetic Algorithms with Limited Convergence....302
*J. Kubalík, J. Lažanský, L. Rothkrantz*

FPGA Implementation of USB 1.1 Device Core....304
*P. Kubalík, J. Buček*

Evolutionary Techniques in Physical Design for FPGAs ..... 306
*M. Daněk, H. Kubátová, Z. Muzikář*

Overload Protecting Methods for SCP Equipment in Intelligent Network and Their Simulation ..... 308
*P. Hofman*

Intelligent Computer Support Methods for Conceptual Design of Systems ..... 310
*J. Bíla*

A Flexible Minimization and Partitioning Method ..... 312
*P. Fišer, J. Hlavička*

Formalization of Ontologies by Means of OMT and UML ..... 314
*J. Bíla*

Optimizing of Neural Networks Using a Genetic Algorithm ..... 316
*A. Kučerová, J. Drchal, J. Němeček, M. Lepš*

Exploration of Design Space in ECDSA ..... 318
*J. Schmidt, M. Novotný, M. Jäger, M. Bečvář, M. Jáchim*

Communication in Componentized Systems ..... 320
*V. Miléř, B. Hudec*

Simulation and Visualization of Combustion Processes in Pulverized Coal Boilers ..... 322
*M. Gayer*

Colour Rough Texture Synthesis ..... 324
*J. Filip, M. Haindl*

The Longest Common Subsequence Problem - A Finite Automata Approach ..... 326
*T. Polcar, B. Melichar*

Text Processing by Binary Neural Networks ..... 328
*T. Beran*

Integrated „Paper“ and Electronic Course in English for Civil Engineering ..... 330
*S. Kasíková, H. Horká, V. Sedláková, M. Vobecká*

Experimental Dual Thread Processor Core ..... 332
*M. Jäger*

Differential Measurement Methods in Global Satellite Navigation Systems ..... 334
*L. Seidl*

Innovation of the Computer Laboratory for Basic Study Students ..... 336
*J. Klusoň, Z. Berka, T. Čechák, L. Škoda*

Comparison of Exact SLE Solving Methods Using the GMP Library and Residual Arithmetic ..... 338
*R. Lórencz, P. Mikšík*

Error-Free Parameter Extraction Using GMP Library and Maple ..... 340
*R. Lórencz, T. Zahradnický*

Algorithm for Computing Modular Inverse Using the Montgomery Almost Inverse – Hardware Implementation ..... 342
*R. Lórencz, J. Hlaváč*

Courseware Development Tool Sets for E-Learning in Exact Sciences ..... 344
*L. Drška*

Intelligent Database of Solved Problems for Knowledge Sharing across the Internet ..... 346
*M. Ševčenko*

Comparation of Formal Approaches to Data Reverse Engineering ..... 348
*M. Hnátek*

Methods for Cooperation and Coordination of Multiple Autonomous Robots ..... 350
*P. Štěpán, M. Kulich, L. Přeučil*

Fault Injection for Time Triggered Architecture (FIT) ..... 352
*H. Kubátová, J. Hlavička, J. Kolář, S. Racek*

Optimization of Simple CPU Core for FPGA ..... 354
*M. Bečvář*

Simulation of High Speed Networks Using Ns2 ..... 356
*J. Klaban*

Modeling a Rail Wheelset for Radial Position Control Analysis ..... 358
*J. Dvořák, B. Šulc*

Subjective Quality Aspects of Image Compression in Multimedia ..... 360
*M. Klíma*

Laboratory Exercises for „Tools of Automatic Control“ ..... 362
*J. Chyský, L. Novák, D. Bauerová*

Artificial Life Simulation ..... 364
*D. Nahodil, D. Kadleček, K. Kohout, A. Svrček*

Auction Algorithms for Large Scale Linear Sum Assignment Problem ..... 366
*L. Buš, P. Tvrdík*

The Need of Non Conventional Clustering Techniques ..... 368
*Mofreh Ahmed Hogo, M. Šnorek*

Data Consistency of the KOS Database in a Heterogeneous Client Environment ..... 370
*I. Halaška, J. Cejp, T. Vlk*

Experiences with Jobs Queueing and Scheduling on a Multiuser Linux Cluster ..... 372
*M. Kačer*

Invariant Modifications for Generation of Benchmark Circuits ..... 374
*M. Kuneš, M. Daněk*

Influence of Noise to Quality of Image Segmentation ..... 376
*M. Novák*

Simple Gossiping in Wrapped Butterflies ..... 378
*M. Šoch*

Neural Networks Used for Target Identification ..... 380
*O. Ertl*

Incremental Parsing Using Faster GLR Parsing ..... 382
*J. Janoušek, D. Teufel*

Remote Control of a Laboratory Experiment Implemented as a Web Service ..... 384
*J. Tamáš, B. Šulc*

Hardware and Software for developing and permanent actualization of English textbook for subject TECHNICAL DOCUMENTATION in electronical form ..... 386
*F. Novák*

Spectral Compatibility of the Digital Subscriber Lines ..... 388
*J. Vodrážka*

Measurement and Evaluation of Specific Properties of DVB-T Indoor Reception ..... 390
*R. Šimík*

Intelligent Adaptive Web ..... 392
*Hajasoa B. Tata, I. Jelínek*

Electronic Library for Intelligent Transport Systems and Telematics ..... 394
*P. Vysoký, P. Přibyl*

## 4. ELECTRONICS & INSTRUMENTATION

Probe for Aerometrical Devices‘ Calibration ..... 398
*D. Pleskot*

Formation of atmospheric aerosol from gaseous products of fossil fuel combustion: Nucleation of acid - water droplets ..... 400
*J. Hošek, K. Studenovský, J. Hrubý*

Aircraft Aerometric System ..... 402
*V. Dvořák*

Signals for ADC modules dynamic testing ..... 404
*D. Varga, J. Roztočil*

Modern Methods of Vector Measurements ..... 406
*J. Šístek, Z. Škvor*

Development of the GMI Permalloy Sensor and its Practical Aplications ..... 408
*A. Platil, M. Malátek, J. Kubík*

Speech Enhancement for Impaired People ..... 410
*J. Ingerle, V. Mocek*

Capillary Discharge Circuit Optimization ..... 412
*P. Vrba, M. Vrbová, A. Jančárek*

Multimedia Text Book ..... 414
*M. Vrbová, M. Vrba, V. Fidler*

MP-SENS: Multipurpose Photonic Sensor System ..... 416
*L. Kalvoda, P. Lukášová, R. Lukáš, S. Vratislav*

Digitalization of the Fluxgate Magnetometers ..... 418
*A. Cerman, A. Kuna*

Computer Aided Education of Courses Signals and Systems and Digital Communications Theory ..... 420
*P. Puričer, J. Špaček*

Miniature Silicon Transducer with Non-planar Backplace ..... 422
*J. Škvor, Z. Škvor*

Measurement of Permittivity of Gases ..... 424
*J. Vejdělek, S. Ďaďo*

6th International Student Conference on Electrical Engineering POSTER 2002 ..... 426
*P. Hazdra, Z. Škvor, L. Lhotská*

Innovation of Courses on Programmable Integrated Circuit Design ..... 428
*P. Hazdra*

Accurate Control of Recombination Centre Introduction in Silicon ..... 430
*P. Hazdra, J. Vobecký*

Piezoelectric Earphone for ANC with Built-in Microphone ..... 432
*V. Píč*

Colorimetry of the New Scanning and Display Systems ..... 434
*J. Kaiser, M. Klíma*

Measuring Optical Losses in Planar Waveguides ..... 436
*V. Drahoš, J. Schröfel*

Modeling of Acoustic Waveguides ..... 438
*Z. Škvor, J. Škvor*

An Upgrade of the Calibration Setups for the DAQ Systems ..... 440
*V. Vacek, V. Vinš, R. Novák*

Fine Measurement of Dimensions Using Intelligent Opto-Electronic Gate ..... 442
*J. Včelák, J. Fischer*

Signal Processing in CNS Systems ..... 444
*P. Kovář, F. Vejražka*

Lasers with Thin Strained InAs Layers in GaAs - Electroluminescence and Photoabsorption at Elevated Temperatures ..... 446
*A. Mačkal, P. Hazdra, E. Hulicius, J. Pangrác, K. Melichar*

New ADC Transfer Ethalon ..... 448
*D. Slepička, M. Komárek*

Modeling of Acoustic Systems ..... 450
*M. Lukeš, F. Rund, P. Honzík*

Analysis and Verification of Leaky Waves on the Conductor - Backed Slotline ..... 452
*J. Mrkvica*

Fiber Optic Waveguide with Liquid Core ..... 454
*P. Solařík*

Educational Program for Numerical Methods in Electromagnetic Field ..... 456
*J. Mrkvica, J. Macháč, P. Černý*

Multichannel Receiver for Adaptive Antenna ..... 458
*P. Černý*

Project: INDECS, The Core ..... 460
*M. Dráb, L. Kalvoda, S. Vratislav, M. Dlouhá*

High Temperature Sensor Front-End for Space Facility ..... 462
*M. Plíhal, J. Masařík, P. Mňuk*

Methods of Partial Discharges Measurement ..... 464
*M. Kříž, J. Vedral*

Implementation of Digital Switching Arrays in FPGA Circuit for Education Purposes ..... 466
*M. Havlan, M. Šedivý*

The Measuring Methods for Analog Front End of xDSL Systems ..... 468
*M. Havlan*

Equipment for Determination of Dependence of GPS Signal Parameters on Environment Quality ..... 470
*P. Kačmařík, P. Kovář, L. Seidl, F. Vejražka*

IN-based Measurements of Voice Transmission Quality in Mobile Networks ..... 472
*J. Holub*

Analysis of Sounds Produced by Small Species ..... 474
*L. Husník*

Universal Processor Module for Intelligent Mobile Sensor System for Monitoring of Physical Quantities in Environment ..... 476
*P. Pfeifer, J. Pitelka*

Monitoring Station Main Unit for Intelligent Mobile Sensor System for Monitoring of Physical Quantities in Environment ..... 478
*P. Pfeifer, A. Sůra*

Acoustic Digital – to – Analogue Conversion ..... 480
*L. Husník*

Methods of Subjective Evaluation of Sound Codecs ..... 482
*L. Husník*

Microscope Scanning System ..... 484
*T. Kubart, R. Novák, T. Polcar*

Comparison of Microwave Structures Modeling Using Frequency Domain and Time Domain Analysis ..... 486
*Z. Hradecký*

Delivery System with Hollow Waveguide for Ophthalmology Treatment ..... 488
*H. Jelínková, M. Němec, J. Šulc, Mitsunobu Miyagi, Katsumasa Iwai, Yi-Wei Shi, Yuji Matsuura, J. Pašta*

Solid State Photon Counters Based on GaAs and GaP Material ..... 490
*I. Procházka, J. Blažej, K. Hamal*

Research of Selective Structures for Mobile Communication ..... 492
*L. Pauk, Z. Škvor*

Crosstalk Analysis in CMOS Integrated Circuits ..... 494
*J. Novák, J. Foit*

Support of Tutorial by Up-to-date Methods of Electromagnetic Wave Propagation Prediction ..... 496
*M. Klepal, P. Pechač, Z. Hradecký*

Measurement of Thermophysical Properities of Fluids by Thermistor ..... 498
*Z. Nývlt*

Contactless Current Measurement with the Anisotropic Magnetoresistors ..... 500
*P. Mlejnek, M. Vopálenský*

Portable Calibration Standard for Satellite Laser Ranging ..... 502
*K. Hamal, I. Procházka, J. Blažej*

Optical Processors ..... 504
*J. Rott, M. Klima*

Optimized Education of Electronic Circuits and Functional Blocks ..... 506
*P. Neumann, J. Hospodka, V. Hanžl*

Microsystem Design for RF Power Measurement ..... 508
*J. Jakovenko, M. Husák*

IGBT Lifetime Killing Process Design Using Simulation Tools ..... 510
*J. Vobecký, X. Jorda, P. Hazdra, P. Godignon, M. Vellvehi, J. Rebollo*

Multi-frequency Laser for Millimeter Satellite Ranging ..... 512
*K. Hamal, I. Procházka, J. Blažej, Yang FuMin, Jungfu Hu*

## 5. MATERIALS ENGINEERING

Computational Simulations of Pulsed Laser Induced Phase-Change Processes in CdTe and CdZnTe ..... 516
*R. Černý*

Polycrystalline Silicon Thin Film Solar Cells Produced by Pulsed Laser Processing: Computational Optimization of the Production Process ..... 518
*R. Černý*

Moisture Transport and Storage Properties of AAC, Ceramic Brick and Calcium Silicate in the Hygroscopic Range ..... 520
*M. Jiřičková, M. Totová, R. Černý*

Measurement of Water Retention Curves of Building Materials....522
*M. Jiřičková, R. Černý*

The Role of Exact Knowledge of Properties of Fiber Reinforced Cement Composites for Their Technical Applications....524
*J. Poděbradská, J. Toman, R. Černý*

Thermal Diffusivity of Carbon-Fiber Reinforced Cement Composites in High-Temperature Range....526
*J. Poděbradská, J. Toman, R. Černý*

The Effect of Gravity on the Moisture Transport in Building Materials....528
*J. Drchalová, R. Černý*

Fabrication Carbon Planar Waveguides....530
*V. Prajzler, I. Hüttel, J. Schröfel, J. Gurovič*

Possibility of Intercritical Heat Treatment of Cast Alloyed Steels....532
*J. Cejp, K. Macek*

High Temperature Oxidation of Thermally Sprayed Coatings....534
*P. Nop, J. Cejp, K. Voleník*

A Preparation and Study of Properties of Cr2O3 Layers....536
*L. Berka, N. Murafa*

Fractographic Study of Cleavage Initiation in A508 Steel....538
*P. Haušild, J. Siegl*

Fracture Toughness of Cast Steels....540
*K. Macek, J. Cejp*

Macromolecular Structures Modelling with Materials Studio Software....542
*L. Kalvoda, O. Knopfelmacher, S. Vratislav*

Investigation of Santonin/Poly(Methylmethacrylate) Mixtures....544
*L. Kalvoda, P. Lukášová, R. Lukáš, M. Dlouhá, S. Vratislav*

Development of Organized Structure of Carbonaceous Particles in Polymeric Composite LDPE + CB....546
*A. Mlích, J. Chládek, V. Bouda*

Assessment of Carburizing Potential of Furnace Atmosphere by Lambda Probe....548
*L. Hudousek, J. Cejp, O. Honzík*

Physical Properties of InP Epitaxial Layers Prepared with Dysprosium Admixture....550
*J. Grym, O. Procházková*

Preparation of Multilayered Coatings by PVD....552
*J. Mířejovský, J. Cejp, R. Novák, J. Kuběnka*

The Influence of Spray Technique on Fatigue Behaviour of Ni-5Al Coated Bodies....554
*O. Kovářík, Z. Procházka, J. Siegl*

Fatigue Lives of Bodies with Thermally Sprayed Coatings....556
*O. Kovářík, Z. Procházka, J. Siegl*

Application of Wavelet Transform in Textural Fractography ..... 558
*H. Lauschmann, J. Šumbera, I. Nedbal*

Study and Preparation of Cr2O3 Layers, as a Protection of Metal Substrates against Corrosion ..... 560
*J. Gurovič, M. Solar, F. Černý, S. Vacková, D. Palamarčuk, I. Hüttel*

Influence of Carbon Black on the Creep Behavior of Linear PE ..... 562
*K. Horáček, J. Steidl, Z. Kořínek*

Laser Treatment of Plasma Sprayed Ceramics ..... 564
*P. Ctibor, I. Karovičová, P. Císařovský, J. Dunovský*

Study of Failure Processes of Nickel Superalloys ..... 566
*J. Zýka, J. Siegl*

Structural Characterization of Cations and Methyl Groups in Zeolites NaY, NaX and NaLSX with Powder Neutron Diffraction ..... 568
*S. Vratislav, M. Dlouhá, V. Bosáček*

Neural Networks and Data Mining ..... 570
*Š. Ježek, J. Runčík*

Mechanical Properties of Plasma Sprayed Coatings at Low and High Deformations ..... 572
*J. Nohava*

Wear Mechanisms of Al2O3 and Cr2O3 Coatings Deposited by Water-Stabilized Plasma Spraying ..... 574
*J. Nohava, J. Siegl*

Three-dimensional FEM Model of the Curved Front of the Growing Fatigue Crack ..... 576
*T. Denk, V. Oliva, A. Materna*

Transmission Electron Microscopy Study of Microstructure of Low Alloyed Steel A508 close to the Zones of Ductile Tearing and Cleavage ..... 578
*M. Karlík, I. Nedbal, J. Siegl*

Comparison of DC-Cast and Twin-Roll Cast Sheets of AlMg3 and AlMg4.5Mn0.4 Alloys ..... 580
*M. Karlík, M. Slámová, M. Janeček, P. Homola*

Fatigue Damage of Hot Rolled and Hot Extruded Ordred Alloys Based on Fe-28Al-4Cr (at%) ..... 582
*M. Karlík, I. Nedbal, J. Siegl, J. Prahl, T. Černoch*

Tribological Properties of Wear Resistant Coatings ..... 584
*T. Polcar, T. Kubart, R. Novák*

Abrasive Wear Resistance of Hard Coatings ..... 586
*T. Polcar, T. Kubart, R. Novák*

Residual and Applied Stress Distributions in Thermally Sprayed Coatings ..... 588
*A. Materna*

Properties of Erbium in APE Er:LiNbO3 Waveguides ..... 590
*P. Čapek, J. Schröfel, P. Nekvindová, J. Špirková, V. Dierolf, C. Sandmann, A. Macková*

Residual Stresses in Oxide Layers and Corrosion Kinetics of Zr-based Alloys ..... 592
*G. Gosmanová, I. Kraus, N. Ganev*

Local Directions of Fatigue Crack Propagation In Microvolume
of Aluminium Alloy 7010 ..... 594
*J. Kunz, I. Nedbal, J. Siegl*

Environment Assisted Fatigue Crack Growth in Austenitic Steel AISI 304 L ..... 596
*I. Nedbal, J. Kunz, J. Siegl*

Shear Lips and Their Influence on Fatigue Crack Growth ..... 598
*J. Kunz, J. Bensch*

Experimental Investigation of Composite Material Properties of Aircraft Structures ..... 600
*I. Jeřábek, R. Theiner, J. Cejp*

Implementation of the XL 30 ESEM - TMP in the frame of advance
methods within the FCI CTU Prague ..... 602
*L. Kopecký*

Influence of MnS Inclusions on Cleavage Triggering in Reactor Pressure Vessel Steel ..... 604
*P. Haušild, I. Nedbal*

Experimental Investigation of Failures of Fired Clay Units ..... 606
*P. Bouška, V. Hanykýř, D. Pume*

Section 1

# MATHEMATICS

# Online Preparatory Course in Mathematics

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The framework of entrance exams in mathematics at CTU is created more than four years. After long discussion about the common requirements and common tests, presented in the monograph „Mathematics – entrance exams at CTU“, published in 2001, started in that year publications of a series of additional tools for preparation of applicants for entrance exams in mathematics. The trial web tests were the first step in this area. The URL address http://mat.fsv.cvut.cz/entrance offers the right environment of entrance exams. More than thousand examples constitute the trial database of examples. The realization of an electronic version of the monograph was the second step. The final version is on CD at disposal. The former publication was completed by a dictionary and hypertext references. Four different educational programmes were prepared in the year 2001: *Conic Sections* and *Trigonometry* as online programmes and *Space Geometry* and *Analytic Geometry – Lines and Planes* as offline programmes.

This year (2002) a complete online programme „*Online Preparatory Course in Mathematics*“ has been prepared. The team of authors Hájková, V., Kočandrlová, M., Křivková, I., Gemperle, F. and Černý, J., completed by three students Černý, V., Havránek, P., Mencl J., prepared a basic version of the course. The online framework is WebCT programme.

The course has 12 parts, which copy the parts of entrance exams in mathematics at the Czech Technical University:

Inequalities
Numbers and Terms
Functions
Trigonometry
Complex numbers
Sequences
Quadratic equations
Logarithms
Analytic Geometry
Plane Geometry
Space Geometry
Conic Sections

Each module has three basic parts:
- The **main part** with repetition of basic notions and their properties. The text uses standard terminology of secondary school mathematics. The commentary in many parts is more than synopsis. The geometric modules have a wider range. The first reason is the great amount of the matter, the second one is the unsufficient knowledge of these parts at the applicants. The main emphasis is on the part of examples. Each module starts with an entrance test. If an applicant is successful in this test he (or she) can drop out the module.

- The **part of typical examples**, the programme offers the users three different types of ends of each example: the result only, a task-oriented help and the whole solution of the example. The user chooses the option by the key buttons.
- **Two types of tests**, an entrance test and the output test in each module.

The passing through the programme is free. There are no prerequisite conditions for the entrance in the modules. The entrance into a module is possible by means of the content.

The framework WebCT allows all typical actions of an online environment. This online course will be completed by the trial tests, which are available at the web site (see above). We expect a dictionary with basic notions, which are not presented in the programme, will complete the course. A series of applets will be prepared in selected parts, which make them more understandable. The preparation of such tools is time-consuming and we continue in realization of these parts next year (2003).

The interest of applicants in the information sources is relatively good. Approximately 4 thousands people bought the paper version of the monograph „Mathematics – entrance exams at CTU“ in last two years. The preparatory courses at CTU approximately more than 2 thousands of participants visit yearly. A comparison of results at the faculty of civil engineering of CTU in entrance exams in the academic year 2000/2001 and 2001/2002 shows the better results in all parameters. This year will show this trend was a random event only. We would like to offer students this new modern form of learning. This form is very interesting for those applicants, which cannot visit the actual courses.

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# A Combined Type of Examinations in Basic Courses of Mathematics

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Mathematics has long been identified as one of the more difficult core subjects to teach and learn. The hierarchical nature of mathematics causes problems for students who lose track of concept functionality. It requires the student to achieve a legitimate understanding of every stage in the subject development. At the Department of Mathematics of FCE, much research has been carried out in the field of mathematics education, towards providing advice for the improvement of teaching material. As we are moving toward modern education, we need to focus our efforts on finding the most effective ways to educate the students and discuss openly the results of our efforts to be able to improve this process.

The predominant scheme for controlling students' knowledge is still the classical one: control papers on solving problems during the term and a final examination consisting of solving a number of problems and elaborating on some theoretical topics prepared according to a pre-set topic list. This classical system of control also has, alongside with its indisputable advantages, a number of decided disadvantages, for example the predominance of mechanically learnt theoretical examples and the trite approaches to their application; the lack of stimulus to the students' creativity in putting the theoretical results into practice. The need arises for finding new forms of teaching and control free of shortcomings mentioned. Bearing in mind the main objective of tests, that is, to stimulate students' resourcefulness, creativity and logical thinking, the conclusion is drawn that the kind of tests which is best suited for mathematical subjects is the multiple choice test. Each test includes 6 problems, which are classified into three groups according to the principal parts of the examination requirements.

The project has solved following individual topic tasks: a preparation of examples for the examination purposes and processing of examinations on one basic course of mathematics in the 1st year of study. An in-house program, which generates examples for exams for all terms, was applied. With help of this program there is possible to choose randomly one example from a database of examples indicated and by this way create an arbitrary number of examinations.

A combined-type examination of mathematics was realized for the object-terminating examination coded MA20 on a parallel of the study branch C in the summer term of the academic year 2001/2002. The examination consists of two independent parts; one of the parts provides a choice for the correct solution (the so called closed-item examination, with one element and four distracters; the part concerns "computing of problems") and the other part (it catechizes the "theory-basement" knowledge) where students create the answers. Students are allowed to use a specified formulae literature for calculating of problems to prove an actual knowledge of processes and principles and not only a memory formulae knowing. Some points depending on the difficulty are assigned to each example, where the mistaken results are penalized by negative point values. The student-created part of the examination is appraised in a usual way and the final mark is derived according to rigorous rules known to students in advance.

An in-house computer system for generating individual examination tests and their computer evaluating is available at the Department of Mathematics of FCE. Each student gets

a distinct test sheet where each problem is randomly generated from a database of problems of a certain class. The element and the distracters for a problem are randomly mixed and the key is saved.

The type of an examination applying a possibility of a choice from offered results has an indisputable advantage in maximal objectivity of evaluation independently of a subject, when a student itself assigns a point score and, consequently, a mark for himself. Students regard a priority as motivation to re-solve a problem if none of the served results is reached out for. That is why the choice of results is served in the so-called complete form, i.e. no answer listed is complementary to the others. An answer of the type "none of the other answers is correct" is excluded.

There can be stated that the experience from the run of examinations of the type in question and interactive communications to students show the fact that this type of examinations fits the students having permanently "better" marks from both other mathematical and non-mathematical objects. The results achieved by students were subjected to statistical processing. Realization of such examinations requires a sufficiently large database of suitable problems. A collection of databases for each class of problems was made. The databases need to be partially innovated for next examination periods. Problems and an analysis of results are discussed and presented in [1] and [2].

The entrance examinations at the beginning of studies at CTU are organized in a similar way at most of faculties. Even if the nature of both examinations is different the common computer-supported procedure described can be applied to one part of the end-of-term object examination as there is solved in the project.

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# Center of Active Learning

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During the last years several universities participated in various mathematical skills investigations of students accepted into the first years of study. Some departments of mathematics continued in working with the series of diagnostic tests that had been running for many years. The results were analyzed at the universities and the faculties, see e.g. [4]. The following list of basic goals of mathematics education was defined. A student should be able to

- Skillfully use the simplest standard tools in the mathematical area in questions
- Use mathematics to analyze different situations from everyday life, professional life and other science
- Read mathematical texts, interpret mathematical formulas and follow mathematical way of thinking
- Communicate mathematical reasoning to others orally and in writing
- Understand the main idea of mathematics: If certain conditions are fulfilled then it is possible to draw certain conclusions and knots for sure they are true
- Use the knowledge of mathematics in new situations in a creative way and judge which methods are useful in different situations
- Combine theories and methods from different mathematical areas and use technical tools effectively and critically.

The real framework of students entering the faculties is greatly far from these final goals. Students come from a very diverse range of backgrounds and educational experience. Many students have not had sufficient opportunity to develop vital skills of algebraic manipulations, which is then the serious handicap hindering progress in more advanced work. There are nationally recognized and well-documented deficiencies in mathematics of applicants from Higher Professional Schools and Integrated Secondary Schools.

Five years ago the Center of Active Learning (CAU) was established at the Faculty of Civil Engineering of CTU in Prague. The centre supports mathematical studies of students in the first year of study. The basic aim of this centre was developing services, which help students to learn mathematics. The constitution of the center was supported by the company Stavby mostů Praha a.s. Stavby silnic a železnic, a.s. and Faculty of Civil Engineering CTU in Prague. Three areas of activities were prepared

- **Lectures and tuition**. Three types of lectures are prepared for the first term of study. The first one is focused on the secondary school mathematics. The second course is focused on the first term mathematics. It has started in November and it has covered selected parts of the course of calculus and linear algebra. This course has continued in January (during the exam period), and it is repeating during the second term. More than two hundred students visit this course in this academic year. There are always two parallel runs of the course with two different discussion themes in the same time. The last course is focused on constructive geometry. The insufficient knowledge of descriptive geometry and geometry at all make

students problems in this course. This additional course enables the repetition of the subject and the main part is attended to the student's questions.

- **Paper based learning materials**. These include sets of study sheets. Each set of three or four pages in length covers basic topics from the first term course – vectors and vector paces, matrices and determinants, systems of linear equations, elementary functions, applications of derivatives, basic integrals.
- **Computer based learning support**. The center CAU has its own web site. This site informs students on actual activities: http://mat.fsv.cvut.cz/cau.

The problem with mathematics at the beginning of studies is not specific only for Faculty of Civil Engineering. It is not typical also only for Czech technical universities. The similar problems have many universities through Europe and their different or similar solutions are designed and realized. The similar center as CAU exists at Loughborough University. The Mathematics Learning Support Center exists 6 years. Its manager is Dr. A. C. Croft. One of the main goals of the grant FRV 2064 was the realization of a visit of MLSC and the exchange of views, ideas and experience in activities of CAU and MLSC.

This visit has been realized in April of this year and supported by the grant mentioned above. One of the main results was the design of the Socrates project prepared together with the following universities: National University of Ireland, Maynooth, University of Sofia (Bulgaria) and Slovak Technical University in Trnava. The main topic is the learning support of mathematics for engineers and the constitution of support centers at the universities. The main goal is the exchange of learning materials and an aspiration to create common learning framework of the centers. The MLSC URL is http://learn.lboro.ac.uk/sci/ma/mlsc/.

There are many differences between the UL framework and the FCE CTU framework. A small number of contact hours at UL (18) and contradiction of the number at FCE CTU (29), the small number of students at the beginning of studies at LU, small number of contact teaching hours for teachers and all these well known differences differentiate the teaching framework of both universities. The new bachelor studies bring near FCE CTU to the Loughborough University in several directions and the experience gained during the stay at this university was very useful.

The personal experience with the working of MLSC is very profitable for the future. The increasing number of students and the decreasing number of teaching hours in mathematics at technical universities in addition with imperfect knowledge of secondary school mathematics of applicants brings important tasks for learning support centers. The process „from teaching to learning" bring more problems for all teachers at mathematics departments and all students at all branches of study. The methods of computer aided assessment, Internet based materials and computer aided learning bring (likely) new framework of our work.

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# Mathematical Properties of Fuzzy Logics

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One important way of representing vagueness of information is an enlargement of the set of truth values from $\{0,1\}$ to the whole unit interval $[0,1]$. This leads to fuzzy logics, which were successfully applied in many areas, especially in fuzzy control. The logical connectives in fuzzy logics like conjunction, disjunction, and negation are represented by functions from the unit square to the unit interval instead of truth tables as it is in the case of classical logic. Thus in fuzzy logic, formulas can be evaluated by any number from $[0,1]$. In this paper we study an extension of the classical notions of tautology, contradiction, and satisfiability to the case of fuzzy logic.

The notions of tautology and contradiction are one of the most basic notions in classical logic. A formula in classical logic is a tautology if and only if its evaluation is always equal to 1 independently on evaluation of atomic variables in the formula. On the other hand, a formula is a contradiction if and only if its evaluation always equals 0. In other words, the tautologies are true formulas and the contradictions are false formulas. The rest of formulas, which are sometimes evaluated by 1 and sometimes by 0, are called contingencies.

If we want to extend these concepts to the case of fuzzy logic, we have to deal with more cases. Let us observe that the notions of tautology, contradiction, and contingency are represented by all non-empty subsets of the set $\{0,1\}$. The tautology is represented by the subset $\{1\}$, the contradiction is represented by the subset $\{0\}$, and the contingency is represented by the subset $\{0,1\}$. It means that in fuzzy logic we have to distinguish all non-empty subsets of unit interval. This leads to the notion of validation set. However usually not all non-empty subsets of $[0,1]$ are validation sets. Therefore we study the most common fuzzy logics and investigate which kinds of the validation sets may appear in particular logics.

We gave a characterization of validation sets for different approaches to fuzzy logic: S-fuzzy logic (introduced by Butnariu, Klement and Zafrany) where the basic connectives are negation and conjunction, R-fuzzy logic (studied mainly by Hájek) where the basic connectives are conjunction, implication and the false statement, R-fuzzy logic with an operation Delta (proposed by Baaz) where the basic connectives are connectives of R-fuzzy logics and Delta, R-fuzzy logic with an involutive negation (introduced by Esteva, Godo, Hájek, and Navara) which combine connectives of S-fuzzy and R-fuzzy logics. All these kinds of logics are further divided according to the t-norm used for interpreting conjunction. There are three basic t-norms: Lukasiewicz, Gődel, and product t-norm. All other continuous t-norms can be represented by means of an ordinal sum of these three basic t-norms up to isomorphism.

In the case of S-fuzzy logics the validation sets are always closed intervals because all logical connectives in these logics are represented by continuous functions. Moreover these intervals contain at least 0 or 1 because all fuzzy logics work classically for crisp values 0 and 1. The situation in R-fuzzy logics is different because some logical operations are represented by non-continuous functions for example negation. Therefore validation sets in R-fuzzy logics need not be closed. Nevertheless they are still intervals. The same holds also for R-fuzzy logics with the operation Delta. The completely different situation is in R-fuzzy logics with an involutive negation where the complexity of the validation sets increases substantially. The

validation sets in these logics may be arbitrary finite unions of intervals. For detailed results see [1,2,3].

There are many other fuzzy logics for which characterizations of validation sets are yet unknown. We already know that the characterizations of validations sets in logics using a strict t-norm instead of the product remain basically the same. This is trivial in case of R-fuzzy logics because they are isomorphic to product logic. In S-fuzzy logics, the situation is different as the isomorphism need not preserve the standard negation, still the same results concerning validation sets are obtained. Recently R-fuzzy logics were studied in which conjunction is interpreted by a continuous t-norm which is an ordinal sum of the basic t-norms.

The second part of our work is related to simultaneous satisfiability. In classical logic, we ask whether there exists an evaluation of atomic variables such that each formula from a given set of formulas is evaluated by 1. On the contrary in fuzzy logic, we ask whether all formulas from a given set are evaluated by numbers greater than certain number x from unit interval. Furthermore we want to find the maximal number x such that all formulas from the given set are still evaluated by number greater than x. This leads to the notion of consistency degree (introduced by Butnariu, Klement and Zafrany) as the maximal joint degree of truth of a set of formulas. Thus we study which numbers from unit interval can be consistency degrees in particular fuzzy logics.

We have discussed three approaches to propositional fuzzy logics, S-fuzzy logics, R-fuzzy logics, and R-fuzzy logics with an involutive negation. Comparing these logics, one distinction becomes apparent. While Gődel and product R-fuzzy logics possess only two weak consistency degrees, 0 and 1, like in classical logic, in other fuzzy logics the weak consistency degree may attain also other values, e.g. 1/2. In most of fuzzy logics studied here, any number from the unit interval may occur as the weak consistency degree of some set of formulas. This emphasizes the semantical difference between various fuzzy logics and gives an argument why logics with involutive negations allow for more power in description of vagueness. For detailed results see [4].

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# Online Course on Numerical Mathematics

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Next academic year most CTE faculties will begin the structured study program. One of the principles of the design of structured study system was professional orientation of graduates of these lines of study. Consequently, theoretical subjects, including mathematics, were reduced as to the amount of material and classes. Such a reduction though may imply an insufficient theoretical background of those graduates of bachelor studies that will decide to continue their education via a master study.

The development of Internet and its common usage outside office provides a possibility to enhance and complete theoretical knowledge by means of online courses. These texts allow the user to get acquainted with the subject of study without attending the classes. Moreover they let the teachers to check the level of knowledge of students with various online tests, including multiple choice tests and open problems tests.

Last academic year CTE accepted and realized several projects that focused on the preparation of online texts, one of them being the project on online course of numerical mathematics. This project resulted in the first part of the intended course. This finished part elaborates topics on approximation of functions (Lagrange and Newton interpolation polynomials, the least squares method), numerical integration and solution of nonlinear equations (bisection of intervals, regula falsi, and Newton's method). At the time being the texts are utilized in classes on numerical mathematics at the faculty of civil engineering on lines V and Z and also on lines C and A, where numerical mathematics is incorporated in the calculus class MA30. The course was also embedded into the WebCT system purchased by CTE.

As the student body responded in a positive way, grant CTU0215111 enhaced these courses with several chapters. Namely:

a) Numerical solution of ordinary differential equations with initial conditions:
- One-step methods
  Euler's method
  Runge-Kutta methods

- Several-steps methods:
  Explicit methods
  Implicit methods
  Predictor-corrector method

b) Numerical solution of ordinary differential equations with boundary conditions:
- Net method
- Ritz method

The texts are sorted on three levels. The topmost level presents theoretical background. It contains links to the second level that consists of illustration of the theory by examples. The third part consists of solved problems. A user can solve the problem on her own, yet the solution is available as a link. There are no tests, as the authors did not consider them

productive for this subject. There is, though, an online conference that lets a user to submit questions that are answered by the authors.

The source files were prepared in TeX. The difficult problem of presentation of Math online is solved by a (nontrivial) compilation of TeX into DHTML containing XML and MathML islands. The rendering of MathML is made possible via plugins and native support of MathML in leading browsers (Internet Explorer 6.0 and Netscape Navigator 7.0). This technology emerged only a couple of months ago and is far from being perfect. It is however so far the best way to display math on Internet.

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# Numerical Solution of Nonlinear Problems from Fluid Dynamics

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The scope of this paper is to present results of certain flow problems arising in computational fluid dynamics. In this paper, we are mainly interested in two different topics. The first one is to investigate numerical approximations of a two dimensional model of the electrolysis process with turbulent layer near the boundary. This problem is nonlinear due to boundary terms. The non-linearity in the boundary forms then causes some significant deterioration of the convergence order.

The second topic is focus onto a computation of the incompressible laminar viscous flow. Particularly, incompressible flow problems provide great potential for research activities since they include a wide variety of difficulties. One has to treat carefully time-dependent partial differential equations in complex domains. Moreover, the system is strongly nonlinear and includes a solution of saddle-point problem due to the incompressibility constraint. In this paper we present one possible approach how to solve all these difficulties.

In the case of numerical modeling of the electrolysis process, we start with reformulation of the system of partial differential equations with the help of stream function. The nonlinear term in boundary conditions describes turbulent flow in boundary layer. The first results for a problem of this type were obtained in [1], where the existence and uniqueness of the solution of thqe continuous problem was proved with the aid of the monotone operator theory. The convergence of the approximate solutions to the exact one was established under the assumption that all integrals appearing in the discrete problem were evaluated exactly. In [2], the convergence of the finite element method was proved in the case that both volume and boundary integrals were calculated with the aid of quadrature formulae. The convergence analysis was obtained in the work [3] thanks to the uniform monotonicity of the problem.

In contrast to standard nonlinear situations here we do not get an optimal O(h) error estimate for linear finite elements. The order of convergence is reduced due to the fact that only uniform monotonicity with polynomial growth holds now. The theoretical results for higher order finite elements lead to the similar estimate. The performed numerical tests showed that such a decrease is not only result of poor numerical analysis but it really appears in numerical simulation of such a problem.

The second part of our work is devoted to the finite element solution of two-dimensional viscous incompressible flow. The Finite Element Method(FEM) is well known as a general discretization method for partial differential equations. It can handle easily complex geometries and also boundary conditions employing derivatives. Anyway, straightforward application of Finite Element procedures often fails in the case of incompressible Navier-Stokes equations.

The reason is that momentum equations are of advection-diffusion type, in which the advection dominates. Thus the equations have a hyperbolic character. The Galerkin FEM leads to useless solutions if the grid is not fine enough in regions of strong gradients (e.g. boundary layer), the required grid refinement is for most applications unfeasible. The other possible way is to use classical artificial diffusion stabilization, but this method provides inaccurate and nonconsistent results (because of lots of diffusion). In our work we use the other possible way: to use a strongly consistent stabilization method for linearized Navier-Stokes equations.

First, we discretize the problem in time. There are several schemes possible for the discretization of the problem. Here we present second order semi-implicit scheme, where viscous terms are treated implicitly. The advantage of this approach is that we get a linear (Oseen) problem for each time step. On the other hand, there are also several difficulties, e.g., with rather complicated changes of the time-stepping value during the computation time. This complication can be treated, e.g., with the use of more sophisticated methods of time discretization. These generally lead to a solution of one nonlinear problem per one time step. The solution of these nonlinear problems then is done in the same fashion as in the previous case.

Next, the spatial discretization is required to satisfy Babuška-Breezi condition. Moreover, the central discretization of incompressible Navier-Stokes equations - especially of the convection part - may lead to 2nd order accuracy, but only if the local mesh width h is fine enough. In relevant application the general result is to set h in relation to the Reynolds number which imposes impossible restrictions onto the mesh. If this relation is not taken into account we obtain oscillations and deterioration of the solution, which have purely numerical character. To stabilize the convective part for higher Reynolds numbers we consider, e.g., streamline-diffusion techniques.

Lastly, we have to solve the saddle point problem. There is number of well-known solution schemes, e.g., pressure correction schemes, projection methods, Uzawa iterations etc. All these schemes belong to family of pressure Schur complement method (see, e.g., [4]). The idea of this method is to eliminate velocities from the coupled system of equations. The obtained system of equations is then solved iteratively.

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# Development of the External Interpolation Module for Microsoft Excel

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The standard tools implemented in Microsoft Excel for data analysis enable the user to carry out financial, engineering and statistical analysis of data files, therefore using this application in many areas of technical practice is widely spread. If the user is not a mathematician or of a similar profession, then Microsoft Excel is often the only program mathematically oriented which he has to his or her disposal.

The tasks of finding mathematical interpolation model of the input data cannot be satisfactorily solved by means of the standard tools of Microsoft Excel. These tasks are frequent in technical practice for students and researchers. Therefore a procedure for interpolation in Microsoft Excel has been developed. The procedure is programmed in Visual Basic for Applications and it enables to construct mathematical interpolation model of the input data by various methods originating in mathematical theory of curves and surfaces of computer graphics. This procedure is available as an Interpolation add-in to users of Microsoft Excel similarly to any other standard functions of application.

A frequent requirement in evaluating the data measured is to find the analytical expression of the relation among variables or quantities - e.g. for further processing in specialized software. By means of standard function it is, in simpler cases, possible to find analytical relationships among variables using methods of regression analysis. In the case that the interdependence of the measured quantities is not evident, or if the measured points are to be interpolated by the appropriate functions for the purpose of further processing using specialized software, the above approach is not applicable and Microsoft Excel cannot be straightforwardly used. In order to overcome this limitation of standard tools of Microsoft Excel, the procedure for interpolation was developed. This procedure allows the user without specialized mathematical skills to solve the tasks of finding the appropriate interpolation mathematical model of the measured data using software he knows and can handle.

The available functions and properties of Microsoft Excel offer the user plot the results measured on a chart for the graphic representation of relationship among the quantities measured. To create a chart, user must first enter the results measured for the chart on the worksheet. Then select that data and use the Chart Wizard to step through the process of choosing the chart type and the various chart options. The user is limited by the choice of the type of the chart. Only the XY - scatter chart enables to plot the behaviour of functions expressed explicitly or parametrically in Cartesian coordinates. This type of a chart allows users to place the numerical values of independent variable quantities on the x-axis and numerical values of dependent variable on the y-axis. Other types of the chart only partition the x-axis into the appropriate number of equidistant segments according to the number of different data categories displayed.

The graphic representation of the dependence between quantities measured can be plotted as points connected by line segments or a smoothed line. There are the following disadvantages of this option:

- the user has no access to the information either about the actual method of the construction of the smoothed line or about its analytical expression;

- the axes of a chart created in Microsoft Excel cannot be calibrated - i.e. it is not possible to determine the relation between the size of the step on the axis and the corresponding increment of the measured physical quantity;

- the shape of the resulting curve may be deformed, because it is not possible to determine the interrelation between the length of the steps on the axes.

- the length of the steps on individual axes automatically changes with any change of the shape and size of individual objects of the chart (for example the change in the size of the letters used for specification of titles and legends, the change of size of the displayed area, the change of thickness of the lines delimiting the displayed area).

The available functions and properties of Microsoft Excel enable the user to find the possible form of the eventual dependence between individual variables. Its analytical expression can be determined using the methodology of regression analysis. The user can add regression curve to plotted curve in XY – scatter chart. The corresponding regression straight line (in the case of linear dependence) or curve (polynomial, logarithmic, exponential) were determined using the least square method. The type of the regression curve can be chosen by the user interactively according to the form of the dependence in any given case. The regression curve can be displayed together with the corresponding correlation equation and the values of reliability, so - called R-squared value. The user must know that the calibration of the graph axes cannot be done. The shape of the displayed curves can be deformed.

The interpolation procedure offers the user four methods to construct the interpolation curve: L-interpolation, N-interpolation, D-interpolation and natural spline interpolation. The principles of these methods are described in detail in the help file included in Interpolation add-in. The user selects the method of the calculation of the interpolation curve. If only the user requires graphical output, the calculated curve is displayed in the resulting chart of the interpolation curve, which goes through the input data. Both axes of this chart created by Interpolation add-in are automatically calibrated therefore the shape of the curve is not deformed. If, in addition to graphical output, the analytical equation of the interpolation curve is also required, the resulting parametric equations of the coordinate functions are output in the worksheet for all the segments of the piecewise interpolation curve.

The resulting mathematical model can be used for further processing in the specialized software. Using the interpolation procedure represents an effective tool for the construction of the interpolation mathematical model of input data. The interpolation procedure can be installed as the add-in for Microsoft Excel and that its instructions as well as functions are available for the user similarly to the standard functions of application.

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# Project of using webMathematica on CTU

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Within the framework of the *Project for Transformation and Development Program for Year 2002* the Czech Ministry of Education granted financial means for project *Integrated IT support of education in prepared study programs of structured studies on CTU in Prague*. One part of the project was aimed at our work in environment webMathematica. We asked for a new server for this environment and a professional license for processing webMathematica, which was solved as a supplementary part of the agreement between Wolfram Research Inc. and CTU in Prague.

The project was finished successfully and by the end of the year we obtained a new server of the following configuration:

| | | |
|---|---|---|
| Motherboard: | 1ks | Supermicro P4DP6 iE7500, 2xP4 Xeon, 2x64bit PCI-X, 4xPCI64 |
| Processor: | 2ks | P4 XEON 2.8GHz L2 512K 400MHZ FSB 0.13u Northwood BOX |
| Memory: | 2ks | 1024MB DDR266 ECC Reg. |
| Hard disk: | 4ks | Seagate ST318452LW Cheetah X15 36GB 3.6ms 10000RPM 8M |
| Networks card: | 2ks | Intel PRO/1000 XF i82544EI Server adapter PCI-X |
| RAID: | 1ks | Adaptec ASR-2120S Ultra320 RAID 0, 1, 0/1, 5, 0/5 PCI64 64MB |

This server will work with operation system LINUX or some other UNIX system (for example FreeBSD).

The server is supposed to provide the following services:
- webMathematica server,
- Mathematica server (for X-windows terminals),
- Matlab server (for X-windows terminals),
- Tomcat server,
- Apache server (SQL, PHP),

Everything is drawn up for maximal utilization of all its possibilities that can be provided both to students and teachers or researchers. This project is fully open and we would like as many people as possible to collaborate on the server contents. The server should be used even for the distant education, making it possible to use the software licensed to the CTU for all kinds of students.

At the first stage of the project we have to establish a team for administration of the server. The team will decide about the conception of development of the server and solve eventual technical problems associated with its operation. After putting in operation we will start with information about the project on web pages that will try to explain the possibilities of webMathematica. On several examples we will show how to produce interactive education text. We will also start distant work with Mathematica and Matlab via the X-windows terminal.

In the next phase of the project we should prepare the conditions for the university staff for easy publishing education texts supported by webMathematica. We would be able (with the assistance of students) to transform most education texts into a form suitable for the

web server. These texts would easily be available for everybody via Internet. We would preferably aim at new subjects that will appear during the transformation of studies and conversion of those that would remain.

In case that the possibilities of webMathematica are not sufficient for all subjects taught at the CTU, in the next part of the project we would try to include even the support of the Matlab web server (Mathworks) and MapleNet (Maplesoft). This project represents the first study that makes it possible to obtain some practical experience with integration of possibilities of the Internet, interactive texts and computer algebra systems (CAS).

Of course, successful development of the project may significantly depend on financial means for its continuation in several next years.

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# Constructive Geometry Teaching Innovation for Study Program Geodesy and Cartography

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Constructive Geometry represents a new concept of geometry, which is required of a modern engineer in the contemporary world of technique expansion. Constructive Geometry combines the standard synthetic methods of Descriptive Geometry with various mathematical methods using analytic ways of solving problems. The aim of Constructive Geometry is to train not only spatial imagination and acquirement to describe and create spatial models but also ability to modify and transform these models, generalize and objectify them according to an instant occasion. Present technique expansion enables faster and deeper achievement of this aim by using wide range of new technologies in teaching - eLearning facilitative tools.

Special attention in solving the grant project was paid to the process of student self study including the tuition. Constructive Geometry teaching and studying demand prime communication teacher-student. Exercises given to students are original and to make algorithms of their solving or to find the solutions in ordinarily accessible printed study materials is almost impossible for students. That is way tuition is considerable part of teaching. However tuition is reckoned among these parts of teaching process, which are fastidious about time and space. The research within the grant project concentrated on involving more efficiency in tuition running and in the process of student self study.

The research within the grant project focused on two main parts. One of them was an innovation of the teaching mode inclusive integrating eLearning facilitative tools into the present teaching practice in Constructive Geometry. A teaching matters innovation comprised the second part of the project research.

Fitting of some new actual topics and themes in the existing syllabus of Constructive Geometry was the important teaching matters innovation goal. The set of proper topics was created primarily by virtue of detection and analysis of geometrical relations and coherences in the cartographic and geodetic professional textbooks. Their final selection was prepossessed by the results of many discussions with geodetic and cartographic experts, teachers of the professional subjects and also with students. The definite form of the innovated syllabus corresponds to a concept of the new structured study program of the Geodesy and Cartography branch of study.

The procedure of the teaching mode innovation was divided into two basic phases: a preparative one and an implementation one. Various geometrical teaching materials suitable for a consecutive electronic transformation were assembled within the preparative phase. Two

assembled portfolios were created - one with the only practical problems and the other one with the problems and also with the theory. It was decided that the first portfolio would be transformed into a collection of on-line geometric exercises and the second portfolio would be digitized and placed on a web site of the subject. At the end of the preparative phase selection of some software tools appropriate for the elected ways of material transformation was made.

The implementation phase focused on

- Formation and programming of on-line geometric exercises and running of them on the Web,
- Digitizing of the drafted teaching materials and enhancement of the existing simple subject web site about them.

One team of three experts made the collection of on-line geometric exercises. They were the author of content and solving procedures, the draftsman and the programmer and SW specialist. The CAD system AutoCAD was used to make the graphical bases of the exercises. The computer program was created to start and keep running of the exercises on the Web. The PHP language was the used programming language.

The digitizing of the drafted teaching materials was made by means of *MS Word* tools and figures and geometrical data were provided with *Mathematica*® and by the scanner. Among generated materials were, above all, two teaching texts – *Modeling of the Reference Surfaces, Spherical Trigonometry in Cartography and Astronomy* - and four collections of exercises: *The Stereographic Projection, The Orthographic Projection, The Gnomonic Projection, Normal Axonometry of Sphere*.

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# Numerical Solution of Incompressible Viscous Flows through Channels

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This work deals with numerical simulation of laminar viscous incompressible stationary flows through channels with complicated geometry. Mathematical model is based on Navier-Stokes (NS) equations. Steady solution is obtained by solving unsteady system using multistage Runge-Kutta method together with artificial compressibility method. Numerical solution of flows through channels has application in the framework of cardiovascular research. In this simple 2D cases are vessels replaced by channels. Mathematical model with suitable simplified assumptions is used. The blood flow is assumed to be incompressible continuum and is also supposed to be Newtonian fluid with constant visosity. With this assumptions blood flow could be described with equations of conservation of momentum and mass. The walls are fixed and one not consideres pulsating nature of flow. The model based on NS equations is written in the conservative, nondimensional and vector form

$$\widetilde{R}W_t + F_x + G_y = \frac{\widetilde{R}}{\mathrm{Re}}\Delta W, \quad \widetilde{R} = diag\|0, 1, 1\|,$$

(1)

$$W = col\|p, u, v\|, F = col\|u, u^2 + p, uv\|, G = col\|v, uv, v^2 + p\|,$$

*F, G* denote inviscid fluxes, p denotes the pressure, (*u, v*) refers to velocity vector, Re is the Reynolds number $\mathrm{Re} = \frac{UL\rho}{\eta}$, where $U$ is speed of incomming strem, $L$ denotes width of a channel. Upstream boundary condition is $W_\infty$, downstream condition is the quantity of pressure and $(u, v) = (0, 0)$ along the walls. We solve the system of equations (1) with $\widetilde{R} = diag\|1, 1, 1\|$ in the computational domain under stationary boundary conditions for $t \to \infty$ to obtain the steady state solution for velocity vector and pressure. The finite difference method, cell centered formulation, together with the 3-stage Runge-Kutta scheme is applied to the considered improved system (1). Numerical method is stabilized by the artificial viscosity term (Jameson's type) added to the RK method.

$$W_{i,j}^n = W_{i,j}^{(0)},$$

$$W_{i,j}^{(r)} = W_{i,j}^{(0)} - \alpha_r \Delta t \overline{R} W_{i,j}^{(r-1)}, (r = 1, \ldots, 3)$$

$$W_{i,j}^{n+1} = W_{i,j}^{(3)},$$

$$\overline{R}W_{i,j} = RW_{i,j} - DW_{i,j},$$

$$RW_{i,j} = \frac{F_{i+1,j} - F_{i-1.j}}{2\Delta x} + \frac{G_{i,j+1} - G_{i,j-1}}{2\Delta y} - \frac{\widetilde{R}}{\mathrm{Re}}\left(\frac{W_{i+1,j} - 2W_{i,j} + W_{i-1,j}}{\Delta x^2} + \frac{W_{i,j+1} - 2W_{i,j} + W_{i,j-1}}{\Delta y^2}\right),$$

$$DW_{i,j} = E\left[\gamma_i\left(W_{i+1,j} - 2W_{i,j} + W_{i-1,j}\right) + \gamma_j\left(W_{i,j+1} - 2W_{i,j} + W_{i,j-1}\right)\right],$$

$$\alpha_1 = 0.5, \alpha_2 = 0.5, \alpha_3 = 1.0, E = diag\|0, \varepsilon_1, \varepsilon_2\|, \varepsilon_1, \varepsilon_2 \in R, \qquad (2)$$

The method is second order in time and space. The time step $\Delta t$ is obtained from the formula, which is necessary for the stability of the RK method

$$\Delta t \le \min_{i,j} \frac{CFL}{\frac{\rho_A}{\Delta x} + \frac{\rho_B}{\Delta y} + \frac{2}{\mathrm{Re}}\left(\frac{1}{\Delta x^2} + \frac{1}{\Delta y^2}\right)} \tag{3}$$

where $CFL = 2$, $\rho_A = u + \sqrt{u^2 + 1}$, $\rho_B = v + \sqrt{v^2 + 1}$, where $u$, $v$ are the maximal values inside the computational domain. In numerical model is used method of artificial compressibility, when equation of continuity is completed with term $\frac{1}{a^2} p_t$. The convergence of iterative process is maintained using the behavior of residual in space $L_2$

$$\mathrm{Re}\,z W_{ij} = \sqrt{\frac{1}{MN} \sum_{ij} \left( \frac{W_{ij}^{n+1} - W_{ij}^{n}}{\Delta t} \right)^2} \,, \tag{4}$$

where MN is the number of gridpoints. Numerical model for simulation of flow in geometricaly complicated domain representing arteries was developed and used in order to simulate flow in the channel with two cavitas and in the channel with bypass. Achieved results are in good agreement with physics. For numerical computation was created software in language C/C++. We suppose improvement of mathematical and numerical model in the future.

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# Finite Element Solution of 2D Flow Problem in a Channel with Singularities

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In this paper we focus our attention on the finite element method applied to the solution of incompressible flow problem in a 2D channel with forward and backward steps, or in an axisymmetric tube with sudden changes of the diameter. We assume the flow is modelled by the Navier Stokes Equations for incompressible flow. The solution domain thus has corners with nonconvex internal angles.

In [1] we studied the problem of axisymmetric flow in a tube with sudden changes of diameter. Our first concern was the asymptotic behaviour of the solution near the corners. The rotational symmetry allows to restrict the problem to two dimensions using the cylindrical coordinates. We used the stream function – vorticity formulation of the Navier Stokes Equations, and obtained fourth order partial differential equation for the stream function. Using the Fourier transform technique we finally obtained the asymptotic behaviour of the solution near the corners. E. g. for the internal angle 3/2 Pi we obtain that the velocity components $v_i$ depend on the distance $r$ from the corner approximately as

$$v_i = r^{0.544483}$$

So the solution has singularity in such corners, and the "magnitude" of the singularity is the same as for the channel flow with the same internal angle. In [1] we also suggested an algorithm for the finite element solution, namely for the local refinement of the finite element mesh in the vicinity of the corners. The algorithm makes use of the information on the magnitude of the singularity.

In [2] another approach to the finite element solution of the flow problem with singularities is studied. We derived the a posteriori error estimate for the Stokes flow in polygonal 2D domains. Our aim was to estimate also the constant that appears in the a posteriori error estimate. In [3] we calculated this constant for some special cases. Then we applied the a posteriori error estimates to the test flow problem in a channel with forward and backward steps. The refinement of the mesh near the corner singularities corresponds to the predicted asymptotic behaviour. We present several successive mesh refinements. As results we show the velocity components, the pressure, and the streamlines. We also show the relative errors on individual finite elements in the vicinity of the corners.

In [4] our student M. Jelínek applied the algorithm for the adjusted finite element mesh suggested in [1] to the same test problem as mentioned in the previous paragraph. Again, the velocity components, the pressure, and the streamlines are presented. Also the relative errors on individual finite elements in the vicinity of the corners are given.The results are in good

agreement with expected solution, and with those obtained by the adaptive rafinement of the previous paragraph.

The algorithm based on the asymptotic behaviour of the solution in the vicinity of corners allows to get more precise results in a shorter time than the adaptive rafinement. But of course, the adaptive refinement of the mesh based on the a posteriori error estimates is more robust.

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# Reconstruction from Many Images

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Attempts to create 3-dimensional (3D) model of a real scene using the knowledge of its 2D images, i.e. 3D reconstruction, appeared already in the 19th century. However, the first method for a general situation with many images obtained using the orthographic camera, i.e. camera which acquires the scene from relatively big (theoretically infinite) distance, appeared in 1992 and works on principle of factorization. In practice, the model of the orthographic camera is often unusable because the cameras acquire the scene from relatively small distance w.r.t. the size of the scene thereupon perspective distortion raises. This distortion considerably complicates 3D reconstruction because so-called projective depths have to be computed in the used model of the perspective camera. The projective depths are proportional to relative distances of points in space to camera centers.

Method [2] solves the problem of 3D reconstruction from perspective images but only if no occlusions standing for the missing data are present in the scene. Urban & al. developed a method solving the problem of occlusions with perspective cameras in certain special configurations.

Our novel method solves the problem of occlusions in scene with perspective cameras generally. It recovers the projective shape and motion from multiple images by factorization of a matrix containing the images of all scene points. Compared to previous methods, this method can handle perspective views and occlusions jointly. The projective depths of image points are estimated by the method of Sturm & Triggs [2] using epipolar geometry. Occlusions are solved by the extension of the method by Jacobs [1] for filling of missing data. This extension can exploit the geometry of the perspective camera so that both points with known and unknown projective depths are used. Many ways of combining the two methods exist, and therefore several of them have been examined and the one with the best results was presented. The new method has been verified on scenes with very different structure of the missing data. It is well suited for both extreme configurations: video-sequence and wide-baseline setup and gives accurate results in practical situations, as demonstrated with a series of experiments on laboratory and outdoor image sets. It becomes clear that the method is particularly suited for wide base-line multiple view stereo. The theoretical properties of the method together with experimental results were published, e.g., in [3].

In reconstruction, the problem of so-called outliers has to be solved. Outliers are badly established point correspondences among images and therefore they have to be removed. The well-proven solution is the general method RANSAC. The method chooses such subsets from the input data in random that sufficiently well describe the searched solution.

Our paper [4] proposes a new method for outlier detection in recovery of projective shape and motion from multiple images by factorization of a matrix containing the images of all scene points. Compared to previous methods, this method can handle perspective views, occlusions, and outliers in image correspondences jointly. The main novelty of this paper is the method for outlier detection whereas the proper reconstruction was described in [3]. In this work we assume that the amount of inliers, i.e. true correspondences, is significantly larger than the amount of outliers. The main idea is that minimal configurations of points in triples of images are sufficient to validate inliers reliably. The RANSAC paradigm is used. Trifocal tensors are computed from randomly selected minimal six-tuples of points in triples of images. After the tensor estimation, the number of points consistent with the tensor is counted. If there are sufficiently enough consistent points, those not used to estimate the trifocal tensor receive one positive vote. The voting is repeated until points in the measurement matrix are sufficiently sampled. The points that obtain zero or a very small number of votes are rejected as outliers. Inliers are used by the method described in [3] to obtain a projective reconstruction. An iterative process can further enlarge the set of inliers. The new method is demonstrated here by experiments with laboratory and outdoor image sets.

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# Mixed-hybrid Discrete Fracture Network Model of the Flow through a Rock Massif: Numerical Analysis of the Developed Model and its Calibration

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The weakest link in the nuclear energy production is the safe storage of highly radioactive spent fuel. One of the proposed repositories of dangerous nuclear waste are underground granitoid massifs. These massifs are however always disrupted by a system of geological faults, fractures, where the majority of the underground water flow occurs. The most accurate possibility for modeling the so called fracture flow are stochastic discrete fracture network models. In these models, the original 3-D fractures are approximated by planar polygonal disks whose frequency, size, assigned aperture, and orientation are statistically derived from field measurements.

In the presented model, we approximate the fractures by planar circle disks, and each disk is subsequently discretized onto a triangular mesh respecting the intersections with his neighbors. We thus obtain a 2-D triangular mesh placed in the 3-D space. Since natural 3-D fractures have varying apertures, the flow is not evenly distributed throughout the whole fracture planes. So called channels of flow occur. In order to simulate this channeling effect, an on-element aperture distribution function is used after the discretization. It assigns to each triangle element an imaginary aperture. Based on it, the hydraulic permeability of the element is set, considering also fracture wall roughness and filling. Like this, the classical model with parallel sides is avoided and the channeling effect can be simulated.

Various theoretical and experimental studies have shown the validity of Darcy's law for fracture systems. The steady saturated fracture flow can thus be described by a second order elliptic equation with a discontinuous permeability tensor. We have used the hybridization of the lowest order Raviart–Thomas mixed finite element method to numerically approximate the true solution. This method ensures good accuracy of the sought after velocity field and satisfied mass balance on the elements and its use is quite innovative in this field. We can easily notice an essential property of fracture networks: since the planar disks intersect in space, there exist interelement edges which are shared by three or more elements in the triangulation. This is not possible in classical 2-D domains, and consequently the standard theoretical results are not directly usable.

In [4], we have carried out the existence, uniqueness, and error analysis of the mixed finite element method for the discussed problem. We had to impose the requirement of appropriate continuity of scalar (pressure) and vector (velocity) fields over multiply shared inter-fracture boundaries in the definition of continuous function spaces in order to use the classical mixed methodology. Consequently, we could have stated the weak mixed solution and obtained its existence and uniqueness. We have introduced a discrete space for the approximation of the velocity field, fulfilling the requirement of the continuity of the normal trace over even multiply shared interelement edges. Defining local and global interpolation

operators on this space, we could have proved the commutativity diagram property, and consequently the existence and uniqueness of the mixed approximation. It was then enough to use the classical hybridization procedure.

In the dual mixed-hybrid FEM introduced by Oden and Lee in 1977, we require no continuity of the velocity field a priori. We impose the interelement continuity of the normal trace via Lagrange multipliers already in the weak formulation instead of it. Since this functions independently of the number of elements intersecting through one edge, imbedding the chosen approximation in the framework of the dual mixed-hybrid FEM seemed more straightforward. We had immediately the existence and uniqueness of the weak solution. However, the hybridization of the mixed method is a nonconform approximation of the weak mixed-hybrid solution, which have brought many difficulties, from verifying the existence and uniqueness to error estimates, see [4]. All theoretical results presented in [4] were confirmed on model problems with known solution.

The introduced model was calibrated on the granitoid massif of Potůčky, Western Bohemia, in the vicinity of the explorational drill hole Ptp-3, and the results can be found in [3]. The input data were available as the result of various geological measurements (core-log evaluation, acoustic camera scanning, etc.). The carried out simulations of the real situation have proved good correspondence between observed phenomenon and numerical approximation. The model gives very accurate velocity field within fracture planes and thus in the whole simulated network. Namely, the channeling effect was observed both in fracture planes and in the entire network.

Just simulation of small domains is possible with the introduced model. To simulate large scale domains, we plan to use an equivalent porous-block approach. In this approach, one uses an equivalent porous medium model, where the permeability tensor of the elements of the partition is set up from the local stochastic discrete fracture network model. In the near future, our main interest is however the simulation of the contaminant transport through the fracture networks with the use of the velocity field given by the introduced stochastic discrete fracture network model.

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# Some Applications of Differential Equations in Mechanics

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In our project we have solved two problems.

## 1. **Optimal shape of a rod**

The first problem, which is mentioned in this contribution is a buckling of ideal rod of variable crossection with length $l$ and constant modulus of elasticity. The rod is jointly fixed in both endes. Our aim is to find "the optimal shape" of the rod. This means, we find a shape, which has a minimum volume and its buckling resistance corresponds with critical force. For simplicity we suppose the rectangle crossection. Note that similar problem was formulated already in 18. century by J. L. Lagrange. The mathematical methods which are necessary to solve these problems were established in 20. century.
Mathematical formulation of our problem is following. We solve the problem

$$EI(x)u''+\lambda u(x) = 0 \tag{1}$$

with the boundary conditions

$$u(0) = u(l) = 0\,, \tag{2}$$

where $u$ is defection of the rod, $E$ is a known constant and $I(x)$ describes a moment of inertia..

Let force $F$ is given. We say that function $I$ is admissable and that the first eigenvalue $\lambda$ of the problem (1), (2) satisfies inequality

$$\lambda \geq F.$$

Denote by $A$ the set of all admissible function. Our aim is to find function $I$, such that

$$\int_0^l \sqrt{12I(x)}dx$$

is minimum on the set $A$. Solution of this problem was published in [1], where it is showen that

$$I(x) = \frac{3F}{E\mu l^3} \int_0^l (lt - t^2) dt (lx - x^2)^{\frac{4}{3}},$$

where $\mu$ is a parameter of the material under consideration.

## 2. **The mathematical model of aerodynamical flow round the body of rectangular shape**

The second problem deals with the numerical solution of mathematical model of two-dimensional flow in special domain, which describes flow round the body of rectangular shape. We deal with the system which consits of the equation (4.3.6) from [2] for unknown stream function $\psi$ and of special boundary conditions corresponding with our problem. The problem was solved numerically by finite difference method.

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Section 2

# PHYSICS

# Improvement of Physic Teaching Based on Student Laboratory Work at Faculty of Transportation Sciences

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It is necessary to reflect fast development of physical knowledge in the level of physics education in all natural sciences and technical branches. The important tool in physics education for students of master programme have practical labs in which they deal with contemporary knowledge of physics.

The student physical labs at the Faculty of Transportation Sciences of Czech Technical University were established three years ago.

The student physical labs, which are a part of the Department of Applied Mathematics, fully cover practical exercise for the subject Physics I and Physics II (about 200 students per year). The lab exercises cover practically all parts of physics. Students work in pairs fully independently and actively measure labs experiments. Such extensively use of student labs needs a corresponding technical base. The current state of the labs has not been satisfactory yet. The reasons are both the fact that the labs were established short time ago and because of the fact that the financial means which were at our disposal during last three years, were not sufficient.

The financial of this grant were used for preparing of two new exercises concerning magnetism and elasticity and for the complement the exercise " Characteristic X-rays and Bragg scattering", because these types of labs had been missing. The topics of exercises were:

- modulus of elasticity
- magnetic moment in the magnetic field
- characteristic X-rays and Bragg scattering, Duane-Hunt displacement law and Planck´s "quantum of action"

There is mentioned one of lab exercises:

Magnetic moment in the magnetic field

A conductor loop carrying a current in a uniform magnetic field experiences a torque. This is determined as a function of the radius, of the number of turns and the current in the conductor loop and of the strength of the external field.
The problem is: determination of the torque due to a magnetic moment in a uniform magnetic field, as a function

1. of the strength of magnetic field,
2. of the angle between the magnetic field and the magnetic moment,

3. of the strength of the magnetic moment.

Series connection is recommended so that the same magnetic field is induced in both coils. In the Helmholtz arrangement, which can be built up with the spacing cross-members supplied, the coils are arranged reversed.

As the important part of this work of new labs exercises were created laboratory guides for the students. The laboratory guides for magnetic moment in the magnetic field, characteristic X-rays and Bragg scattering, Duane-Hunt displacement law and Planck´s "quantum of action" have been implemented in a laboratory exercises textbook Laboratorní cvičení z Fyziky II.

The pamphlet and laboratory guides were created for modulus of elasticity. The pamphlet contains also the basic theory and basic information concerning evaluation of measurement precision and especially the measurement uncertainties.

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# Physics Experiments in Optics and Optoelectronics at CTU

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The present state of knowledge of technical university students in the branch of modern optics and optoelectronics does not reflect the contemporary development of this progressive technology field. So we proposed a project to improve our physics teaching course in the field of wave optics and optoelectronics. A new programme was realized at our departments and it created new conditions for a current laboratory training in the above mentioned branches of optics. Under the project several set-ups were completed for the following experimental study topics: (a) application of wave optics – measurements of thin films, lens curvature radius and refractive index by means of interference phenomena, (b) coherence sources of radiation – study of semiconductor light sources, (c) properties of optoelectronics devices – light sources and radiation detectors. Each of these setups is used by 700 students every year in average. It was essential to prepare instructions for students containing the basic theory and directions for use to perform the measurements.

The primary goal of the project was to design and prepare some new measuring set-ups where optics and optoelectronics tasks could be studied with a help of relatively contemporary instruments. We can mention two following suggested laboratory tasks, out of the several setups: (a) Measurements of the thickness of the thin film and (b) Characteristics of the optoelectronics elements and devices.

**Measurement of the Thickness of Thin Film**
**Objective of the measurement :** Determine the layer thickness **t** of the thin film and evaluate its uncertainty.
**A short introduction to the problem:** To measure the thickness of the thin film we utilize the setup that consists of quasi-monochromatic sodium light source, a microscope with a light divider, micrometric ocular lens and a special thin film holder. This simple method of the thickness measurement employs interference in a wedge air gap.

**Study of the Semiconductor GaAs Laser**
**Objective of the measurement** :

1) Verify a calibration of the monochromator using spectrum of Hg lamp.
2) Measure light characteristic of the semiconductor laser, i.e. dependence of the radiant flux on laser current. Plot the dependency and determine laser threshold current.
3) Measure emission spectrum of the laser below the laser threshold current. Determine wavelength of the stimulated emission and estimate FWHM of the emission peak.
4) Determine power efficiency of the laser above he threshold region and compare it to manufacturer value.

**Introduction to the problem and a principal of the physical quantity measurement:** This part contains both the theory and a detailed description of the laser and instruction for measurement.
Investigated laser was manufactured using GaAs/GaAlAs material. It operates in continuous mode and is delivered together with a short optical fiber transmitting emitted beam. The fiber is fixed to one face of the laser while the other face accommodates encapsulated photodiode. Stimulated emission of the laser has wavelength $\lambda = 810$ nm and is out of visible wavelength range.
Most of the instructive materials, manuals, handouts and schedules are available to students on the departmental WWW serves.
As far as the future steps in improving the laboratory-training curriculum are concerned we would like to equip our labs with additional modern instruments.

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# The Innovation of Physic Teaching at Faculty of Transportation Sciences CTU

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It is necessary to reflect fast development of physical knowledge in the level of physics education in all natural sciences and technical branches. The important tool in physics education for students of master programme have practical labs in which they deal with contemporary knowledge of physics.

The student physical labs at the Faculty of Transportation Sciences of Czech Technical University were established three years ago.

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The financial of this grant were used for preparing of a new exercise " Characteristic X-rays and Bragg scattering", Duane-Hunt displacement law and Planck´s "quantum of action", because this type of labs had been missing. The topic of exercise was:

There is mentioned the lab exercise:

Characteristic X-rays and Bragg scattering

Principle
X-ray spectra are analyzed by means of various monocrystals and plotted by recorder. The energy of the characteristic lines is determined through the glancing angle position of their various orders of diffraction.

Problem
The intensity of the X-rays emitted by the copper anode at maximal anode voltage is to be recorded by means of a LiF-monocrystal as function of the Bragg angle (glancing angle).

Duane-Hunt displacement law and Planck´s "quantum of action"

Principle
By means of x,y-recorder, X-ray spectra are recorded as a function of the anode voltage. From the short-wave length limit of the bremsspectrum, the Duane-Hunt displacement law and Planck´s "quantum of action" are determined.

Problem
1. The intensity of the X-rays emitted by the copper anode at various anode voltages is to be drawn as a function of the Bragg angle by an x,y-recorder.
2. The short wavelength limit (or maximum energy) of the bremsspectrum is to be determined for the spectra of 1.
3. The Duane-Hunt displacement law and Planck´s "quantum of action" are to be verified by these measurements.

As the important part of this work of new lab exercise was created laboratory guide for the students. The laboratory guide, the basic theory and basic information concerning evaluation of measurements precision and especially the measurement uncertainties have been implemented in a laboratory exercises textbook Laboratorní cvičení z Fyziky II.

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# Radiation Damage in $YAlO_3$:Ce and $YAlO_3$:Ce, Zr Scintillators

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$YAlO_3$:Ce (YAP:Ce) single crystal is known as efficient and fast scintillator that will find its application in multi-detector systems or plates in medical imaging or in the electron microscopy. This material can be characterized by high light yield (up to 18000 photons/MeV) fast response and mechanical and chemical stability [1, 2].
During the scintillation process the transport of the thermalised charge carriers is influenced by the capture of the thermalised charge carriers at deep or shallow point-defect-based trapping states. This fact may lead to light yield decrease, slowing-down scintillation decay kinetics and material instability. The charge carriers trapped in deep traps form radiation induced colour centres, which are stable at room temperature. This phenomenon is called radiation damage and can be quantified by radiation induced absorption coefficient μ, which can be calculated from the following equation:

$$\mu = (A_{irr} - A)/d \qquad (1)$$

where $A_{irr}$ and A are the absorbances after and before irradiation respectively, d is the sample thickness. Colour centres are created as a result of a need for restoring a charge balance in the lattice [2].
Reduction of concentration of the mentioned point defects (often cationic or anionic vacancies) can be achieved for example by aliovalent ion doping. The aliovalent ions introduce an excessive charge in the lattice and can therefore significantly change the concentration of intrinsic point defects and consequently the concentration of colour centres [2, 3].
The goal of this work was to study both the influence of $Zr^{4+}$ codoping on radiation damage of YAP:Ce scintillator and effects related to the Ce doping concentration.
Six samples of YAP:Ce were analyzed. Concentration of $ZrO_2$ in the melt ranged from 0 to 1000 ppm and $CeO_2$ from 15000 to 35000 ppm. Samples were irradiated by $^{60}Co$ gamma source at dose rate of 17 Gy/h. Applied doses were 10, 55, 200 and 500 Gy. Optical absorption spectra before and after irradiation were measured at SHIMADZU UV 3101 PC spectrophotometer from 200 to 800 nm. The radiation induced absorption coefficient was calculated (equation 1) and resulting induced absorption spectra were decomposed into the sum of gaussians by SPECTRASOLVE computer program. For general comparison of the radiation hardness among the samples the total radiation damage was calculated as an integral of the induced absorption spectra. The parameters of each gaussian (peak position, amplitude and FWHM (full width at half of a maximum)) give us the information about the concentration and other properties of each colour centre.
Induced absorption spectra of all the samples were consistently decomposed into three gaussians. Parameters of them are similar when compared to the results of earlier studied YAP:Ce scintillator by some of us [1]. Each of them can be ascribed to one color centre, but it

is possible that more than three colour centres can participate in the radiation induced absorption mechanism.

Amplitudes of the gaussians decrease with increasing concentration of Zr for the highest values of Zr concentration (above 400 ppm). Dependences of the gaussian positions are almost independent on Zr concentration, some fluctuations of the less intensive peak position are probably caused by its small weight in the spectra and consequent instabilities of this parameter during the run of a computer fitting programme. Dependences of the FWHM on Zr concentration do not show a stable trend. This is due to the fact that FWHM is a parameter very sensitive to the disturbances in the surrounding lattice and such finding can point to varying quality of YAP host crystals within the set of samples studied.

Total radiation damage decreases almost linearly with increasing Zr concentration and is in correlation with decreasing thermally stimulated luminescence intensity and acceleration of scintillation decay, which have been observed earlier [3]. The value of the total radiation damage for Zr undoped sample was about three times higher than that of the sample with the highest Zr concentration.

This study confirmed the positive influence of Zr codoping of YAP:Ce scintillator, while changes in the Ce concentration have not significantly changed neither the gaussian parameters nor the total damage values.

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# Spin Correlations of Top-Antitop Quarks Produced in Proton-Proton and Antiproton-Proton Interactions at Energy 14 TeV and 2 TeV

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The Standard Model (SM) is at present a good theory of elementary particles, although it includes some free parameters, like masses of quarks and leptons, decay properties, etc. which need to be determined experimentally. The top quark is exceptional, with its high mass and short life-time of $10^{-24}$s. During this short time it can not hadronise and it decays as a free quark. Therefore, the decay products maintain the properties of the quark and provide information about the production and decay mechanisms for the top quark. During 1992-6 the Tevatron accelerator in Fermilab (Batavia, USA) collided protons and antiprotons, accelerated up to a centre-of-mass energy of 1.8 TeV (Run I). The top quark was there discovered in 1995. Hence, investigation of its properties is rather at the beginning.

The aim of my work was to investigate of the production of top-antitop pairs and their spin correlations. Final states with two leptons are better experimentally detectable, since there are less background events. However the cross section is lower compared to the other channels (4.6% with electrons or muons in the final state). Reconstruction of the kinematic topology is more difficult than for events with only one detectable lepton and several jets in the final state. I have reconstructed the events full topology, and this allowed me obtaining a better results compared to previous work on similar subject.

Observation of the expected spin correlations should confirm that the top quark has a non-zero spin and it decays before hadronisation. The spin correlations is sensitive to the existence of non-standard interactions of the top quark, like CP violation, influence of the Higgs boson and SUSY particles on the production mechanism. It has been investigated in Fermilab in Run I on six events with two observed leptons and two b-jets in the final state, by the D0 experiment. This should be compared with the results in the Tevatron Run II (improved accelerator and detector D0) using more events and of course after starting the LHC accelerator in CERN.

I developed a Monte-Carlo generator based on PYTHIA 6.156, which includes the spin properties of the top-antitop quarks production. ATLFAST 2.22 was used to simulate the ATLAS detector. The code was optimized for the use of the Root 3 framework for data analysis.

The complete density matrix was implemented for the production and following decay of top-antitop pairs to gain a better accuracy and independency from the used spin basis. For the sake of comparison, an additional simulation was made with only diagonal elements for the density matrix in the helicity basis.

The most important background process is the production of top-antitop pairs, where at least one top decays to a b-quark, a tau and a tau-neutrino. The tau lepton can decay to one antilepton and two neutrinos. The detected final state particles are the same as in the investigated process, but the kinematic topology is different. Such events may affect the kinematic reconstruction of the event topology and (using the present reconstruction algorithm) the observed spin correlations are strongly influenced. Events with a tau are significantly different from signal events, mainly in the distribution of the transverse momentum

of the observed charged leptons. Therefore I applied a cut on the charged leptons $p_T$>25 GeV. At the parton level the ratio between signal and the tau background is S/B = 1/0.382. After applying the all kinematic cuts, simulating the detector response and reconstructing the event topology, the ratio is improved essentially: S/B = 1/0.117.

The following event selection criteria were used: events with two detected leptons (e or mu) of opposite charge, pseudorapidity $|\eta|$<2.5, transverse momentum $p_T$>25 GeV, two tagged b-jets with $|\eta|$<2.5 and $p_T$>25 GeV, missing transverse energy $E_T^{miss}$>40 GeV, invariant mass of the two charged leptons and of the two b jets sufficiently far from the $Z^0$ boson mass $|M_{l,anti\ l}-M_{Z0}|$>5 GeV, $|M_{b,anti\text{-}b}-M_{Z0}|$>5 GeV.

| Year | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Number of produced top-antitop pairs with 2 leptons in the final state | $5.3\cdot10^5$ | $1.1\cdot10^6$ | $1.6\cdot10^6$ | $2.1\cdot10^6$ | $2.7\cdot10^6$ |
| Number of observed events after selection criteria | $2.2\cdot10^5$ | $4.5\cdot10^5$ | $6.7\cdot10^5$ | $9.0\cdot10^5$ | $1.1\cdot10^6$ |
| Significance of spin correlations in number of standard deviations | 10 | 14 | 17 | 20 | 22 |

In the table I summarized the obtained results of my study of the top-antitop spin correlations calculated under the assumption of the low luminosity LHC runs L=10 $fb^{-1}$/year and ttop-antitop production cross section 833 pb. In the table the number of events corresponds only to 6.4% of produced top-antitop pairs, which include the events with two leptons (e or mu) in the final state (including the final state with e or mu in tau decay). Thus if several hundreds thousands events would be observed in the ATLAS experiment, the spin-spin correlations of top-antitop pairs could be measured. This could enable to study the dynamics of heavy quark production and decay even beyond Standard Model.

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# Non Thermal Plasma Technologies for VOC Decomposition

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The volatile organic compounds (VOC's) are used in a wide range of applications. In the paint industry organic solvents such as toluene, xylene and methyl chloride are commonly used as paint thinner or are used for cleaning of the wall surfaces. In the high technology semiconductor industry, organic solvents such as toluene, trichlorethylene, tetrachlorethylene and trichlorethane are used. These pollutants are normally mixed with air. Their removal from effluent streams is a widespread problem of great environmental importance.
These VOC were observed to affect human health significantly for people living near industrial facilities as well as factory workers. Some selected VOCs and their health effects are shown in Table 1.

Table 1. Selected VOCs and the health effects. Threshold level value (TLV).

| VOC | TLV [ppm] | Formula | Effects |
|---|---|---|---|
| Trichlorethane | 200 | $CH_2CLCHCL_2$ | Probable birth defects, heart problems |
| Acetone | 10 | $CH_3COCH_3$ | Carcinogen |
| Trichlorethylene | 50 | $ClHC=CCl_2$ | Liver and kidney disease, paralysis of nerve centers |
| Toluene | | $C_6H_5CH_3$ | Headache, dizziness |
| Formaldehyde | | HCHO | Sore throat, dizziness and headache |

Following conventional technologies are used for removal of these VOCs.

- Thermal incineration. Exposure of VOCs to temperature exceeding 1000°C in air for a long time provides almost complete decomposition. But such a high temperature for a long time requires a huge amount of energy; therefore this method is very inefficient.
- Catalytic oxidation. This method allows lower operating temperatures. A disadvantage however is, that catalysts are sensitive to poisoning by sulphur, chlorides, leads etc. Therefore they require frequent replacement.
- Adsorption. The VOC is retained on the surface of adsorption material such as carbon, zeolite or polymer. The removal efficiency is high, however the adsorbents require regeneration or disposal after a certain period.
- Biofiltration. Biofiltration uses microorganisms to convert VOC into carbon dioxide, water and mineral salts. The sensitivity to temperature, humidity and gas composition represents the major drawback of biofiltration.

The above listed classical technologies require relatively high capital costs and hence they are inefficient for lower concentrations of VOC. Contrary to these technologies the discharge based non-thermal plasma technologies can be highly effective in promoting oxidation, enhancing molecular dissociation or producing free radicals to stimulate plasmachemical reactions leading to the VOC decomposition even for low concentrations of VOC. There are several types of non-thermal plasma reactors, which have been tested for VOC decomposition. Among them are corona discharge (DC or pulsed), dielectric barrier discharge and the discharge stabilized by the flow of a gas.

For the purposes of VOC decomposition we tested multi-hollow needle to plate plasmachemical reactor (MHNP) using the atmospheric pressure discharge enhanced by the flow of the mixture of air with VOC through the needles [2,3,4]. The high-speed gas flow near the exit of the needles cools the electrodes; hence the higher values of the discharge current can be obtained without the danger of the discharge transition to the spark. Another advantage of this arrangement is that all the mixture passes through the discharge region and therefore it is affected by the plasmachemical processes.

We performed an experimental study of the basic electrical characteristics of the discharge in the mixture of air with n-heptane as well as the study of the n-heptane decomposition by the MHNP reactor. The experimental set-up is described in [2]. We choose n-heptane as a representative of alkanes with saturated bonds. The most probable reaction channels leading to the n-heptane decomposition are the dissociation of the C-C single bond and the dissociation of the C-H bond in the $CH_3(CH_2)_5CH_3$ molecule. It was found that volt-ampere characteristics of the discharge for the needles positive are strongly influenced by the n-heptane concentration. It was also found that for the initial concentration of n-heptane 108 ppm in the stream of air with a flow rate 140 slm, for the energy deposition into the discharge 52,8 kJ/m$^3$ and for the relative humidity of the exhaust mixture 7% the decomposition efficiency reached 37 %. It was also found that the decomposition efficiency increases with the increase of energy deposited into the discharge. The experimental results are in detail described in [3].

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# Visualization of High Current Discharges at Atmospheric Pressure

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In this paper is presented a visualization of high power electric discharge with the parameters of the lightning channel. Experiments were held in the High Power Discharges Laboratory of Institute of Plasma Physics and Laser Microfusion with collaboration of the International Centre for Dense Magnetized Plasmas in Warsaw.

The apparatus is supplied with three parts of capacitor bank. The section A, B and C have capacity 1 μF, 9 μF and 22,5 mF, respectively. The Bank C has divided into four parts. The total electric charge was approximately 120 C. The electric current of the discharge supplied from section A reached its maximum of 35 kA 15 μs after the start of the discharge. Then, after 5 discharge periods starts the section B with electric current maximum 2 kA and discharge period 8 ms. The current in the section C reached about 300 A. Duration of the discharge is a few hundred ms. The discharge area, where the phenomenon was observed, was 42 cm long copper wire with diameter of 30 μm fixated between electrodes.

For diagnostics the digital camera, type FASTCAM-ultima1024 model 16K was used, with time resolution 2000 (4000) frames per second and image size 512x256 (512x128) pixels. In both case the shutter speed was 1/128000 sec. Camera was positioned side on to the wire and it registered total discharge. The sequence of electrical current was recorded on digital oscilloscope.

The discharge channel is non-stable and its evolution is characterized by fast transformation of its shape. We can see forming of king instabilities, helical structures, bright spots and pinching and explosion of a part of the channel.

The plasma channel development could be described by the existence of an axial magnetic field (component along the discharge channel designed Bz) and its transformation inside the plasma. This axial field with a random orientation can be spontaneously self-generated at the Z-pinch implosion or explosion in the consequence of fluctuations of plasma density, implosion velocity and cylindrical symmetry of magnetic field (analogy to the magnetic field generation in stars and planets).

At the final phase of the plasma implosion the kinetic energy does not transform directly into heat, but partially to the axial component of magnetic field. The final helicity of composed azimuthal and axial magnetic field is dependent on the intensity of the spontaneous self-generation of the axial component, on the radius of the pinch layer and on Bz periodicity along the z-axis. The lower helicity belongs to internal layers of the pinch and the periodicity along the z-axis is related to the periodicity of m=0 instabilities. The final phase of the implosion is connected with development of these instabilities and radial explosion of the plasma from the pinch localities with higher diameter.

This expanding plasma is crossing through the external magnetic field with opposite helicity (due to opposite orientation of closed Bz lines in external layers of the pinch) and it is caught into azimuthal current loops with opposite current orientation than that connected with internal

helicity of magnetic lines. Inside of these loops the total axial magnetic field is much smaller than inside of the helical structures and the loops can pinch. The dynamic behavior of the observed helical formations was roughly estimated in paper [1] by a ratio of imploding pressure of azimuthal magnetic field and expanding pressure of axial magnetic field. Then, at the plasma expansion, the influence of Bz is limited due to generation of the opposite azimuthal current, while the compression influence of the azimuthal magnetic field is increased and the expansion can be stopped. In some cases the compression can convert into implosion. During the implosion discussed before the damping of the generated and compressed axial Bz lines is increasing. The expansion pressure of the axial magnetic field is vanishing during the time of diffusion and penetration of magnetic fields of both opposite orientations. This process enables the pinching of the necks, acceleration of the plasma in z-direction and formation of the balls. Then the time of steady state and transformations is given by the time of magnetic fields dissipation. The ball, which is formed in discharge channel after its helical and pinch forms is characterized with the diameter of 1,3 cm and the lifetime was about 5 ms. Electric current during this phase, in the time 250 ms after beginning discharge, was 280 A.

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# Signal Processing of Time - Depending Signals of Periodically Working Machines

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The transform used for a signal processing most is Fourier Transform. Due to this transform to the frequency domain, time information is lost. The Short Time Fourier Transform is a compromise between the time and frequency based views of a signal. It provides some information about both when and what frequencies a signal event occurs. The precision of obtained information is limited because it is determined by the size of the window used.

Wavelet transform represents the next logical step, a windowing technique with a variable-sized region. The major advantage of this method is the ability to perform local analysis – which is to analyse a localised area of a larger signal.

Cyclic signals, for example, the vibration and sound reciprocating machines, such as diesel engines, represent a special case, where in the long term they may be considered stationary, but where short-term variations within the cycle are of interest.

With machine run-ups and run-downs, it is sometimes desirable to express the results as an Order Analysis, where the frequency axis is changed to one of harmonic order, independent on shaft speed.

If we use for the case, which was mentioned above, Short Time Fourier Transform we obtain a 3-dimensional spectral map. Particular harmonic frequencies fall along radial lines and can be separated from constant frequency components (such as resonances and mains frequency related components) which follows lines parallel with the time axis. This type of display is ideal for determining whether a noise or vibration problem within a particular speed range is primarily due to a large forcing function (and if so, which one) or to excessive amplification by a structural resonance. But we have to mentioned that the number of period differ in each window. This problem could be solved by Order Analysis.

The signal used to control the sampling of the A/D converter can be generated by a tracking ratio adapter, which takes a synchronising signal (typically a pulse once per shaft revolution) and produces an output signal whose frequency is multiplied by the set ratio. The multiplying factor, $F$, by which the fundamental frequency should be multiplied, is given by $F=N/n_1$, where $N$ is the number of samples and $n_1$ is the number of period. Every period of the fundamental frequency will be occupying $F$ samples along the memory. Harmonic frequencies correspond to harmonic orders, but harmonic orders do not change their $x$-coordinates in spectral map in contrary to harmonic frequencies.

Signals of periodically working machines, which were measured, were processed by classical methods of signal processing – Short Time Fourier Transform and Wavelet transform, and by a new method – Order Tracking Analysis. Some characteristics of processed signals and their physical interpretation has been surged. Psychoacoustical tests are in preparation; psychoacoustical indexes will be obtained by usual statistical method. On their basic the

suppressions of the most disturbing frequencies will be suggested to improve acoustical properties of tested machines.

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# Detection of Neutrons at PF-1000 Facility

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The implosion of the deuterium plasma toward the Al wire was operated at the PF-1000 facility in the Institute of Plasma Physics in Warsaw at the current amplitude of 1.5-1.8 MA. The Al wire of 120 μm diameter and 4-5 cm length was located on the top of the inner electrode. The pulse of radiation in XUV and soft X-ray range was detected at the minimum diameter of the plasma focus phase and it was composed from lines of Al VI – Al XII ions. The presence of the Al wire in the axis of plasma focus outlet had no influence on the hard X-ray production and neutron yield. The neutron pulse was characterized by the FWHM of ≈ 200 ns and the yield up to $5x10^{10}$. The maximum of the neutron production was occurred up to 200 ns later than the maximum of the soft X-rays.

The plasma focus discharges is being studied due to high efficiency of the X-rays and the neutron yield production (at the deuterium as a filling gas). The results of the study of the interaction of the hydrogen current sheath with the Al wire of 120 μm diameter were presented in [1]. In paper [2] the results of XUV, X-ray and neutron production at the implosion of the deuteron current sheath without the wire in the electrode outlet were summarized. This contribution summarizes influence of the Al wire located on the top of the inner electrode on the X-ray and neutron emission at implosion of the deuterium current sheath.

The PF 1000 device was operated at the energy of 600-650 kJ and the current maximum of 1.5-1.8 MA. The Al wire (length of 3 cm and 120 μm diameter) was located on the axis of the electrode without galvanic connection.

The radiation from visible to hard X-ray ranges was measured side on by two gated soft X-ray multichannel plates (MCP - each of 3 ns exposure, 10 ns delay between expossures, filtered by 5.2 μm polyster - $C_8H_8$,1.11 $gcm^{-3}$), by the PIN silicon detectors (filtered by 10 μm Be), by 2 visible frame cameras with 3 ns exposure, by two scintillators (Ne102a filtered by 10 μm Al or 20 μm Cu for X-rays in keV range), by the XUV grazing incidence spectrograph for the range 2-10 nm (to scan K-shell lines of C, N and O and L-shell lines of Al) and by the 2D imaging mica crystal spectrograph in keV range (for study of Al K-shell lines. Three scintillation probes, located back on at distances of 6.5 m, 40.2 m, and 85 m from the electrode outlet, were used to perform time-resolved measurements of the hard X-ray (20-50 keV) and neutron emission.

The temporal dependence of the soft and hard X-ray and neutron production was observed. The soft X-rays (detected by PIN) were emitted during 300-500 ns with FWHM of 60 – 200 ns. X-rays in range 8 – 25 keV were emitted in temporal correlation with soft X-rays, but usually with 2 narrower peaks of FWHM of 30 – 60 ns. The hard X-rays in range above 50 keV were emitted in temporal correlation with neutrons. The neutron signals were shifted to plasma focus area 6 cm in front of the electrode assuming 2.45 MeV neutron energy. This energy with very small differences was evaluated from the temporal position at different distances and the same FWHM of neutron pulses. The neutron pulses (the FWHM of ~ 200 ns) belong to shifted scintillation signal detected in distance 6.5 (or 40.2) m. These pulses

started usually after the soft X-rays and their maximum occurred up to 200 ns later than the maximum of the soft X-rays The total neutron yield reached values up to ~ $4x10^{10}$, approximately 30-50% of those without wire. High neutron yield was observed in shots with an extremely stabile corona imagined by streak camera. Thus, the presence of the higher Z-elements in the axis area of the electrode outlet of 1 mm diameter and 4-5 mm length did not considerably neutron generation.

The radiation of the corona around the wire started ~ 70 ns before the PIN diode maximum in visible, XUV, soft X-ranges of wavelength. The diameter of the imploding plasma sheath was a few cm and the corona of the diameter of 2-3 mm radiated uniformly without perturbations along the total length of the wire at this time. The maximum of the soft X-rays (reference time zero, t=0) was in temporal correlation with a minimum of the current derivative and with a minimum of corona diameter imaged in visible, XUV and soft X-ray range. The radiation was emitted uniformly along the total length of the wire at this time. Later the soft X-ray intensity was decreasing with the corona diameter increasing. The increase of the diameter in visible range was imaged by the streak camera (the velocity of onset ~ $6\times10^3$ $ms^{-1}$). Small perturbations are observable on the surface and the localities with more intensive radiation have larger diameter.

Instead the H- and He- like Al lines were emitted from all the length of the wire corona of ~ 1 mm diameter, the He-like Al satellites were emitted from much brighter and longer form. The temperature of the plasma calculated from the FLY code reached value up to 500 eV.

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# Modelling of GaAs Stress-Strain Curves and Photoplastic Effect

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The electronic excitation, e.g. by light illumination, of a variety of semiconducting materials can result in a decrease of their plastic flow stress due to an increase of dislocation mobility. This is referred to as the negative photoplastic effect. Such an effect is explained in terms of recombination-enhanced defect motion and well interpreted by the so-called phonon-kick mechanism of defect migration, where phonons emitted on nonradiative electron-hole recombination process at dislocation sites contribute to the elementary processes for dislocation movement through a reduction of the corresponding activation energies [1].

As reported in [2], the illumination has an influence on the form of the stress-strain curve. Unfortunately, the experimental conditions are described improperly and some important data are missing, such as for instance the stress orientation. Compression tests were performed on n-type GaAs at 423 K (with predeformation) and 793 K at a constant strain rate. Monochromatic illumination has decreased the yield point at the temperatures below 573K, while for temperatures above 573 K there is no influence on the yield point.

We use the single slip model accounting for three types of dislocations (alpha, beta, screw) presented in [3] and calculate the stress-strain curve for gallium arsenide deformed at 413 K. The photon illumination is taken into account by a change of dislocations velocities parameters as described in [1].

Because the plasticity is governed by the dislocation multiplication, an analysis of the evolution of dislocation densities during deformation helps us to understand the different stages of the calculated stress-strain curve. The change of dislocation activation energies caused by illumination induce an abrupt increase of dislocation multiplication rate till a saturation is reached; then the dislocation densities remain constant, the stress as well. When the light is switched off, alpha and beta dislocations multiply very slowly and their densities are sufficient for multiplication of screw dislocations controlling the plastic deformation.

According to [2] and the experimental curve: “On switching off the light the deformation stress regains its level in the dark.” Moreover, “This effect can be observed many times on switching on and off the illumination.” This amazing fact needs a deeper understanding because it invokes a lot of questions. Indeed, in our model the stress reduction is obtained by dislocation multiplication. Because of the dislocation density evolution, the model is not able to regain the stress level in the darkness and to continue the original stress-strain curve. The darkness curve can be taken up again when the dislocation density remains approximately the same during illumination. Because in our model dislocations continue to multiply, a constant total dislocation density can be achieved by stronger annihilation.

We propose the following scenario: Turning on the light increases the dislocation velocity. As the dislocation multiplication depends on the velocity, the dislocation density also increases. When a critical dislocation density is attained, higher dislocation velocity causes frequently collisions and consequently more effective annihilation reducing considerably the total dislocation density. After switching off the light, dislocation multiply and their total density regains the value corresponding to the given point on the curve in darkness. However, experimental observations are needed to confirm the validity of this hypothesis.

To simulate the whole stress-strain curve annihilation should be taken into account in the dislocation multiplication laws. We suggest this improvement for a future development of the model.

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# Modelling of Plastic Zone around Vickers Indent. Analytical Approach.

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Indentation tests have been used for many years as a standard method to evaluate the mechanical properties of materials. We describe the microindentation test and the observations of the plastic zone created by the Vickers indents on (001) GaAs-face. The plastic zone is simulated by analytical calculation with different elastic stress tensors.

Observations by high voltage transmission electron microscope showed that the plastic zone around the indents is anisotropic and consists of several parts [1]:

- perfect dislocations with Burgers vectors inclined to the surface, which have moved into the crystal on {111} planes which converge beneath the indenter;
- perfect dislocations with Burgers vectors inclined to the surface which have moved into the crystal on {111} planes which diverge from the indenter;
- perfect dislocations with Burgers vectors parallel to the surface, which have moved primarily parallel to the surface and outward from the indenter in both <110> directions to form rosettes;
- microtwins in {111} planes only in the [110] rosette arm nucleated on - or very close to - the indented surface. All twinning dislocations emerge at the indented surface.

To obtain a complex picture of dislocation motion around indentations, the stress field produced by the indenter should be determined. Different elastic solutions expressed in the analytical form are used for calculation of the shape and dimensions of the plastically deformed region. The stress tensor of Hill [2], Boussinesq, Mindlin are used as well as the “blister” type field and combination of the blister and Boussinesq field. To compare the different stress fields, we determine the extension of the plastic zone by considering that its radius is given by the distance at which the resolved shear stress on a given slip system reaches some critical value called critical resolved shear stress (CRSS). The resolved shear stress is evaluated by calculating the glide component of the Peach-Koehler force acting on the corresponding dislocation in the indenter stress field.
To compare the shape and dimensions of the plastic zone obtained by means of different stress fields, calculations are performed for 1/2[1-10] (111) slip system, representing the rosette dislocations, and 1/2[0-11] (111) slip system, corresponding to glide in convergent or divergent planes. Because of the stress tensor symmetries it is not necessary to consider other slip systems.

Since the results obtained with each stress tensor are similar, especially when the shape of the plastic zone on the surface is regarded, it is concluded that even the simple and from the calculation point of view unpretending spherical Hill stress field approaches the experimentally obtained result quite well. Note that Yoshioka in his investigation of indented Si single crystals

[3] also concluded that the stress distribution could be considered as nearly spherical, although the plastic zone is far from it.

Alternatively to the different analytical solutions, the stress field distribution around an indent can be calculated numerically. An advantageous tool is the finite element method. Two finite element analysis products were used for calculation of the stress and strain fields - Castem 2000 and Abaqus/Explicit. The plastic zone is then determined with help of the Von Mises yield criterion. Calculations of the stress field around Vickers indent confirm the results obtained with the analytical expressions for the stress tensor. From the numerical calculations it follows that the most important stress concentrations are near the edges of the indenter, under the surface. The distribution of the Von Mises stress hints the extension of the plastic zone that is comparable to the results obtained by use of the different analytical stress fields. The isolines of the Von Mises stress confirm spherically symmetric distribution of the stresses and thus the convenience of the Hill's solution.

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# Mathematical Methods in thePhysics of Microworld

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The research of the group of 5 collaborators from the Department of Physics of CTU-FNSPE and 6 from the Department of Mathematics of CTU-FNSPE was carried out in 2002 in the framework of the long term research project in mathematical physics. The research was devoted, among other topics, to generalized symmetries connected with the physics of microworld, the associated algebraic and geometric structures, and their applications to classical and quantum systems. In this connection, special models were studied in terms of the corresponding Schroedinger operators as well as via the solution of the Schroedinger equation and the Hamilton equations. The investigations by the participating qualified researchers were performed in direct collaborations with the students of Mathematical Engineering at FNSPE. They are given below under each research theme together with our foreign collaborators.

The research topics were the following:

(1) Quantum groups and related algebraic structures, their representations; quantum integrable models: 15 publications by Burdík, Havlíček, Hlavatý, Šťovíček together with Prof. A.U.Klimyk (Kiev), Dr. A. Pashnev (Dubna), Doc. O. Navrátil (CTU) and students of FNSPE (Václav Kavka, Hynek Lavička, Ing. Libor Šnobl).

(2) Gradings and graded contractions of Lie and Jordan algebras: 4 publications by Havlíček, Pelantová, Tolar together with Prof. Jiří Patera (Montréal) and students of FNSPE (Jiří Hrivnák, Petr Novotný, Milena Svobodová).

(3) Quantization and quantum mechanics in finite-dimenstional Hilbert spaces, applications in quantum optics (coherent states) and quantum information theory (11 publications by Chadzitaskos, Jex, Šťovíček, Tolar together with Dr. A. Delgado (Ulm), Prof. W. P. Schleich (Ulm), Dr. P. Törmä (Helsinki), Prof. G. Alber (Darmstadt), Prof. A. Odzijewicz (Bialystok) and students of FNSPE (Petr Luft, Petr Pecha, Ing. Jaroslav Novotný, Martin Štefaňák, Jan Vyměta1).

(4) Mathematical models of quasicrystals and their applications to wavelets and pseudorandom number generators: 10 publications by. Burdík, Pelantová, Masáková with international collaborators (Dr. Ch. Frougny (Paris VII), Prof. J.-P. Gazeau (Paris VII), Dr. L.-S. Guimond (Paris VII), Prof. Jiří Patera (Montréal)) and students of FNSPE (Ing. Miroslav Andrle, Ing. Jan Patera, Petr Ambrož, Petr Baláži, Milena Svobodová).

(5) Schrödinger operators periodically dependent on time, solutions of Schrödinger equation and Hamilton equations for special models, classical chaos: 9 publications by Gemperle, Jex, Svoboda, Šťovíček together with Prof. P. Duclos (Toulon), RNDr. L. Krlín, CSc. (ÚFP AV ČR), RNDr. P. Šeba, DrSc. (FzÚ AV ČR), Prof. A. Zeilinger (Vídeň) and students of FNSPE (Mgr. Milan Krbálek, Ing. Ondřej Lev, Karel Maršálek).

Quantum properties of matter are becoming increasingly important in modern technological applications. This leads to the necessity to investigate quantum or classical models which yield qualitative as well as quantitative view of the observable characteristics of physical systems. We have used simplifying assumptions on symmetry or geometry which allowed us to derive typical models possessing at the same time physically relevant properties of real systems, and to solve them in a mathematically rigorous way. In this manner such mathematical models have served as suitable laboratories for the study of fundamental properties of microsystems.

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# Double Beta Decay Experiment NEMO3 – Current Status and Czech Contribution

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**Double beta decay**

Double beta decay is a rare spontaneous transition between two nuclei with the same mass number A in which the charge Z changes by two units. The decay proceeds for even-even nuclei where the initial nucleus is less bound than the final one and both are more bound than the intermediate nucleus. The two-neutrino double beta decay ($2\nu\beta\beta$), $(Z,A) \rightarrow (Z+2,A) + 2e^- + 2\nu_e$, is a process in agreement with the Standard Model and has already been measured for several nuclei [ 1 ]. On the other hand, the neutrinoless double beta decay ($0\nu\beta\beta$), $(Z,A) \rightarrow (Z+2,A) + 2e^-$, is forbidden in the standard electroweak theory because it violates lepton number conservation and involves right-handed currents for the decay to excited states. The $0\nu\beta\beta$ decay is the most promising test of the Majorana versus Dirac nature of neutrino because such process may occur only if there are Majorana neutrinos, which are massive and identical to antineutrinos. That means that double beta decay experiments are able to explore completely new physics beyond the Standard Model.

**NEMO3 experiment**

The main goal of the NEMO3 experiment is to study neutrinoless double beta decay to a half-life limit of $10^{25}$ years. This value corresponds to the sensitivity for the effective neutrino mass $\langle m_\nu \rangle$ of the order of 0.3 – 0.1 eV. Besides $0\nu\beta\beta$ decay, NEMO3 allows a thorough study of the $2\nu\beta\beta$ decay to the ground and excited states of several nuclei. Another interesting feature of the detector is that it can measure the ultra-low intrinsic contamination in $^{208}$Tl and $^{214}$Bi of double beta decay sources thanks to very efficient background suppression and sophisticated detection techniques. This project is realized by a large international collaboration which at the present time involves France (CENBG Bordeaux, IReS Strasbourg, LAL Orsay, and LPC Caen), Russia (ITEP Moscow and JINR Dubna), the Czech Republic (CTU Prague and Charles University of Prague), the USA (INEEL Idaho Falls and MHC South Hadley), Finland (Jyväskylä University), and Japan (Saga University). Particle detection in NEMO3 is provided by a tracking wire chamber while measurements of energy and time-of-flight are done by a calorimeter.

The detector is composed of 20 equal sectors, it has cylindrical shape, its height is of about 3 m and its diameter makes about 5 m. The tracking wire chamber, which provides a three-dimensional reconstruction of charged particle tracks, is made of 6180 open octagonal drift cells operating in Geiger mode and is filled with a mixture of He gas and 5% ethyl-alcohol. The calorimeter, which surrounds the tracking volume, consists of 1940 blocks of plastic scintillators which are coupled to very low radioactivity photo-multiplier tubes (PMTs) specially developed for the NEMO experiment by Hammamatsu. The NEMO3 detector accommodates almost 10 kg of sources of different double beta decay isotopes like $^{100}$Mo (7 kg), $^{82}$Se (1 kg), $^{116}$Cd (0.4 kg), $^{130}$Te (0.5 kg), $^{150}$Nd (40 g), $^{96}$Zr (10 g), and $^{48}$Ca (7 g) [ 2 ]. These sources, placed in the center of the wire chamber, are in the form of thin foils (thickness of about 55 μm). Neutrinoless double beta decay can be observed only if all possible types of background originating in natural radioactivity are completely suppressed or

reduced to extremely low levels. For this purpose, the following measures were taken: all the construction materials and detector components are of very low activities, particularly the sources and internal parts have to be ultra-free from $^{208}$Tl and $^{214}$Bi, magnetic field of 30 G is applied for rejection of ($e^+e^-$) pairs, shields against external photons and neutrons [ 3 ] are installed around NEMO3, and finally the detector is placed in the Modane Underground Laboratory (France) which provides an efficient shield against cosmic rays of 4850 meters of water equivalent (m.w.e). For more details about NEMO3, see for example [ 2 ].

**Current status of NEMO3**

The final tests of the calorimeter, tracking wire chamber, electronics, and data acquisition system were realized from January to March 2002. A magnetic coil was mounted on the detector in February and then the calibration of the calorimeter was carried out. Since that time the NEMO3 detector has been collecting experimental data. First, before the installation of the iron shield in April, the experimental data were dominated by external backgrounds. However, since the end of May the NEMO collaboration have been carrying out runs in almost the final configuration for the double beta decay measurements. Although the neutron shield, which is necessary for the $0\nu\beta\beta$ decay search, is not yet fully installed, this fact does not influence the $2\nu\beta\beta$ decay channel. At the present time, recent experimental data from NEMO3 are being analyzed in order to study the stability and performances of the detector, backgrounds, and $2\nu\beta\beta$ decay.

**Czech contribution**

Two Czech institutions, the CTU Prague and Charles University of Prague, have been directly involved in the NEMO3 experiment since 1999. They have managed the production of the following blocks for NEMO3: stand for the detector (1999), mechanical frame (2000), ten water tanks for the neutron shielding (2002). Moreover, the Czech physicists, in close collaboration with the French laboratories, have been actively participating since 2000 in the detector assembling, tests of hardware (calorimeter, wire tracking chamber, and electronics), as well as in the detector survey and data acquisition (background acquisition, runs with neutron sources, double beta decay runs, etc.). In 2002, the Czech group at the CTU-FNSPE also measured attenuation properties of different materials for the NEMO3 neutron shielding. At the present time, data analysis and detector performance studies are being processed by the NEMO Collaboration. From the Czech NEMO group, L. Vála is directly involved in the data analysis which is focused on the study of the $2\nu\beta\beta$ decay of $^{100}$Mo to excited states in $^{100}$Ru [ 4 ].

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# Acoustic emission study of cleavage initiation in notched tensile specimens tested in DBTT range

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In this paper acoustic emission (AE) technique is used to study the physical steps of damage preceding the final fracture of A508 steel tested in the ductile-to-brittle transition temperature (DBTT) range. AE technique provides a well-suited method to detect rapid micromechanical events, such as avalanche dislocation movement [1], mechanical twinning [2] or microcracking [3]. Combining this method with interrupted tests and fractographic analysis, early stages of damage can be identified.

Altogether ten specimens were tested. The mechanical tests were carried out on a INSTRON 1186 testing machine equipped with a cooling device consisting of an ethanol bath and liquid nitrogen cooling coil. During the test the flow of liquid nitrogen was stopped to avoid a noise. The temperature increase at the end of tests did not exceed 4 °C. The AE signal was monitored during each test using a highly sensitive LB10A transducer having a sensitivity of 85 dB ref. 1 V ms$^{-1}$, a flat response from 100 to 500 kHz and a built-in preamplifier giving a gain of ~ 30 dB. This transducer was coupled to the specimen head using a cyanacrylate layer waveguide and steel springs. A computer-controlled DAKEL-LMS-16 AE facility was then used to record the AE counts. The DAKEL AE facility applies a two-threshold level system of detection and evaluation of AE, recently recommended by an ASTM standard. The AE signals are filtered, amplified and then evaluated at two threshold levels to get two AE counts denoted $N_{C1}$ and $N_{C2}$. The total gain at the lower threshold level (count $N_{C1}$) was about 90 dB and the total gain at the higher level (burst count $N_{C2}$) was about 70 dB.

Two specimens were loaded to fracture at -50 °C and four at –10 °C. In addition four tests at -10 °C were interrupted before final cleavage fracture. Two from four specimens, which had undergone the interrupted tests, were used for microstructural examination in transmission electron microscope. Remaining two specimens were fatigue loaded until final fracture in order to reveal the damage state before the cleavage fracture. The initial applied load $F_{max}$=2 kN (with report of charge $R_s$=0.1) was progressively increased by 10% each $10^6$ cycles until complete fracture of the specimen. So prepared fracture surfaces were analysed in scanning electron microscope.

Several AE pulses are observed after the general yielding. After reaching of the maximum load, AE activity slightly decreases. The final cleavage fracture was always preceded by one distinct high-energy acoustic event. No obvious differences were detected in AE activity comparing the tests carried on at –50 °C and –10 °C.

The decrease of the AE count rate after reaching of the maximum load may be explained in following ways:

- An increasing density of forest dislocations with developing plasticity reduces both the velocity and the free length of moving dislocations, consequently, reducing the AE amplitude.

- The blunting of notch spreads the plastic deformation to the larger volume.

- The cohesive surface energy of manganese sulphide inclusions was estimated by Baker et al [4] to be only about 2 $J.m^{-2}$. The large inclusions debond earlier in the loading history so that AE decreases.

Acoustic emission is generated by a sudden local rearrangement of the internal stress field and can therefore be produced by only rapid events such as twinning or microcracking. It was shown that ductile fracture generates almost no detectable AE. Microstructural and fractographic analyses showed that neither twins nor cleavage microcracks are present in specimens which had undergone the interrupted tests, and the observed dislocation structure is formed homogeneously (without e.g. localised slip bands). On the other hand, many cracked and debonded large manganese sulphide inclusions were observed in the dimples on fracture surfaces of specimens which had undergone the interrupted tests. Hence AE activity results probably from cracking or debonding of MnS particles.

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# Algorithms for phase evaluation in interferometric measurement techniques

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The research was focused on a detailed theoretical analysis of several chosen methods for evaluation of the interference fields, which can be used in many noncontact interferometric measurement techniques in practice, e.g. in holographic interferometry, speckle interferometry, testing of optical surfaces, etc. The main goal in interferometric measurements is to determine accurately the phase difference of the investigated interference field, which mostly originates from the interference of the reference and the object wave field.

Various methods for evaluation of interferometric measurements exist in practice. We can divide them into two distinct groups: electronic and digital image processing techniques. This work focuses on the latter. These methods use digital image processing techniques for quantitative evaluation of the interference field and are perspective for full automatic measurement systems, because they meet trends and demands put on modern non-contact measurement methods in industry.

The work deals with problems of the most valuable methods for an automatic evaluation: the fringe skeletonizing method, the Fourier transform method and the phase-shifting method. Some of these methods use only one intensity frame, i.e. interferogram, to determine the phase values, the other methods need to record several interferograms to calculate unambiguously the phase. All these methods have significant advantages and disadvantages and the decision to use a certain method depends mainly on the special measuring problem.

Particular phase evaluation techniques has been compared on examples of the interference patterns using a computer simulation. For reliable comparison of properties of individual described methods the interference patterns with the same phase information were simulated. These interferograms were evaluated with the mentioned methods. The phase values were modeled by chosen Seidel aberration polynomials. The simulated interference field was also influenced by noise and it was subsequently evaluated using all above-mentioned methods. From the results of the performed analysis we can conclude that the phase shifting method is more accurate than the remaining evaluation methods in every case, when it is possible to use this method in practice.

The research mainly focuses on the derivation of the algorithms, which can improve phase evaluation of the interference field. The fringe skeletonizing method has been fully analysed and some improvements were made in the process of identification and numbering interference fringes. The proposed mathematical procedures for automatic phase evaluation were programmed and verified on several examples of the interference patterns with different shapes and spatial frequencies of the interference fringes. The process of filtering the Fourier spectra of interferograms, in order to obtain reliable and accurate results, was studied mainly for the Fourier transform method.

The largest part of the research was devoted to a complex analysis of the phase shifting technique. The principle of the method is based on evaluating the phase values from several phase modulated measurements of the intensity of the interference field. It is necessary to carry out at least three phase shifted intensity measurements to determine unambiguously and very

accurately the phase at every point of the detector plane. The phase shifting technique offers fully automatic calculation of the phase difference between two coherent wave fields that interfere. There exist many phase shifting algorithms for phase calculation that differ in the number of phase steps, in phase shift values between captured intensity frames and in the sensitivity to factors that affect interferometric measurements. Many existing phase-shifting algorithms are based on an assumption that all phase-shifts at all pixels of the intensity frame are equal and known. However, it is very difficult to achieve this case. Many phase evaluation algorithms, which are more or less sensitive to some types of errors that can occur during interferometric measurements, were developed in recent years. The algorithms derived in this work can be used for any phase-shifting measurement technique and they offer the advantage of insensitivity to phase-shifting miscalibration. Several multi-step phase-shifting algorithms with an arbitrary chosen but constant phase-shifts between the captured intensity frames are proposed. The phase-shift value is assumed unknown but constant in these algorithms and therefore it must be recorded at least four phase shifted intensity frames. These algorithms are insensitive to the phase shift miscalibration, which is very common in practice of interferometric measurements. A big advantage of the described algorithms is the possibility of pointwise phase-shift calculation. If the phase shift is miscalibrated, then it does not need to be calibrated. It also has the advantage of applying the phase-shifting technique in a converging or diverging beam, where the phase-shift is non-uniform across the beam.

It was also carried out an analysis of the proposed algorithms with respect to possible influences on the process of interferometric measurements. Some important potential error sources have been chosen and these influences were implemented in the model of the phase evaluation process. The properties of proposed multi-frame algorithms have been also investigated and the algorithms were compared with respect to their accuracy, sensitivity to the described types of errors and the computation time. The root-mean-square of the phase errors was used as a criterion for comparison of the different phase shifting algorithms. The errors in the phase measurement process can be decreased by applying an appropriate error-compensating algorithm and the analysis performed in this work can be used for decision between compared phase evaluation algorithms. On the basis of this analysis there were chosen the optimal multi-step phase shifting algorithms, which are most accurate.

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# Analysis of evaluation process in interferometric technique for deformation measurement

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The big effort in optical metrology during last two decades has been focused on the development of high precision techniques for measuring shape deformations of surfaces in engineering, which enable to make a fully automatic measurement evaluation. The measurement process in technical practice put heavy demands on present measurement methods, especially the non-destructive character of the measurement, high sensitivity and accuracy, possibility to measure the whole test object at a time during static or dynamic events in industrial conditions, compatability of the measurement results with numerical models of the test object, and possibility to perform the measurement in both macroscopic, and microscopic range with an automatic analysis and evaluation in real time.

Several optical three-dimensional measurement methods are available for non-contact, full-field-of-view and non-destructive inspection of the shape deformation of surfaces in industry. Using a specific method depends on the size of the investigated area of the test surface, the microstructure of the surface and the required measurement accuracy.

A big development of interferometric measurement techniques, which carry out the measurement results in real time and offer fairly large possibilities for deformation measurement, can be seen at present. The interferometric methods are based on the principle of interference of the two coherent wave fields (object and reference). The reference wave field interferes with the object wave field after its reflection from the surface of the test object. The interference field is recorded by a photodetector in an appropriately chosen plane. From the distribution of the intensity in the detector plane it is possible to determine the phase change of the object wave field, which is closely related to the displacements of the test object surface. For detection of the interference field these methods use modern electrooptic devices, e.g. CCD array sensors, which rapidly increase the speed of the measurement process in comparison to classical holographic methods and which enable to carry out the analysis of the measurement nearly in real time.

The research was focused on the detailed theoretical analysis of the proposed method for measurement of three-dimensional shape deformation of surfaces. The method uses four object beams and the phase shifting technique for the phase analysis. A high precision piezoelectric transducer with a small mirror, which is moved in the path of the reference beam, is used as the phase shifting device.

As we can see phase evaluation plays a very important role in the overall process of deformation evaluation. The phase values have to be determined very accurately, in order to obtain proper results. We made a thorough analysis of the phase evaluation technique considered for the proposed interferometric technique. The work also deals with some problems associated with digital image processing of interference signals, especially with problems of noise and nonlinearities in input data, and the phase unwrapping problem. There were proposed new optimized procedures and algorithms for processing of the phase values with a higher accuracy. The theory of the phase shifting method has been investigated and a general algorithm for phase evaluation was derived.

Several evaluation algorithms were proposed and a complex analysis of the measurement process was performed in the presented work. Many factors that have a negative effect on the final accuracy of the measurement were considered in the analysis. The influence of these factors can be described as systematic or random errors in the measurement and evaluation process. The work deals with main types of systematic and random errors that can occur during the phase evaluation process. Some important potential error sources were chosen and these influences were implemented into the model of phase evaluation. The analysis of the process of non-contact deformation measurement was simulated numerically and the evaluation algorithms were compared with respect to their accuracy of phase evaluation, sensitivity to the described types of errors, and computation time demands. The root-mean-square of phase errors was used as a criterion for the comparison of the accuracy of the different algorithms. It was also shown that the resulting phase measurement errors can be effectively reduced using suitable phase calculation algorithms. The performed analysis can be applied for a complex comparison of the accuracy and stability of such algorithms.

It was noted that the phase change of the object wave field is the primary quantity for interferometric testing. However, the phase distribution gives only a first impression of the deformation of the surface. In practice, the three-dimensional displacement field is often required to investigate the static or dynamic mechanical behaviour of various test objects. To calculate the displacement vector one needs other quantities, e.g. coordinates of the object points to determine the sensitivity matrix. One can see that the measurement of three-dimensional displacements is a complex process, where several factors play an important role, e.g. the accuracy of phase evaluation or the geometric setup of the experimental measurement system.

The theoretical analysis of the accuracy of the displacements measured with the proposed interferometric method has been performed. There were considered influences of errors in phase calculation and sensitvity matrix determination. Next work will be focused on practical realisation of experiments, i.e. non-contact measurment of shape deformation of industrial surfaces, with the described measurment method. The proposed evaluation algorithms and procedures will be implemented in the software.

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# Low Frequency Waves in Plasma Fibers with Gravitational Field

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In plasma we can find a great number of waves. In magnetic field presence, there are also several low frequency modes which have considerable influence on plasma fiber stability and behavior. The most important ones are called Alfven wave, fast magnetoacoustic wave and slow magnetoacoustic wave. The general dispersion relation for low frequency modes has a form:

$$\left[(\omega^2-\omega_{pi}^2)(\omega^2-\omega_{pe}^2)-\omega_{pe}^2\omega_{pi}^2\right]^2 \times \left[(\omega^2-\omega_{pi}^2)(\omega^2-\omega_{pe}^2)-\omega_{pe}^2\omega_{pi}^2+c_e^2c_i^2k^4-(\omega^2-\omega_{pe}^2)c_i^2k^2-(\omega^2-\omega_{pi}^2)c_e^2k^2\right]=0$$

After a simple manipulation the dispersion relation can be divided into three modes:

$$\left[(\omega^2-\omega_{pe}^2)(\omega^2-\omega_{pi}^2)-\omega_{pe}^2\omega_{pi}^2\right]^2 \times \left[(\omega^2-\omega_{pe}^2-c_e^2k^2)(\omega^2-\omega_{pi}^2-c_i^2k^2)-\omega_{pe}^2\omega_{pi}^2\right]=0$$

My work is divided to unlimited waves in unlimited space and in cylindrical geometry. The low acoustic waves in unlimited space with gravitational field plus types of grains led to this expression:

$$\frac{1}{4\mu^2(m_1+m_2)^2}$$
$$(\rho_1\rho_2\omega^3(-\rho_2(\mathrm{B}^2\mathrm{k}^2-2\mu\rho_1\omega^2+\mathrm{B}^2\mathrm{k}^2\mathrm{Cos}(\alpha))m_1-\rho_1((\mathrm{B}^2\mathrm{k}^2-2\mu\rho_2\omega^2+\mathrm{B}^2\mathrm{k}^2\mathrm{Cos}(\alpha))m_2)$$
$$(\rho_2(2\mu\rho_1\omega^2(-\mathrm{k}^4c_1^2c_2^2+4\pi\mathrm{G}(\rho_1+\rho_2)\omega^2-\omega^4+\mathrm{k}^2(-4\pi\mathrm{G}(c_2^2\rho_1+c_1^2\rho_2)+(c_1^2+c_2^2)\omega^2))+$$
$$\mathrm{B}^2\mathrm{k}^2(\mathrm{k}^4c_1^2c_2^2+4\pi\mathrm{G}(\rho_1-3\rho_2)\omega^2+3\omega^4+$$
$$\mathrm{k}^2(4\pi\mathrm{G}(c_2^2\rho_1+c_1^2\rho_2)-(c_1^2+3c_2^2)\omega^2))+$$
$$\mathrm{B}^2\mathrm{k}^2(\mathrm{k}^4c_1^2c_2^2-(12\pi\mathrm{G}\rho_1-4\pi\mathrm{G}\rho_2+\omega^2)\omega^2+3\omega^4+$$
$$\mathrm{k}^2(4\pi\mathrm{G}(c_2^2\rho_1+c_1^2\rho_2)+(-c_1^2+3c_2^2)\omega^2))\mathrm{Cos}(2\alpha))m_1+$$
$$\rho_1(2\mu\rho_2\omega^2(-\mathrm{k}^4c_1^2c_2^2+4\pi\mathrm{G}(\rho_1+\rho_2)\omega^2-\omega^4+$$
$$\mathrm{k}^2(-4\pi\mathrm{G}(c_2^2\rho_1+c_1^2\rho_2)+(c_1^2+c_2^2)\omega^2))+$$
$$\mathrm{B}^2\mathrm{k}^2(\mathrm{k}^4c_1^2c_2^2+(4\pi\mathrm{G}(-3\rho_1+\rho_2)+3\omega^2)\omega^2+$$
$$\mathrm{k}^2(4\pi\mathrm{G}(c_2^2\rho_1+c_1^2\rho_2)-(-3c_1^2+c_2^2)\omega^2))+$$
$$\mathrm{B}^2\mathrm{k}^2(\mathrm{k}^4c_1^2c_2^2+4\pi\mathrm{G}(\rho_1-3\rho_2)\omega^2-\omega^4+$$
$$\mathrm{k}^2(4\pi\mathrm{G}(c_2^2\rho_1+c_1^2\rho_2)+(3c_1^2-c_2^2)\omega^2))\mathrm{Cos}(2\alpha))m_2))$$

The dispersion relations calculated are typically divided into two basic modes, longitudinal and transverse, according to the angle between the electric field component of the wave and the propagation vector **k**. However, to make things unnecessarily complicated, the nomenclature for the various plasma wave modes derived is far from systematic, being a mixture of historical names (e.g., Langmuir, Alfven, Bernstein), of names descriptive of the wave motion (e.g., ion acoustic waves, electron cyclotron waves, transverse waves), and of names characteristic of the theory used to derive the wave properties (e.g., magnetoionic waves, MHD waves, drift waves).

We solved a MHD set of equations of the unlimited space plasma pinch with magnetic and gravitational self-interaction and found the behavior of magnetoacoustic waves in this structure. The program code was written in FORTRAN 95, FORTRAN compiler and linker were used from Compaq Visual Fortran embedded in the MS Developer studio GUI.

The solution of this dispersion relation very good coresponds with theoretical model. without magnetic field we have two spherical wave surfaces. With magnetic filed is evidently anisotropic behavior.

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# Analysis of force fields of power redistributed optical beams

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If an arbitrary optical beam is transformed with an optical system, then the energy of the beam is spatially redistributed in dependence on properties of the optical system. The transformed optical beam is a source of a force field that has force effects on a dielectric object in this field. It is possible to model a force field of the required properties in a very small volume. The force field can be either static or dynamic, temporally and spatially. It is possible to model, for example, rotational force field in an area of several micrometers that can be used as a non-contact micromotor in the micromechanisms, i.e. mechanisms with the size of several micrometers. The different area of using the proposed techniques is molecular biology and genetics, where the described force fields can be used for manipulation with the microobjects.

The field of microtechnologies and micromechanisms, which are based on several different physical principles, starts to develop nowadays. One of the most perspective scientific areas is to be the principle of using light as a source of force fields that react with the dielectric objects found in these force fields. At present the research all over the world is focused particularly on micromanipulation with the microorganisms in molecular biology, genetics and microbiology. Recently, the research results in the described areas of research led to the development of optical micromanipulators that are able to choose and manipulate (move) with microobjects, e.g. with bacteria and similar small microorganisms without their damaging. The problem needs to model an appropriate field of force with a laser beam, which is transformed using a standard optical setup, e.g. standard microscope lens.

With the previously described techniques it is not possible to generate an arbitrary force field, but only closely specialized type of a force field. This is a restrictive property of the previous techniques and it is desirable to develop a general theory that makes possible to design optical systems generating a force field of known physical properties. These problems are not solved in the world yet and therefore it is necessary to pay increasing attention to them, because the proposed technique becomes a basic part of modern microtechnologies.

The target of our project is to design and develop a general theory of force fields of power redistributed optical beams and a theory of optical systems that transform the standard optical beam with the known distribution of energy to the beam with the redistributed profile of energy, which generates force fields of the required properties, either static or dynamic.

The problems will be solved at two levels, partly with classical theory of electromagnetic field based on Maxwell's equations, partly with the theory of quantum electrodynamics. For a simple spatial distribution of the generated force field will be derived general analytic equations that provide a deeper view of the solved problems, and for more difficult distributions of the force fields will be proposed suitable numerical procedures with subsequent computer software, which will enable to perform a computer simulation and visualisation of the spatial distribution of the investigated force fields.

Furthermore, we will develop the theory of optical systems that transform the standard optical beam with the known distribution of energy to the beams with the redistributed profile of the beam energy. These beams will generate the force fields of the required physical

properties. The results will lead to designing several non-classical optical systems that can be applied with some modifications in the different areas of science and engineering.

The proposed solution includes several quite original procedures, especially in the theoretical part. The result of the project will be a general theory of optical systems generating the force fields of required properties. These theoretical results will be verified on several chosen examples. On the basis of the developed theory it will be possible to carry out a computer simulation of the solved problem and to design the optical systems for a practical use in industry and science. With respect to the fact that our project is a basic research project it cannot be expected any industrial applications in short time period. Some industrial applications should be expected in a relatively short time in the field of molecular biology, genetics and simple microtechnologies, where optical beams can act as a optical non-contact motors, and also in the field of optical microsurgery.

In the primary part of our research the emphasis is placed on the theoretical analysis and computer simulation of the problem. There was carried out a complex analysis of the investigated problem. Further, we started to develop the theory of the force fields of power redistributed optical beams. On the basis of some theoretical results there were numerically simulated various force fields with respect to physical properties of the optical beam.

In the next part of the research project we will develop the theory of the optical systems that transform standard optical beam with the known distribution of energy to beams with the redistributed profile of the beam energy, which generates force fields of required physical properties. The numerical simulation will be performed for more difficult distributions of force fields and suitable numerical procedures will be proposed for the computer software, which will enable to perform a computer simulation and visualisation of the spatial distribution of simulated force fields. Finally, there will be carried out necessary supplying experiments for verifying the theoretical results on several chosen examples of power redistributed optical beams.

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# Approximation of wavefronts in optical testing techniques

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The presented work is focused on several techniques for fitting wavefront data in optical metrology. Interferometric measurement techniques, e.g. classical interferometry, holographic interferometry, electronic speckle pattern interferometry etc., are based on the principle of interference of two coherent wave fields, the reference and object wave field. Physical properties of the object field are modified after its interaction with the test object and we measure the distribution of the intensity of the interference field recorded in the plane of the photodetector. From the captured intensity values we can determine the phase difference between the reference and the object wave field. The phase values are closely related to the wavefront deformation caused by interaction with the test object. Several different phase evaluation techniques, which enable to determine phase values from the recorded intensity distribution, i.e. interferogram, exist in engineering practice. When testing optical elements we are mostly interested in the optical path difference between the test wavefront and the reference wavefront.

The measured data are usually known at a series of discrete data points and we need to interpolate them to obtain a continuous distribution of the optical path difference or the phase difference. A global approximation reduces the fringe data to a specified two-dimensional function. Once the proper function has been fitted to the interferometric data, it can be evaluated at chosen points and the data can be analysed. The least-squares method is the most commonly used technique to fit measured data to a suitable function.

The most common functions that are used for fitting the optical path difference in interferometry are polynomials. We can express the data by a linear combination of properly chosen polynomials. Seidel polynomials are usually used for testing of optical surfaces in optical industry. These polynomials are used mainly for expressing the aberrations of rotationally symmetric optical systems. If the wavefront deformation will not change rapidly with respect to spatial coordinates, it can be sufficient to use only low-order polynomials to obtain the required accuracy of approximation.

In practice, it is often advantageous to use for approximation of the wavefront data orthogonal polynomials on the specified region of interest. The orthogonal polynomials have several advantages in comparison to other types of functions. If the wavefront is expressed as a linear combination of orthogonal polynomials, the wavefront variance is equal to the sum of the variances of the individual polynomial terms. Therefore adding or subtracting of some of the orthogonal polynomial terms does not affect the fit coefficients of other polynomial terms. We can subtract one or more fitted terms from the evaluated wavefront without having to recalculate fit coefficients for other polynomial terms.

We can derive various two-dimensional polynomials, which are orthogonal on two-dimensional regions of the different shapes. In practical measurements, the shape of the area of interest is mostly circular or rectangular. One of the most important polynomials, which are used mainly in optics, are Zernike polynomials. These polynomials are orthogonal over a unit circle with the centre in the origin. Zernike polynomials are also invariant with respect to the rotation of the cooordinate system.

In case of the rectangular measured area it is advantageous to use Tschebyschev or Legrende two-dimensional polynomials, which are orthogonal over the interior of a rectangle. In our work there was derived appropriate form of above-mentioned orthogonal polynomials that can be used for global approximation of the wavefront deformation in optical metrology.

Another possibility for evaluating the wavefront deformation by a single analytical function is the approximation of the wavefront data using a two-dimensional rational function. The rational function is expressed as a ratio of two two-dimensional polynomials. We focused on the theoretical analysis of the method for approximation of the wavefront data using this method.

Our work deals mainly with the least-squares global fit of the rational function to the measured data. Once the rational function has been fitted to the fringe data, the wavefront deformation can be determined at each point and further analysis can be performed. The properties of the proposed method were fully analysed in this work.

The fitting technique has been applied to several different interference patterns and a comparison with the polynomial fitting method has been performed for various fringe evaluation methods. The root-mean-square of the difference between the measured and approximated wavefront data has been taken as a criterion of the quality of the described fitting process. An advantage of the proposed technique over the polynomial approximation is the lower number of coefficients, which are needed for approximation of the wavefront with the same accuracy. The drawback of the technique is the impossibility of physical interpretation of the fit coefficients in comparison to Seidel or Zernike polynomials. The quality of the performed approximation has been studied on several computer simulated data with the different magnitude of the wavefront deformation. The wavefront data were simulated using appropriate Seidel aberration polynomials.

There was also studied the effect of noise in input data on the overall accuracy of determination of the optical path difference. The simulations were performed for several fringe patterns and it was shown that the proposed fitting techniques are adequate for analysing interference patterns in optical testing methods.

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# Modern optical techniques for testing of quality of optical elements

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The present technology of fabrication of optical elements, i.e. lenses, prisms, plane parallel plates, mirrors, etc., does not allow to made them absolutely perfectly and therefore these elements affect the wavefront aberration. Other sources of the aberrations of the described optical elements are the defects in materials, which can are used for fabrication of individual optical elements, e.g. inhomogenities of optical glass. These two categories are called manufacturing aberrations.

Any designed optical system is composed of several optical elements that must be made within defined tolerances to guarantee an achievement of the required imaging properties of the optical system. In practice, testing of optical elements can be carried out using various measuring techniques. Using some specific testing technique depends on characteristics of the tested optical part (lens, prism, plane parallel plate, mirror, etc.) and the range of allowable tolerances for the size, quality of optical surfaces, transmission, etc.

The simplest methods for checking of the geometrical shape of the optical surface are mechanical measuring methods. These techniques have many disadvantages, e.g. the possibility to measure the shape of the tested optical surface only at a discrete set of points situated on the surface, the possibility to damage the investigated surface with the measuring instrument, a long time needed for measurement, etc. With respect to mentioned drawbacks these methods are used seldom, especially for testing of optical elements of lower quality or in piece production of special optical parts. A typical representative of measuring instruments based on mechanical testing methods is a coordinate measuring machine that enables to measure the deviation of the tested optical surface from an ideal reference surface with the accuracy better than 1 μm.

For very precise measurements of optical surfaces the techniques based on the principle of interference or diffraction of light are used. The simplest optical method for measuring deviations of the tested optical surface from the nominal surface is a comparison of the tested surface with the calibrated optical surface, which is made with an order higher accuracy than the tested surface. The calibrated optical surface is very carefully placed close to the measured surface and the interference fringes are observed. From the geometrical shape of these interference fringes a quality of the measured optical surface can be determined. However, fabrication of calibrated optical surfaces for different types of optical elements is very difficult and expensive. Further, both calibrated and tested optical surfaces can be damaged during the measurement process, e.g. the optical coatings may be damaged by the mechanical measuring instrument. It is evident that there was a big effort put into the development of non-contact and fully automatic evaluation of the shape of fabricated optical elements.

Nowadays, modern noncontact interferometric techniques are used for testing of the optical surfaces in optical industry. The basic principle of the measurement is the interference of the reference wavefront and the tested wavefront, which is reflected or transmitted by the tested optical element. The reference wavefront can be in practice plane, spherical or generally aspherical. The measurement process can be implemented by appropriately constructed Fizeau

or Twyman-Green interferometers. With the present development of solid-state array sensors, e.g. CCD, and other optoelectronic elements the evaluation of measurement using mentioned interferometers became fully automatic. An arbitrary shape of optical surface (flat, spherical or aspherical) can be tested with various types of appropriate phase measurement procedures. These techniques determine the phase of the investigated wave field from the measurements of the intensity of the interference field that arises from the interference of the tested and reference wave fields in interferometric testing. The accuracy obtained with above-mentioned interferometric systems is from $\lambda/20$ up to $\lambda/100$, where $\lambda$ is the wavelength of light. The achievable accuracy satisfies most of accuracy requirements for testing of the optical surfaces in optical industry.

Other type of methods for controlling of the properties of optical elements are non-contact geometrical optical methods. These methods are widely used in optical industry for their accuracy, objective approach and relative simplicity. We can use an autocollimator for very precise measurement of angles and flat optical surfaces.

In our work we focused on the measurement process and the analysis of the quality of optical elements using modern optolelectronic elements and automatic evaluation techniques. Our research deals with geometrical tolerances of the shape of optical surfaces and with imaging properties of the tested optical elements. The most frequently appearing criteria of the quality of optical surfaces and elements are analysed in detail. There were considered both geometrical-optics criteria and diffraction criteria. A detailed analysis of basic manufacturing aberrations of the optical elements was performed. Such terms as the focal length and the *f*-number of a plane parallel plate were defined and the equations for their calculation were described. Furthermore, the relations for calculation of the wave aberration, astigmatism and Strehl definition of the optical elements with plane surfaces were derived.

The research is also focused on application of several methods for an automatic evaluation of the optical path difference in optical testing. In our work there was performed a practical measurement of spherical optical surfaces with the interferometer Zygo GPI XP and there were compared different phase evaluation techniques for automatic analysis of the tested wavefronts.

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# Solid-state Saturable Absorbers for Neodymium Lasers

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The compact pulsed near infrared sub-nanosecond lasers operating at 1 um wavelength are required in wide range of applications including environment sensing, laser marking, telecommunication, medical diagnostics, measurement techniques, range finding, frequency conversion, optical parametric oscillators and Raman laser pumping etc. The most efficient lasers emitting in this spectral range are neodymium host lasers pumped by diode lasers, but flashlamp pumping is still used in low repetition high power systems. The best active media with respect to maximum average output power are Nd:YAG, Nd:YLF and Nd:YVO4 crystals. The pulses in sub-nanosecond range are generated by mode-locking techniques, which have been performed in flashlamp pumped systems for more than thirty years mainly using liquid saturable absorbers. These are organic dyes that are toxic and decompose gradually under UV radiation and therefore their replacement is highly desirable. Semiconductor saturable absorbers based on InGaAs/GaAs are an attractive alternative since they are non-toxic, chemically stable, and solid-state and moreover their linear and non-linear optical properties can be tailored by modifying the parameters during their growth molecular beam epitaxy techniques.

In typical design used in last years for continuously diode pumped solid state lasers the semiconductor saturable absorbers are directly integrated into a mirror structure, resulting in a device, whose reflectivity increases as the incident optical intensity increases. In these low gain systems the low non-saturable losses are most important and only very small depth of modulation (about 1-2 %) of absorber is required.

On contrary, high power flashlamp pumped solid-state lasers with high gain require the higher depth of modulation (more than 15 %) and the simultaneous Q-switching action of the absorber is desirable. For this purpose the semiconductor saturable absorbers without Bragg mirrors, inserted inside the laser resonator, can be used.

In this paper we report on progress in research of solid-state saturable absorbers based on InGaAs/GaAs multiple quantum well (MQW) structures. Our samples are grown on 400 um thick GaAs substrates at Center for High Technology Materials, University of New Mexico, by MBE method. Samples used for mode-locking of flashlamp pumped lasers have 50 quantum well, each consisting of a 8 nm thick InGaAs between two 10 nm thick GaAs layers. The low signal transmission of the samples in non-polarized light under normal incidence is 30 – 33 %. The saturation intensity is 300 uJ/cm2 and saturation of transmission from 60 % to 75 % is observed (the probe beam was a train of 50 ps pulses incident at Brewster angle).

Utilizing these samples stable passively mode-locked regime was obtained in linear, 1 m long nearly hemispherical resonator at pump energy slightly above the laser threshold, which was 17 J. The envelope of the pulse train contained around 10 pulses measured at the level of 50 % of maximum amplitude. The pulse duration was 52 ps and the energy in the whole train was 3 mJ [1].

We have discovered, that due to the etalon effect on the saturable absorber it is not necessary to use the Brewster angle but even insertion under smaller angle can result in smaller losses. This is an important fact that has not been taken into account in previous experiments.

A novel approach to laser pumping is the use of laser diodes. The advantages are low voltage, compact design and higher efficiency (the diodes can be tuned to match the absorption peak of the active medium).

Samples used for mode-locking of diode pumped lasers have 10 quantum wells, each consisting of a 8 nm thick between two 10 nm thick GaAs layers. The low signal transmission of the samples in non-polarized light under normal incidence is 40 - 42 %, thus the insertion losses of these samples are smaller than of those designed for flashlamp pumped systems. Lower insertion losses make these samples suitable for use in diode pumped system that have generally lower gain.

As a pump source we used a 80 W quasi-continuous linear diode array giving 18 mJ in 200 us long pump pulse. The diode was fitted with cylindrical microlens that collimated the light in fast axis resulting in total divergence of 6 x 0.2 degrees. This radiation was first used to side-pump the laser crystal directly without any additional optics – the results are discussed in [2].

In end pumping configuration the combination of the cylindrical and short focus spherical lens was used to focus the pump light into the end of the crystal (1 cm long Nd:YAG rod with 4 mm diameter AR coated for 800 nm and HR for 1060 nm at pumped end; 88 degree cut and AR coated for 1064 nm at other end).

In free running operation the laser threshold was 20 A of pump current and the maximum output energy achieved with 80 % (86 % and 96 %) reflectivity output mirror was 3.7 mJ (3.0 mJ and 2.0 mJ) corresponding to total conversion efficiency of 22 % (17 % and 12 %).

For mode-locking operation a suitable laser cavity had to be designed using a ray-tracing software – mode matching in the crystal is important for pumping efficiency and the power density incident on the MQW is critical for mode-locking operation.

The designed resonator consisted of a convex mirror M1 (r = 1 m) with reflectivity of 8 %, a short focus (r = 20 cm) HR mirror M2 and a flat highly reflective mirror M3. The saturable absorber was place between the M2 and M3 mirrors. The correct intensity incident on the MQW saturable absorber was achieved by modification of the M2 – M3 distance. This time a sample with 10 periods of GaAs/InGaAs quantum wells was used. In mode-locking operation the envelope of the pulse train contained 6 pulses measured at the level of 50 % of maximum amplitude [3].

In conclusion a successful use of two types of multiple quantum well semiconductor saturable absorbers for mode-locking of neodymium lasers, both diode and flashlamp pump was demonstrated and operation in mode-locking regime was achieved.

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# Photovoltaic Properties of Fe:$LiNbO_3$

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Photorefractive lithium niobate crystals $LiNbO_3$ have proved to be a promising material for the realisation of many optical information systems including volume holographic storage, image processing, image amplification and photorefractive spatial soliton. Photovoltaic constant and photoconductivity are the most important parameters for the description of photorefractive behaviour because the magnitude and speed of light-induced refractive index change depend mainly on these. The photovoltaic current density and photoconductivity depend linearly on the light intensity. The photovoltaic current and photoconductivity Fe:$LiNbO_3$ and proton exchanged waveguides in Fe:$LiNbO_3$ have been measured as a function of the optical intensity up to about several kW/cm$^2$ by the use of surface electrodes.

Light intensities in the range about 1W/cm$^2$ up to about $10^4$W/cm$^2$ have been obtained by focusing the beam of an argon ion laser (514 nm wavelength). The Fe:$LiNbO_3$ samples (thickness 3 mm) were positioned within the Rayleigh length of the foci, and the focused beam was well adjusted to aluminium electrodes placed at the surface of the sample. These electrodes we used for the measurements of both photovoltaic current and photoconductivity. The electrode gap with was 12 μm and the spot diameter was 50 μm full width at half maximum (FWHM). Thus, as the illumination has been performed from the electrode side. The main advantage of using surface electrodes is the possibility of investigating both bulk samples and samples with planar waveguides beneath the electrodes.

The photovolaic current has been measured whit a picoampermeter, which was constructed in our laboratory. The picoampermeter was combined with the current amplifier (inverting amplifier-amplification $10^9$) and the voltmeter. The photoconductivity has been measured with the voltmeter with very high input impedance about $10^{15}\Omega$.

We used two samples Fe:$LiNbO_3$ for our experiments. The Fe content of the samples has been determined to be about 247ppm for the first sample, and 184 ppm for the second sample. All samples were in the form of [1-10]-cut plates (-45° rotated as against x-cut) with a thickness of about 3 mm (first samples 2.88 mm, and second samples 3.22 mm) and lateral dimensions 19 mm (z-direction) and 15 mm (y-direction). All of the samples optical planar waveguides have been produced by the proton exchange process. The optical waveguides have been produced after we measured bulk photovoltaic properties of the samples. The proton exchange was performed in benzoic acid with 1 mol-% lithium benzoate at 213°C for 2 h (PE samples). All of these samples have been subsequently annealed at 350°C for about 1,5 h (APE samples). The optical waveguides have 2 mod, and the thickness about 5 μm. Finally, aluminium electrodes at the surface of the samples have been produced with vacuum deposition. For the electron gap we use 10 μm thin optical fibre after deposition we obtain 12 μm gap. The electrode length was 15 mm along y-direction, and 19 mm along z-direction in all cases. In that way currents in the crystal z and y direction could be measured.

With regard to photovoltaic measurements the situation is very difficult. Here, no external voltage has been applied on the crystal. Inside the illuminated region we have a photovoltaic current density $j_{phv}$ due to $j_{phv}=\beta_{ijk}Ie_je_k$, where $\beta_{ijk}$ is the photovoltaic tensor, I is absorbed the

light intensity in the sample, $e_j$, and $e_k$ is the polarisation direct of the light. The illuminated region now represents a current source. The resulting charge separation, which occurs perpendicular to the electrode gap, leads to a current through the picoampermeter connected to the electrodes. Electrons moved by the photovoltaic effect, and the electrons completely contribute to the external current. The measured photovoltaic current is $i_{phv}=\beta_{ijk}Ie_je_kS$, where S is the illuminated area. S=l d, where l is the spot diameter (l=50 μm), and d is the electrode gap (d=12 μm). We measured currents in the crystals z and y-direction. The photovoltaic current density is in the y-direction $j_y = -\sqrt{2}/2\beta_{22}I\cos^2\theta + \beta_{15}I\cos(k_{12}x)\sin 2\theta$, and in the z-direction is $j_z = \beta_{33}I\cos^2\theta + \beta_{31}I\sin^2\theta$. The crystal was illuminated in the x-direction. θ is the angel between the light polarisation plane and y-direction or z-direction. $k_{12}$ is $k_{12}=(2\pi/\lambda)(n_o-n_e)$, where $n_o$ is the ordinary refractive index, and $n_e$ is the extraordinary refractive index. We measured light intensity dependence, and angular dependence on the photovoltaic current. We obtain the photovoltaic constants $\beta_{33}$, $\beta_{31}$, $\beta_{22}$ from the photovoltaic tensor. The photovoltaic constants depend on crystal properties only. The results of photovoltaic measurements are for two samples at a wavelength of λ=514 nm. During measured the photovoltaic current we observed very strong pyroelectric effect, which was caused with a change temperature T the sample. The photovoltaic current can be measured after stabilisation the temperature (dT=0).

We obtain on the first sample Fe:$LiNbO_3$ (Fe concentration 247ppm) absorption $\alpha=2.593cm^{-1}$ this results: photovoltaic current $i_{phv}$=16-23 pA at I=1.57 kW/cm$^2$, photovoltaic constant $\beta_{33}=2.46x10^{-9}V^{-1}$, $\beta_{31}=1.81x10^{-9}V^{-1}$, and $\beta_{22}=1.80x10^{-9}V^{-1}$. For first sample with optical waveguide we had this results: absorption $\alpha=2.087\ cm^{-1}$, photovoltaic constant $\beta_{33}=2.07x10^{-9}V^{-1}$, $\beta_{31}=1.63x10^{-9}V^{-1}$, and $\beta_{22}=1.06x10^{-9}V^{-1}$. The second sample had this parameters: Fe concentration 184 ppm, absorption $\alpha = 1.03\ cm^{-1}$, photovoltaic current $i_{phv}$=6-12 pA at I=992W/cm$^2$, photovoltaic constant $\beta_{33}=1.82x10^{-9}V^{-1}$, $\beta_{31}=1.26x10^{-9}V^{-1}$, $\beta_{22}=2.47x10^{-9}V^{-1}$, and for optical waveguide: absorption $\alpha=0.738\ cm^{-1}$, photovoltaic constant $\beta_{33}=2.31x10^{-9}V^{-1}$, $\beta_{31}=1.86x10^{-9}V^{-1}$.

For photoconductivity measurement is important very voltmeter with higher input resistant. We had voltmeter; witch is combined with noninverting amplifier (input resistant $10^{15}\Omega$) and voltmeter. The electrical field distribution is, of course, inhomogeneous for the given electrode structure. Nevertheless, the photoconductivity values can be calculated from the measured photovoltaic current with quite good accuracy. The photoconductivity electric field $E_{ph}=-j_{phv}/\sigma$, where σ the conductivity consist of dark conductivity $\sigma_d$ and photoconductivity $\sigma_{ph}$ ($\sigma=\sigma_d+\sigma_{ph}$). The dark conductivity is ignored, because with our measured devices we can it measured. Then the photoconductivity voltage is $U_{ph} = \pi\frac{d}{2}E_{ph}$, where d is electrode gap. The photoconductivity and photoconductive field linear increase with light intensity at λ=514 nm. For Fe:$LiNbO_3$ the photoconductivity $\sigma_{ph}$ increase from 0 to $2x10^{-9}\ \Omega^{-1}cm^{-1}$, and the photoconductive field $E_{ph}$ increase from 0 to 5 $kVcm^{-1}$. For optical waveguide the photoconductivity $\sigma_{ph}$ increase from 0 to $25x10^{-9}\ \Omega^{-1}cm^{-1}$, and the photoconductive field $E_{ph}$ increase from 0 to 1 $kVcm^{-1}$.

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# Modification of Polymer Layers by Atmospheric Corona Discharge

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Polymers have been applied successfully in fields such as composites, microelectronic devices, bio-material adhesion, tribology, protective coatings, and thin film technology. In these applications the polymers involve interaction with other types of materials (polymers, metals, semiconductors, ceramics). The surfaces of polymers can be characterized by a low surface energy and thus bad adhesive properties. Examples of technological applications involve polymer-adhesive, polymer-metal interfaces in electronics, microelectronics, printing, painting, packaging and more.

Both atmospheric and low-pressure electrical discharges are used for enhancing properties of polymer substrates. This is believed to arise from the alteration of the chemical and (or) topographical nature of the substrate. The deposition and modification of thin films is mostly performed by high frequency or microwave discharges under vacuum conditions in the range between 0.001 and 1 mbar. Due to the requirement of a vacuum system, these processes are very expensive, particularly for large substrates. Therefore, the plasma-enhanced deposition and modification of various films at atmospheric pressure is a promising approach to perform the modification of large-sized low-cost products such as polymer foils, metal bands, textiles or papers.

Several types of atmospheric electrical discharge are in common usage. The corona discharge can be identified as bright filaments extending from the sharp point electrode towards the substrate. More often, parallel plate dielectric barrier discharges can results in a more uniform electrical breakdown, and this is often known as a silent discharge. The effect of corona discharge on polyethylene (PE), polypropylene (PP), polyethelenterephthalate, polystyrene, polyisobutylene and others was extensively studied by many authors. Corona treatment in atmospheric air introduces oxygen and nitrogen species into the polymer surface and changes the polymer structure by the formation of radicals, cross-linking, ether, hydroxyl and other chemical groups. The average energy of electrons in the corona discharge is about 10 eV. After a brief corona treatment ($t < 0.1$ s), the possibilities of UV light induced chemical reactions should be minimized.

The spark discharge is more efficient in introduction of oxygen functionalities at the polymer surface. The spark jet plasma is here characterized by low gas temperature ($T < 60$ °C for $t < 3$ s) and average electron energies in the range of 10 event. The jet plasma can be produced by a spark, corona or RF discharge. Gas flows out of chamber very quickly as a plasma flame.

The results various methods of pretreatment of polymers are given in terms of wettability (surface energy) and adhesion (lap shear strength) improvement. From the above-mentioned methods, corona (silent) discharge treatment is best established in industry. However, low-pressure plasma, spark jet plasma and UV/ozone treatment can produce higher surface energies in some cases.

Plasma surface modification results in a different quality of enhancing the adhesion properties of polymers. Electrical discharges contain electrons, ions, excited neutrals and photons. All of these species can react with a polymer surface. Their relative concentrations and energies vary with the type of discharge employed and can have a strong influence on the mode of surface modification. Corona treatment of polymeric substrates proceeds via free-radical mechanisms, whereas reaction of ozone with excites substrate is an important feature of silent discharge treatment. Both of these processes are highly energetic.

Electrical air discharge treatment of polymer results in both textural and chemical changes at the substrate surface. Silent discharge modification induces a much greater degree of morphological disruption than low-pressure plasma treatment for all of the polymers.

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# Discharge Tube with Virtual Cathode

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Till this time known method of the excitation of the discharge between electrodes make use of electron emission by the cathode either secondary or thermo emission. Usually we speak about the self-maintained discharge. Lifetime of the cathode, that is weared down by the emission, limits in principle lifetime of the whole discharge tube. Discharge can, according to contemporary state of the art, be induced also by the inductive way. Arrangement for excitation of such discharge is rather expensive. Construction of the inductive excited discharge tube is considerably influenced by the necessity of the limitation of the losses in excitation magnetic circuits. Especially longitude of the discharge and pressure of the working gas are limited by the economic standpoints. Working is always connected with spurious electromagnetic radiation, whose restraint is expensive and limiting for arrangement of the discharge tube.

The above-mentioned disadvantages notably limits the new discharge tube with non-heated cathode with a working gas. Tube is formed by anode and non-heated cathode among them is connected DC power supply. The matter of the new solution is fact that in the proximity of the cathode the discharge tube is modified in the form of inductive circuit, in that the ferromagnetic toroidal core with excitation winding is connected to the excitation generator. Inductive circuit passes to the part of the discharge tube with anode. Electric potential of the anode is higher than the electric potential of the cathode.

In advantageous fulfilment will be between anode and inductive circle set at least one recombination electrode, whose electric potential is inferior to electric anode potential.

It is possible to say that in principle new discharge tube with virtual cathode was created. Self-maintained discharge here is burning between anode and cathode, where from plasma formed by the induction circuit diffuse to the cathode positive ions, while to the anode flow electrons, which provoke excitation and ionisation of atoms needed for the compensation of ambipolar diffusion and recombination.

The advantage of the presented discharge tube with non-heated cathode is possibility of the excitation of the non-self-maintained discharge with minimum abrasion of the cathode. Moreover, we cannot happen so-called cathode losses connected with emission of electrons and discharge at the same time is not source of spurious electromagnetic field. Power supplied to the inductive circuit by the generator is lower than power of the common induction discharge tube and construction of the generator with respect to the smaller demands to energetic efficiency is less expensive. Induction circuit is small and can be electrically shielded. It radiates then less spurious electromagnetic energy. The magnitude of the electric current flowing between the anode and cathode is in the wide range of the voltage between anode and cathode does not depend on this voltage and it is possible to use directly voltage power supply.

Discharge tube consists of electrically non-inducting cover formed of a tube and an induction circuit filled with a gas or vapours. Inside a discharge tube there is an anode and

a cathode. An electrical potential of anode is higher than an electrical potential of a cathode. Through an inductive circle, which is formed by the tube, a ferromagnetic core (toroid) is thread through and is wrapped by an excitation winding. An alternating electrical current from the generator flows by this winding. In the induction circuit there is excited electrodeless discharge. Positive ions are diffunding from the plasma of the discharge to the cathode and they recombine. Neutral atoms or molecules (according to a used gas) move back from the cathode to the electrodeless discharge. The electrons from the plasma of the electrodeless discharge are attracted and accelerated by the anode. They can excite or ionise neutral particles or they can recombine with positive ions and then form a non-self-maintained discharge in tube. At the end of the tube the electrons are captured by the anode and an electrical current flows between both electrodes.

These basic described experimental arrangements can be modified by the various ways:

Ignition of induction discharge is possible with advantage facilitate AC electric field between electrodes placed outside induction circuit and connected to the excitation or auxiliary winding of the ferromagnetic core.

If the discharge is excited in gas vapours, whose pressure is for optimum working conditions of the discharge suitable to stabilize, it is possible to make series connection of the excitation winding and the magnetization winding of the stabilization ferromagnetic circuit which is designed so that AC magnetization gets its warming-up on the so-called Curie temperature. Ferromagnetic circuit should be located in so-called cool point of the discharge tube or e.g. so that it should be thermally connected with amalgam, if the discharge is working in mercury vapours. Used ferromagnetic material must have suitable Curie temperature.

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# A Study of the Cooling Facility in Preparation for the ATLAS Inner Detector Testing

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The Department of Applied Physics has been participating and cooperating in cooling systems development for the Atlas Inner Detector since 1995. The ATLAS Inner Detector combines high-resolution detectors at the inner radii with continuous tracking elements at the outer radii, all contained in the Central Solenoid, which provides a nominal field of 2 T. The highest granularity is achieved around the vertex region using semiconductor pixel detectors (PIXEL part) followed by a silicon micro strip detector (SCT). At larger radii typically 36 tracking points are provided by the straw tube tracker (TRT).

The Inner Detector will be assembled and tested on the surface prior to its installation in the underground experimental area. The work is expected to be carried out in the SR building on the ATLAS site at CERN. An adequate evaporative cooling plant is required to be built and available, namely for the SCT and Pixel parts of the Inner detector [1].

We present a pilot study of the cooling plant that should cover requirements for overall testing procedures of the whole SCT detector (approx. 22 kW of cooling power needed) and also the partial cooling requirements at the individual assembly sites for PIXEL (approx. 3 kW of cooling power needed) and SCT structures (approx. 1.8 kW of cooling power need).

The main compressor-condenser unit was sized for the plant and three main distribution places for a refrigerant delivery were allocated. Manifolding modularities were designed and tube lines layout was prepared including the tubes sizing and pressure drop calculations [2].

There are two testing modes under the consideration. The first “Warm testing mode“ is being prepared for the initial tests during a final assembly at SR building. The use of the $C_4F_{10}$ refrigerant is foreseen for this application. Evaporation temperature in the supporting structures sticking together detector modules is foreseen around 16 ºC or slightly above this value (depending on the dew point temperature in the assembly hall), While temperatures on the silicon surfaces may reach values around 30 ºC when the expected heat loads are evacuated. A separate individual cooling unit is planned to be employed.

The second, so called “Cold testing mode” is meant as the final testing process prior to placement of the completed inner detector in the underground experimental area. The cooling system working with $C_3F_8$ refrigerant has been chosen for the final application. This type of the system has been under the development and testing since 2000 [3].

A possibility of the multiple use of the same mechanical hardware for the both testing modes was also studied and evaluated [4].

The last part of the project deals with an assessment of the supporting equipment and facilities needed to operate the cooling plant, i.e. heaters and relevant power supplies, insulation and sealing means, flushing gas system, base parts of the DAQ system and various mechanical spares.

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# Numerical simulation of Plasma Fibers Energy Losses

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## Introduction

Current fibers are observed in laboratory and space plasma very often. These fibers survive for a relatively long period of time. The configuration is maintained by own magnetic field. Two configurations are very famous: Z-pinch in which the supporting current is axial and magnetic field azimuth, and theta-pinch in which on the contrary the supporting current is azimuthal and magnetic field axial. Most of the current fibers are combination of these limit cases and have typical helical structures.
The equilibrium or near-equilibrium state is caused by equality of plasma pressure gradient and Lorentz force (magnetic pressure gradient). This type of equilibrium evolves in famous Bennett profile of particle density. Formally it was calculated for uniform current density, but nowadays the density profiles are known in much general cases.
The plasma current generates magnetic field that is important for the equilibrium. However the current increases fiber temperature via Joule heating. Increasing temperature leads to higher plasma pressure and the equilibrium would be instable. Role of the opposite channel to the Joule heating plays radiation of the fiber. Radiative processes cool the fiber and enable maintenance of the equilibrium. First calculations of radiative equilibrium configuration did Pease and Braginski. They discovered that under some conditions the cooling process can overcome the heating one and the fiber electromagnetically collapses to the axis.
In the Department of Physics of the FEE CTU the study of plasma fibers has a long tradition. They are studied both experimentally and theoretically. Approximately since 1997 runs the parallel theoretical research in the subject of computational simulations. Formally had been made general studies of many body systems and simulation of their behavior by Monte Carlo method, recently are studied quasineutral systems by Particles in Cells method (PIC). The simulation of the plasma pinches is done via PIC method. This program solves the movement of the particles in the external fields, the change of the field as a reaction of the movement of the particles and again the movement of the particles in the forced fields. It does not solve neither the energetic looses caused by peculiar movement of the particles, nor their recombination yet.

## The Solution of the Movement and Radiation

The radiation of the fibers is very important feature because it is the most efficient channel of energy losses. Detailed synchrotron and bremsstrahlung radiation processes in the plasma fiber will be treated in this paper. The goal of this work is the diagnostics of the plasma pinch in the sphere of the energetic radiation of the charged particle. The radiative fields are visualized on a two-dimensional sphere located far away from the radiation sources. The code of the program

from which the calculations are coming is written in FORTRAN 95. For the translation the compiler and linker from Compaq Visual FORTRAN 6.6 were used.

It is necessary to use the relativistic scheme for the calculation of the bremsstrahlung and synchrotron radiation, dominating during high velocities. Buneman's relativistic scheme was used here. From motion of the charged particle, we can calculate intensity, its time course, and dependence on direction.

There are furthermore radiative processes in the plasma related to recombination and excitation processes in the atomic shell. These processes are treated as global ones, no detailed analysis is included.

**Conclusions**

The radiative fields are visualized on a two-dimensional sphere located far away from the radiation sources. All the calculations serve as a diagnostic part of the "3D PIC model". We hope to obtain model of the pinch one step nearer to the reality after the inclusion of these results into energetic losses of moving charged particles into PIC model.

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# Interactive Physics via Java Applets

# (FEE CTU)

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During last decade new interactive methods in teaching physics took place. A great number of hypertext materials of different quality appeared on WWW pages of various institutions. Two years ago in the Department of Physics (FEE CTU) was founded the server ALDEBARAN [4] (http://www.aldebaran.cz/) dedicated to the education of physics and astrophysics and for the propagation of the scientific results in plasma physics. Nowadays there are complete tutorials for astrophysics, physics, theoretical mechanics, quantum physics, statistical physics, magnetohydrodynamics and plasma physics. The server also enables effective testing of the students' knowledge in Astrophysics via system described in [2].

Several years ago a fruitful cooperation with the Department of Physical Electronics of the Faculty of Nuclear Sciences and Physical Engineering and with the Institute of Physics of the Faculty of Mechanical Engineering began. Together we had prepared several interesting educational WWW projects, for example [1, 3], supported by CTU grants.

Our latest endeavor was to collect a set of educational applets from several branches of physics for interactive insight of interesting phenomena. The student must have a possibility to change parameters in simulated physical experiments and from the results find out the basis of the considered phenomenon.

The applets were developed in collaboration of the Department of Physical Electronics of the Faculty of Nuclear Sciences and Physical Engineering and our department. Our Department of Physics developed a collection of applets for electric and magnetic phenomena. Namely this collection includes:

1. *Electromagnetic Simulator*. This applet deals with the simulation of charged particles movement in homogeneous electric and magnetic fields. The student can simulate drifts in the fields, trochoidal motion, and acceleration of particles in electric field with component parallel to magnetic filed lines.
2. *Heaviside Field*. This applet enables to simulate the dependence of electric and magnetic field on the velocity of the moving charged particle. The Heaviside field is one of the simplest fields and the student has opportunity to investigate the characteristics of this field. Input parameters are: charge, velocity, type of field visualization, and animated background.
3. *Charged Particles in Magnetic Dipole*. This applet is engaged in the simulation of charged particles movement in magnetic dipole field. The student can simulate the effect of magnetic mirror in the pole areas, Larmor rotation, gradient $B$ drift and the curvature drift causing motion in the east-west direction.

4. *Charged Particles near Conductor*. This applet deals with the simulation of charged particles movement near conductor. The current generates typical magnetic field and the student can study the charged particle motion in this field. Gradient $B$ and curvature drifts can be simulated as well as the importance of adiabatic invariants. Larmor motion as well as azimuth and longitudinal drifts can be simulated in the vicinity of the conductor.
5. *Magnetoacoustic Waves*. This applet simulates the magnetoacoustic wave propagation through the plasma. The wave surfaces of the Alfven, fast and slow magnetoacoustic waves can be deformed according to the external magnetic field magnitude. The anisotropic and multimode propagation is evident.

This collection of applets is completed by other applets developed earlier in our department (*Wave Properties*, *Beats*, *Lissajous Figures*, etc.)

All the applets were developed in the JAVA programming language. Ordinary differential equations were solved by Runge Kutta forth order scheme adapted for relativistic motions by Dan Škandera. The applets are used in the lectures of Physics and are available on the ALDEBARAN server for everybody who is interested in the phenomena described above.

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# Determination of thermophysical properties of HFC refrigerants by molecular simulations

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Vapour-liquid phase equilibrium (VLE) calculations in chemistry and chemical engineering are traditionally carried out by means of empirically based thermodynamic equation of state (EOS) and/or liquid-state activity-coefficient models. The main goal of such calculations is the prediction of the *PTxy* behaviour of the mixture (where *P* is the system pressure, *T* the temperature, and *x* and *y* denote the compositions of the coexisting phases). To implement these approaches, one requires as input information accurate data concerning the vapour pressure behaviour of each constituent pure fluid. These data are then combined with the mixture model; in addition, a mixture parameter appearing in the theory is often evaluated by means of an experimental measurement on the mixture. Given this input information, the system behaviour is then calculated using standard thermodynamic relations. The accuracy of these approaches in predicting the experimental data varies; as with all empirically based methods, the path to further progress is not always clear. An alternative, and much less well-developed approach, uses as input a molecular-based intermolecular potential model for the species and their interactions. The properties of the mixture are then calculated by computer simulation.

Alternative refrigerants HFC-152a ($CHF_2CH_3$), HFC-134a ($CF_3CH_2F$), HFC-143a ($CF_3CH_3$), HFC-125 ($CHF_2CF_3$) are modelled as a dipolar two centre Lennard Jones fluid and alternative refrigerants HFC-32 ($CH_2F_2$), HFC-23 ($CHF_3$) are modelled as a dipolar Lennard Jones fluid. We calculated vapour-liquid equilibrium of these refrigerants by Gibbs-Duhem integration and vapour-liquid equilibrium of two binary mixtures (HFC 125+HFC 134a, and HFC 134a+HFC 32) by the reaction Gibbs ensemble Monte Carlo (RGEMC) method. Potential parameters of the model are fitted to the critical temperature and vapour-liquid equilibrium data. Results for model liquid are presented in (1) and these for alternative refrigerants are presented in (2).

Fischer at all proposed an equation of state for dipolar two-centre Lennard-Jones liquid (3). We used this equation for a calculation of cooling capacity of Rankin's circuit. Rankin's circuit is one of a model circuit, which is very close to a real circuit and represent a real behaviour very well. We chose a circuit with evaporation temperature –15°C and condensation temperature 30°C. We calculated a cooling capacity of Rankin's circuit working with model fluid and this for real fluid. For model liquid we used a Fischer equation and for real fluid we used a REFPROP database (4). We calculated a cooling capacity for HFC-134a, HFC-143a, HFC-152 and for HFC-125 and for comparison also for HCFC-22. Results are in Table 1.

Table 1: Cooling capacity of Rankin's circuit

| Refrigerant | Cooling capacity $\varepsilon_R$ determined by experimental values | Cooling capacity $\varepsilon_R$ determined by model fluid | Difference (%) |
|---|---|---|---|
| HCFC-22 | 5,03 | | |
| HFC-134a | 5,07 | 4,93 | -2,8 |
| HFC-143a | 4,83 | 4,67 | -3,3 |
| HFC-152a | 5,15 | 5,06 | -1,75 |
| HFC-125 | 4,62 | 4,64 | 0,04 |

It is clearly seen that HFC refrigerant can fully replace HCFC-22, because a cooling capacity is nearly the same. It is also clearly noticeable that equation of state based on model liquid represents properties of HFC refrigerants with very good accuracy useful for engineering applications. It is also evident that 2CLJD liquids represent properties of HFC refrigerants with good accuracy suitable for engineering applications.

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# Study of Theoretical Models of the Pinches with Helical Structure

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Many of phenomena in plasma physics, such as X-ray or neutron generation, nuclear fusion and others, behaves under high pressure and temperature. One of the ways to get such density and temperature provides pinch effect, where plasma particles are compressed to the axis due to the magnetic pressure. Most often is made used of the pinch effect in spark discharges and plasma focus devices (Z-pinch) [1] but there are many other types such as theta pinch, X pinch, screw pinch, reversed field pinch. Third parameter, that must be mostly satisfied, is time within the density and temperature hold. There are many ways to stabilize pinch to get longest time during the maximum concentration phase, for instance using of liner or axial magnetic field.

Presence of the axial magnetic field play important role for stabilizing effect. Such configuration, where the azimuthal magnetic field $B_\phi$ together with axial component $B_z$ is present is called helical configuration because the magnetic field lined and also electric current lines are formed as helix [2]. The magnetic helicity, defined by relation $H_B = \mathbf{B}\cdot\mathrm{rot}\mathbf{B}$ has nonzero value and total helicity is invariant in ideal magnetohydrodynamics. Axial magnetic field can originate spontaneous due to the dissipative processes because in helical structure must be in any case present electric current density component, which is parallel to the magnetic field and such combination is called force free configuration.

In my work I was concerned in theoretical models of the helical pinches under various conditions for symmetry. In the most symmetrical case the magnitudes depends only on the radial coordinate $r$. Such case was studied in previous years for steady-state pinch and as one- and two fluid MHD approximation models [3]. Less symmetry means more phenomena, which are included in model; for instance in the case of dependence on the axial coordinate it is possible to get some solutions close to the vortex structure or $m_0$ instability [4]. Dependence on the azimuth coordinate enables the current density to be distributed to several regions inside in the pinch and this is close to the filament structure, which is really observed.
Assumptions for the models are

- one-fluid MHD approximation,
- no viscosity forces,
- isotropy Ohm's law,
- various conditions for symmetry.

Basic equation system for plasma consist from equations for magnetic field **B**, equations for mass density $\rho$ and velocity **v** and polytropic enclosure. This system presents 8 independent equations for 8 magnitudes **B**, **v**, $\rho$, $p$.

The cases of various symmetry are combination of dependences on time $t$ and azimuth and axial coordinates $\phi$ and $z$ respectively:

| dependence | $\equiv 0$ | $\neq 0$ |
|---|---|---|
| $\frac{\partial}{\partial t}$ | steady–state case | time evolution |
| $\frac{\partial}{\partial \phi}$ | azimuth symmetrical pinch | filaments, azimuth instabilities *(M0, …)* |
| $\frac{\partial}{\partial z}$ | axial symmetrical pinch | Instabilities in axial direction *(sosage, …)* |

Only one case with full symmetry leads to the ordinary differential equation, the others are always models based on partial differential equations. Cases with less symmetry could be analytically solved with some additive assumptions, for instance in the case with azimuth and axial symmetry could be separated the equations for $B_\phi$ and $B_z$ in the case of small conductive plasma; the solution of them is the same as in the diffusion in cylindrical geometry. In [4] is analyzed steady–state case with azimuth symmetry with some other assumptions, e.g. that the mass density is constant, which is the case where the current is localized on the surface of the pinch with constant temperature or where the current is uniformly distributed across the pinch channel and the temperature profile across the pinch is parabolic. It is assumed that many of the solutions could be obtained only numerically.

For Numerical solution of the dynamic cases of helical pinch was used finite difference method in Lagrangian formalism, which is convenient for cases, where the boundary condition make surface, which is moving together with plasma fluid. The independent variables in the Lagrangian description consist of labels fixed with the fluid particles themselves. Consequently, the labels move with the fluid throughout its motion.

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# Study of DLC Thin Films Prepared on Si and Metal Substrates

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DLC (Diamond-Like Carbon) coatings have been suggested as protective surface layers against wear. In this paper we have investigated the properties of the DLC films, prepared by the RF and DC PACVD method and multiplex IBM/PACVD method on the steel and silicon substrates, such as: a microhardness of these layers, the dependence of microhardness on bias voltage and adhesion of these films to the substrates and etc.

**Introduction.**

Diamond-like carbon (DLC) films have attracted a considerable attention recently due to their properties of a high mechanical hardness, high electrical resistivity, low friction coefficient, optical transparency and chemical inertness [1]. These properties make the DLC films suitable for numerous potential applications in hard and wear-resistant coating, lithography, protective optical and biomechanical coatings, electroluminescence materials and field-emission devices [2,3]. Various techniques have been used for preparing the DLC films, including ion-beam deposition, reactive magnetron sputtering, pulsed laser deposition, filtered cathodic vacuum arc, direct current plasma CVD, radio frequency plasma CVD, electron cyclotron resonance microwave plasma CVD and multiplex IBM/PACVD method .

**Experimental and results.**

The DLC films were deposited with direct current plasma assisted chemical vapor deposition process (DC PACVD), radio frequency and a multiplex IBM/PACVD on silicon (111) and steel substrates. The steel substrate consists of 0.9 % C, 4.14 % Cr, 6.1 % W, 5 % Mo, 2.02 % V. These samples were polished up to a mirror finish, using a series of standard metallurgical polished steps.

Before the preparation, the samples were cleaned with acetone and isopropanollian in an ultrasonic bath.

The DLC films were prepared by the RF and DC PACVD method on our substrates with the same parameters, apart from the bias voltage, which was varied. This parameter was varied between - 400 V and -900 V for the direct current and between 100 and 500 V for the radio frequency current .

After preparation, we researched the microhardness of these layers, dependence of the microhardness on bias voltage and the adhesion of these layers to the substrates. The microhardness was about 13GPa for the direct current and about 23GPa for the radio frequency. The curve which represented the dependence of microhardness on bias voltage for the layers prepared by the DC PACVD method has the maximum near the 250-300 V and the curve which represented the dependence of microhardness on bias voltage for the layers

prepared by the RF PACVD method hasn't any peculiarity, but in our bias voltage interval the microhardness increase with the bias voltage.

Then we also deposited DLC films by the IBM/PACVD method and studied the microhardness of these films and adhesion to the substrates. The microhardness for the films deposited by this method was about 14GPa.

The adhesion of DLC films prepared by the different methods and on different substrate was not the same. The adhesion for the layers prepared on silicon substrate for all methods was enough good. Different situation we have seen for the layers prepared on steel substrates. The layers prepared by the RF PACVD hadn't good adhesion to the substrate when the thickness is 1 μm and higher and for the layers prepared by other methods we have also observed good adhesion.

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# Mechanism of Subgrains Formation in Metals Induced by Creep

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A simplified view of dislocation structure evolution in many metals and alloys includes a progression from dislocation dipole loops arrays (tangles, veins, walls) to the formation of dislocation boundaries that have a net rotation across them. Extended nearly planar rotational boundaries are integral features of the dislocation microstructure in advanced stages of plastic deformation and creep [1]. These boundaries separate regions of differing slip and must thereby accommodate the resulting mismatch in lattice rotations. At creep conditions the misoriented regions are called subgrains.

In [2] there has been proposed to explain the formation of subgains as a result of a trend to reduce the number of active slip systems by periodic lattice rotations and in that way to avoid energetically more costly multislip. The trend to a subgrain formation is treated in the framework of continuum mechanics as instability against internal bending. The model is analyzed for the case of plane strain symmetric double slip. It is shown that the evolution of a quasi-regular arrangement of regions with differing slip activity is a necessary consequence of a minimization of the incremental energy under imposed loading conditions. The subgrain boundaries then accommodate the resulting mismatch in lattice rotations. The basic idea follows Biot's general theory of inhomogeneous deformation modes (the internal bending) treated as strain instabilities in pre-stressed solids [3].

The rigid-plastic version of the model is employed as a suitable tool. In that case the deformation consists of plastic strain, plastic rotation, and lattice rotation. For a given set of active slip systems the compatibility requirement provides kinematically possible combinations of these deformation components and specifies the orientations of the corresponding subgrain boundaries in the crystalline material. The selection of a preferred subgrain pattern from the set of the kinematically possible modes is based on minimization of incremental internal and dissipated energies. The selected pattern of the lowest energy has the highest probability to be realized. The energy criterion specifies conditions under which the pattern mode is preferred to a quasi-homogeneous strain.

From the variation formulation of crystal plasticity in [4], it follows that the preferred internal structure minimizes the incremental energy functional

$$I = \int_{\Omega} \left( \sum_{i=1}^{N} \bar{\tau}^i \gamma^i + 1/2 \sum_{i=1}^{N} \sum_{j=1}^{N} h^{ij} \gamma^i \gamma^j \right) dV , \qquad (1)$$

where the integration is carried over the volume of the crystal $\Omega$, $\gamma^i$ are increments of slip in $N$ active slip systems, $\bar{\tau}^i$ are the critical resolved shear stresses corresponding to the pre-stress, and $h^{ij}$ is the hardening matrix.

For plane strain model of a crystal deformed by symmetric double slip it can be deduced that the subgrain structure consists of four types of regions of different slip (climb) activities. In each type of subgrains the deformation is approximately homogeneous. It can be shown that $I$ is smaller for the subgrain structure than for a homogeneously deformed crystal subjected to the same average creep strain if

$$(h+q)\left[\frac{2\xi}{\sin 2\phi}\right]^2 + (h-3q)\left[\frac{1-\xi^2}{\cos 2\phi}\right]^2 < 0 \qquad (2)$$

where $h$ is the coefficient of self hardening, $q$ represents latent hardening, $\xi$ is a root of the Biot's characteristic equation [3], and $\phi$ represents the angle between the slip directions of considered double slip and the tensile axis. Hence, the subgrains are formed if (2) is satisfied.

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# The Model of Dislocation Structure Formation Based on the Theory of Continuous Distribution of Dislocations

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The continuous theory of dislocations of Bilby-Kondo-Kröner-Kroupa-Mura-Kosevich [1,2] has been the first attempt to treat rigorously a large assembly of dislocations. The theory has been mainly focused on the geometric description of the incompatibility and/or the internal stress problem arising due to a given dislocation distribution. In this sense the continuum theory of dislocations has became a classical part of theoretical physics. However, despite of much expectations the theory has not provided an adequate background for a physically justified theory of plastic properties of solids. The basic problem, already hinted by Kosevich [3], is to find a proper averaging of the dislocation distribution in deformed crystals. By a rough averaging some factors governing plastic deformation at the meso-scale are lost. The aim of the paper is to find out how to modify and refined the classical continuum theory of dislocations to explain the observed spontaneous formation of dislocation structures and their transformations. These effects play a prominent role in plastic, creep, fatigue, and fracture properties of solids. The paper is focused on early stages of the structuralization process in dislocation cells forming materials during cyclic plastic deformation.

One of the main difficulties which has to be overcome by the continuum theory of dislocations is the simultaneous existence of two dislocation populations with different characteristic length scales and mobile properties: (i) the long segments of glide dislocations which carry plastic deformation, (ii) the small elongated prismatic dislocation loops of predominantly edge character which are leftovers of stored dislocations. The standard dislocation density tensor or its refinements, e.g. [2], are unable to describe the situation for the following reasons:

a) The size of the prismatic dipolar loops is of the order of 10nm, while the segments of glide dislocations extend over distances of micrometers. The glide dislocations are moved by the resolved shear stress, the loops are drifted by stress gradients and/or swept by the glide dislocations. Hence, the glide dislocations and the loops have to be treated as different entities.

b) The interaction between the glide dislocations and loops depends sensitively on the local orientation (character) of the glide dislocations. Hence, it is necessary to introduce densities of the glide dislocations for each orientation separately. The consideration of the full range of orientations removes also the problem that the classical dislocation density tensor is equal zero whenever “positive” and “negative” dislocations cancel each other on average.

c) During deformation, the glide dislocations become curved. The local curvature of the glide dislocations is one of the leading factors controlling the pattering. However, the dislocation curvature is considered neither in the classical, nor in the refined continuous description of dislocations.

To remove these remedies one can either abandon the continuous description and consider each dislocation as an individual object. This approach is currently pursued by the computer simulations of discrete dislocation dynamics. Or, in the continuum approach, one can use a more refined averaging. The present model of meso-scale plasticity follows the latter possibility.

In the paper which is focused on the early stages of cyclic plastic deformation, the deformed metal crystal is treated as an elasto-plastic continuum homogeneously filled with mutually interacting loops and glide dislocations [4]. The mathematical model of dislocation patterning is based on the continuum theory of dislocations. It consists of four groups of equations: (i) the crystal plasticity equations, (ii) equations of the continuum theory of dislocations for the plastic strain carried by fluxes of glide dislocations with different initial orientations, (iii) the balance of forces acting on glide dislocation segments leading to an equation of motion for the glide dislocations, and (iv) the balance law for the stored dislocations in the form of the dipolar loops.

To demonstrate that the proposed model provides a suitable framework for the modelling of formation of dipolar dislocation patterns, a simplified version of the model is analyzed. A dislocation cell forming crystal is deformed in plane strain conditions by single slip carried by glide dislocations originally of screw character. The model predicts the geometry of dislocation patterns corresponding to the dislocation structures observed in early stages of cyclic deformation of cubic crystals oriented for single slip. The scale of the patterns is expressed in form of analytical formulae. However, a fully quantitative specification of the corresponding material parameters is still an open problem.

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# Simulations of Femtosecond X-Ray Emission from Aluminum Targets Irradiated by Short Laser Pulses

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High-intensity ultrafast lasers with chirped pulse amplification have opened a new field of study of laser interaction with solid targets. These plasmas have attracted attention as potential sources for ultrafast-pulsed x-rays in the sub-keV and in the keV range. K-$\alpha$ emission is a particularly interesting x-ray source due to relatively high laser energy transformation efficiency and short pulse. It was already used in pump-probe experiments to measure dynamic response of various materials by means of x-ray diffraction with picosecond temporal resolution [1].

Intense K-$\alpha$ pulses are emitted when radiation of tabletop terawatt laser is focused onto a solid target. The target and laser irradiation conditions have to be optimized in order to achieve both high conversion efficiencies and subpicosecond durations of x-ray pulses. The x-ray pulse length is extremely difficult to measure experimentally, as the resolution of state-of-art x-ray streak cameras is $\geq 1$ ps. However, a special sophisticated technique [2] enabled to determine the K-$\alpha$ pulse length upper limit of 650 fs. The x-ray pulses were longer than 200 fs and the estimated pulse lengths were in the range 300 – 400 fs [2].

The purpose of our study is to calculate both the efficiency of laser energy transformation into K-$\alpha$ emission, and to obtain the duration and the shape of the emitted pulse. We will assume moderate laser intensities, as according to analytical estimates subpicosecond K-$\alpha$ pulses are achievable only for intensities $I\lambda^2 \leq 10^{17}$ W/cm$^2\times\mu$m$^2$. We present here the results calculated for conditions of experiments where 100 -120 fs pulses of p-polarized Ti:Sapphire laser ($\lambda$ = 800 nm) irradiated at the incidence angle of 30° and 45° solid bulk Aluminum targets. Prepulse of intensity $4\times10^{14}$ W/cm$^2$ was applied at variable time separation ahead of the main pulse of maximum intensity $2\times10^{16}$ W/cm$^2$.

The experiment is modeled in one-dimensional planar geometry. The interactions of obliquely incident p-polarized femtosecond laser pulses with plasma are here investigated via our relativistic PIC code using "boost" frame. Detailed description of our PIC code is presented in paper [3]. Exponential electron density profiles at plasma-vacuum boundary are assumed with density scale lengths L corresponding to various main pulse delays. Mean ion charge Z = 10 and initial temperatures $T_e$ = 100 - 600 eV and $T_i$ = 100 eV are taken from the experiment. Thick targets are assumed here and simulation box is limited to a thin area of highly ionized plasma near plasma-vacuum boundary. In the simulation box, exponential density profile is supplemented by area of thickness $\approx\lambda$ of constant maximum density. For computational timesaving reasons, the maximum density is "ad hoc" fixed to $n_e = 10\, n_c$, where $n_c$ is the critical density. The boundary condition at simulation box – target boundary ensures that electrons flowing out from simulation box are substituted by a flow of Maxwellian electrons at initial temperature. PIC code output for Monte Carlo code includes time when electron crosses the boundary and its velocity vector.

Energetic electrons generated near the target surface during absorption of intense p-polarized laser radiation penetrate deep inside the target and shoot out electrons from the internal K-shell. Monte Carlo code simulates electron trajectories with temporal resolution in

detail, including all elastic and inelastic scattering events. Energy losses due to bremsstrahlung emission are incorporated in the continuous slowing down approximation. Cross section for the production of K-shell vacancies is taken from literature. K-shell vacancies are preferentially filled via non-radiative Auger process; the fraction of radiative transitions leading to emission of K-$\alpha$ photons is assumed here 0.04 for Aluminum. At present, our Monte Carlo code does not include hot electron slowing down induced by self-generated electromagnetic fields in the solid target. However, this effect should be minor for the assumed laser intensities, though it is dominant for $I \geq 10^{18}$ W/cm$^2$. The reduction of photon number during their transport to the front side of the target according to the Beer's law is taken into account together with the time of flight.

Our simulations, presented in [3], reveal extremely short K-$\alpha$ pulse lengths of order 250 fs (full width at half maximum), which is in a good agreement with the simulation results presented in [2] and also with the experimental estimates [2]. The integral energies of K-$\alpha$ emission are similar to the experimental values. The decrease in the emitted energy with the plasma density scale lengths L is similar to the other simulations, but it is in contradiction with experimental results where for laser incidence angle 45° maximum emission is observed for the main pulse delay 9 ps corresponding to density scale lengths $L = 0.35\ \lambda$. Further refinement of the simulation model is needed to reach a good agreement with experiment. We also present here the K-$\alpha$ emission energy versus the thickness of Aluminum layer in multi-layer targets.

The emitted K-$\alpha$ pulses are up to two orders of magnitude shorter than the duration of emission of He-like resonance lines [4] and the emitted energy is comparable or even higher. Thus, K-$\alpha$ emission is the most suitable source for material dynamic testing with subpicosecond temporal resolution.

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# Laser Interferometry in Ultrasonic Physics

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The objective of our work is to develop optical method for measuring acoustic pressure. Measurement of the integral acoustic pressure in the air by a laser interferometric probe is compared with measurement using a microphone. We determined the particular harmonic components in the acoustic field in the case of relatively high acoustic power in the ultrasonic frequency range.

Conventional methods for measuring acoustic pressure using a microphone are not quite suitable for some applications. These conventional methods have three drawbacks: they are restricted to about a 100 kHz frequency band, the body of the microphone influences the acoustic field, and contact measurement may sometimes not be possible. These problems are found e.g. in acoustic measurement in small diameter pipes [1].

The acoustic field was generated by a power ultrasonic generator with a steel buffer at a frequency of 20 kHz with second and third harmonics of the base signal. Other harmonic components in the acoustic field arose as the result of the relatively high energy in the propagating waves. We solved this problem in optically transparent pipes by using an optical interferometric sensor – a laser probe.

First, we optically measured the acoustic pressure from a piston source in open space, before measuring in the glass waveguide. The optically obtained results were compared with results obtained by the microphone and with piston radiator theory. We intended to prove that the data from the two measurements of higher harmonic components of the acoustic field are in good agreement.

**Acousto-optics interaction**

When the light ray goes through a volume with variable pressure, the refractive index and the velocity of light propagation differ according to the density changes. We can describe this process as phase modulation of light by acoustic waves. This holds in terms of the Raman-Nath diffraction regime, which is restricted by the Klein-Cook parameter $Q$ and the Raman-Nath parameter. The integral phase change of the laser (electromagnetic) wave in the distance $z$ from the acoustic source over the interaction length (in the direction of the x-axis) corresponds to integral of acoustics pressure.

The interaction of a laser beam with the acoustic wave causes also spatial diffraction, which can be expressed by means of diffraction angles. For this low frequency acoustic field there are negligible angles of diffraction, so we can consider all $n$ orders of diffraction as a single laser beam. It can be expressed as a sum of Bessel functions of the first kind with Raman-Nath parameters as arguments [2].

**Laser interferometric detection**

We chose the heterodyne laser interferometry method for detection of acoustic pressure. The advantages of this method are the high signal to noise ratio (80dB) and the possibility of absolute determination of the signal level. The output signal of the interferometer carries information about the phase changes of the detected laser beam. This information is transformed from the optical band to a much more acceptable lower frequency range. The detailed characteristics of the output signal created by the simple harmonic acoustic wave are introduced in [2]. This paper also describes methods for determining the amplitude of the

pressure from the frequency spectrum of this signal. More complex acoustic fields produce more complex interferometer output signals. We cannot compute the amplitude of the pressure from the simple ratio of individual signal amplitudes corresponding to certain frequencies. It is necessary to use the whole signal frequency spectrum. We solved this problem in a way analogous to the processing of frequency modulated radio signals. After the phase demodulation the obtained amplitudes are directly proportional to the averaged values of the acoustic pressure of the individual harmonic components [3].

**Experiments**

Ultrasonic waves are generated at base frequency 20.3 kHz by a couple of piezo-electric transducers connected at one end with a steel buffer, which radiates as a piston generator into the ambient air. The acoustic signal is a nearly sinusoidal wave with small second and third harmonics of the base signal. Two buffers were used. The output power of the generator can be changed from 20% to 100%.

The level of the generated signal was measured by a 1/8´´ microphone. The acoustic field was scanned at different distances from the aperture of the radiator by means of a computer controlled scanning 3-axis bridge.

A detailed description of the optical apparatus is given in [3]. The spectral analyzer, which has a frequency demodulator (DFM) with variable bandwidth, demodulates the signal from the photodiode PD. The demodulated signal is recorded by the other spectral analyzer.

**Results**

We performed many measurements to check the laser probe measurements with those using the microphone. Microphone measurements had to be performed over the entire length of the acoustic field to obtain integral values that were similar to those obtained by the optic method. The transfer constant of frequency modulation was estimated from a calculation of the simple harmonic signal demodulation. Optical measurement was performed in the presence and in the absence of the microphone to determine whether the microphone influences the acoustic field. Our results prove that it is possible to use a laser probe for measuring integral acoustic pressure. The results are in a good agreement. Accuracy in placement of the probes (mainly the microphone) and measurements at different times produced some deviations in the results obtained using the different systems [4].

The results obtained in this study help us to measure acoustic fields in glass pipes where a microphone cannot be used. The results of measurements in glass pipe we are processing now.

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# Ablation of Materials by a Single Pulse of Soft X-Rays Emitted from Laser - Produced Plasmas

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It has been demonstrated in numerous papers [1-3] that the interaction of short-wavelength radiation with a solid material in vacuum induces the transfer of macroscopic amounts of the material into the vacuum. Synchrotron radiation and radiation emitted from hot dense plasmas have been used in these experiments as x-ray sources. XUV-radiation-induced removal of solids has been studied for use in micromachining, of microelectronic and micromechanical elements and devices, and for making durability assessments, of potential ICF reactor first wall materials and of optical elements, which are exposed to intense short-wavelength radiation in a laser-plasma interaction chamber or during SASE-FEL radiation focusing. X-ray ablation of metals has also been used for determination of the energy content of intense radiation pulses emitted from hot dense plasma. Ejected material can be collected on a chosen substrate so that high-quality thin films are produced.

The short wavelength radiation sources used for materials removal emit at both low (synchrotron radiation sources) and high peak power (sources based on hot dense plasmas). With low-peak-power sources, materials are removed by photon-induced desorption of material components from the irradiated sample surface. Each x-ray photon carries enough energy to break any chemical bond. This energy is also usually higher than the cohesive energy of any crystal. There fore the photons absorbed in the near-surface region may also create small fragments of the sample material, which are emitted into the vacuum. It is necessary to underline that, in the case of low-peak-intensity irradiation, material is removed from the surface and a very thin near-surface layer only. Quite a different situation is expected when a high-peak-power source delivers a single high-energy pulse onto the sample. The sample is exposed to a high local dose of radiation (given by the energy content of the pulse and the absorption length of the radiation in the irradiated material) in a short period of time (given by the pulse duration) – thus a very high dose rate. This means that a large number of events which cause radiation-induced structural decomposition (i.e. polymer chain scissions, etc.) occur almost simultaneously in a relatively thick layer of irradiated material. Since a significant part of the radiation energy absorbed in the material is thermalized, sudden overheating of the layer, which is also chemically altered by the radiation, must be taken into account. On the whole, the overheated fragmented region of the sample represents a new phase, which tends to blow off into the vacuum.

In this contribution we present the results of a study of the ablation of PMMA, PTFE, and Si irradiated by intense soft x-ray radiation emitted from laser-produced plasmas. The high - temperature plasma was created by focusing a 1315-nm laser beam from the PALS, iodine laser system (Institute of Physics, ASCR, Prague) on the surface of a metallic target placed in a vacuum chamber. A gas fill in the interaction chamber was used to reduce charged particle emission from the plasma before arriving at the sample surface. By varying the operational parameters of the plasma sources, we covered a wide range of photon energies, pulse energies,

and pulse durations of the short-wavelength radiation pulses with which the chosen samples were irradiated.

It has been demonstrated that the operating conditions of this sources can be optimized to provide enough soft x-ray radiation, emitted in sufficiently short pulses, to ablate PTFE, PMMA and Si. Polymer layers with a thickness of several hundred nanometers were ablated by a single shot, under optimum irradiation conditions. Silicon, an example of an inorganic, covalently bound crystalline material, is much more resistant to x-ray ablation than organic polymers. PTFE sample was ablated to level of depth from 0.1 μm up to 0.6 μm, PMMA up to 0.8 μm and Si up to 0.2 μm through a nickel mesh by intense XUV radiation emitted from laser produced plasma, driven by the laser pulse focusing on the molybdenum-target surface.

This finding, plus the hydrodynamic-like structures which were observed in irradiated areas of the polymer samples, supports a model of x-ray ablation based on the assumption of radiation-induced scissions of the polymer chains, resulting in formation of a fluid-like phase. Removal of macroscopic amounts of the material is then realized by expansion, ejection, and vaporization of this phase (overheated by the dissipated fraction of absorbed radiation) into vacuum. Reduction of the soft x-ray fluence by increasing the plasma-sample distance and locating the target at the laser beam focus, results in a dramatic decrease of ablation efficiency. The localization of samples at different distances from the x-ray source made it possible to investigate the x-ray dose and dose rate effects on ablation processes under constant spectral properties of the x-ray source. Comparing this result of ablation depth profiles we can measure the space dependence of X ray intensity with respect to the assumed $r^{-2}$ decrease in the intensity far away from the plasma.

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# Shallow Traps Energies in $SrTiO_3$ Crystals Doped with Manganese

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$SrTiO_3$ is a perovskite type quantum paraelectric with a temperature-dependent $TO_1$ soft phonon mode. At ~105 K it possesses a cubic-tetragonal structural phase transition $O^1_h \rightarrow D^{18}_{4h}$. The transition-metal $Mn^{4+}$ impurity ions with $d^3$ configuration reveal very unusual luminescence properties of zero-phonon emission line (ZPL) $^2E \rightarrow {}^4A_2$, which is associated with strong interaction with $TO_1$ mode and with instability of $d^3$ impurity ion in $^2E$ excited state with respect to $TO_1$ mode related polar distortions. In our previous work [1], it has been found that at steady-state excitation at $T < 100$ K, the $Mn^{4+}$ photo-luminescence (PL) intensity in $SrTiO_3$ decreases with time. This effect was tentatively assigned to charge conversion $Mn^{4+} \rightarrow Mn^{5+}$. To prove this idea, we have performed a study of thermally stimulated luminescence (TSL) of $SrTiO_3$:$Mn^{4+}$ at 12 -110 K after light irradiation of the sample from the 355-520 nm spectral region at 12 K and PL kinetics from 4.2 – 150 K.

The $SrTiO_3$:Mn ($10^{-2}$ wt% in melt) single crystals have been grown by the Kyropoulos techniques. The presence of octahedral coordinated $Mn^{4+}$ ions substituting $Ti^{4+}$ was inspected by EPR spectroscopy. The $Mn^{4+}$ luminescence consists of a rather pronounced narrow zero-phonon line at 13 826.8 $cm^{-1}$ and well-developed vibrational sidebands extending in the Stokes side up to 12 500 $cm^{-1}$ ($T = 15$ K). The main maxima in the excitation spectrum of this luminescence at 77 K were found at 18 182 and 23 585 $cm^{-1}$, and they were attributed to the $^4A_2 \rightarrow {}^4T_2$ and $^4T_1$ transitions in $Mn^{4+}$, respectively [1].

TSL glow curves of $SrTiO_3$:$Mn^{4+}$ after irradiation of a sample with 380 and 460 nm light at 12 K exhibit 11 glow peaks in the temperature range from 20 - 100 K. TSL intensity has been detected at about 735 nm, i.e. at the sidebands maximum of $Mn^{4+}$ ($^2E \rightarrow {}^4A_2$) photo-luminescence. The glow curves present two typical cases: a light of 380 nm belongs to the spectral region where the onset of the absorption edge is extended so that in this case the traps located in the specimen's surface layer are preferentially populated, whereas a 460 nm light makes it also possible to populate the traps in the whole bulk. The glow peaks No. 1, 7, 8, and 10 (see Table 1) belong to bulk traps. In order separate the individual glow peaks, TSL measurements were performed after partial heating up to selected temperatures ("partial cleaning"); afterwards, the peaks were analyzed by "an initial rise" method [2]. The peak temperatures and the activation energies for all TSL glow peaks are summarized in Table 1. We suggest from our experiments the following model of TSL: In the course of sample irradiation, a charge conversion of $Mn^{4+}$ to $Mn^{5+}$ and/or $Mn^{3+}$ occurs as has been observed, e.g. in $YAlO_3$:$Mn^{4+}$, and created free electrons and holes are trapped at low temperatures by traps. The TSL glow peaks are then associated with thermal release of carriers from shallow traps followed by $Mn^{5+} \rightarrow Mn^{4+}(^2E)$ and/or $Mn^{3+} \rightarrow Mn^{4+}(^2E)$ charge capture and $^2E \rightarrow {}^4A_2$ radiative decay of $Mn^{4+}(^2E)$.

This model could also explain the PL intensity decrease with time of sample exposition at $T<100$ K, since the $^2E \rightarrow {}^4A_2$ luminescence intensity decreases together with the concentration of $Mn^{4+}$ centers, and initial PL intensity restoration after heating of samples to

higher temperatures than 100 K. However, the nature of carrier's traps cannot be established from our experiments.

TABLE 1 Peak temperatures ($T_m$) and activation energies ($E$) of corresponding TSL glow peaks of $SrTiO_3:Mn^{4+}$.

| Peak No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_m$ (K) | 24.1 | 26.2 | 30.7 | 34 | 38.2 | 44 | 55.9 | 66.6 | 73 | 77 | 93 |
| E(meV) | 33 | 37 | 48 | 51 | 64 | 90 | 112 | 116 | 133 | 141 | 153 |

The decay curves of PL excited at 532 and 355 nm in the 4.2 - 105 K temperature range can be fit by the sum of two exponentials ($\tau_f \sim 140$ - 8 μs, $\tau_s \sim 1600$ - 80 μs), and by one exponential ($\tau \sim 5$ - 0.3 μs) for higher temperatures up to 150 K.

As the excited state $^2E$ of $Mn^{4+}$ is split in a tetragonal crystal field into two levels, we can suppose the existence of two components in decay of the luminescence in temperature region T < 105 K. The decay time of the lower state is usually longer ($\tau_s$) than of the higher one ($\tau_f$) due to inter-transition between these levels, both being slightly temperature-dependent. However, our temperature dependencies of $\tau_f$ and $\tau_s$ are very complicated to be explained just within such simple excited state dynamics.

The decay time of $Mn^{4+}$ luminescence was formerly reported by Stokowski [3], and it was found to be about 5 ms at 77 K, which is essentially longer than our experimental result. The shortening of $Mn^{4+}$ emission kinetics in our samples can be induced e.g. by an interaction of $(Mn^{4+})^*$ ions with surrounding crystal defects. We assume that an electron in the excited state of $Mn^{4+}$ ion can be excited further into the conduction band and/or by the tunneling process to the near shallow trap(s). At a sufficiently high temperature, subsequent re-capture of these electrons by the $Mn^{4+}$ ions can occur resulting in the same radiative de-excitation of $Mn^{4+}$ but rather delayed. If we denote a probability of $(Mn^{4+})^*$ ionization as $p_T = 1/\tau_T$, then the observed luminescence decay time $\tau_m$ can be expressed as $1/\tau_m = 1/\tau_i + 1/\tau_T$, where $m$ is $s$ and $f$, and $\tau_i$ is true slow and fast decay time component, respectively. Since the probability $1/\tau_T$ must be temperature-dependent, and we have observed a rather rich thermoluminescence pattern evidencing many different trapping states within 20 - 100 K even after 532 nm light irradiation, ionization of $Mn^{4+}$ is quite probable and complex temperature dependence of $\tau_m$ can be understood.

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# New Passivation Materials Power Semiconductors

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PN junction of every silicon device subjected to a high voltage must be terminated to avoid a surface breakdown. Quality of the junction termination has a big impact on the functionality and reliability of modern power semiconductor devices (PSD). The development of PSD gradually approaches the stage when technologically very demanding elements (fast recovery diodes, IGBT, GCT, IGCT) are projected for voltage classes ranging from 6 to 8 kV. In such application, the conventional passivation layers do not possess reliable and reproducible parameters of blocking characteristics. For this reason, more resistant materials have to be looked for. The published results of foreign institutions indicate that from the physical viewpoint the most suitable substitution seems to be a semiconductor layer of hydrogenated amorphous carbon (**DLC** – Diamond like Carbon) processed by the PECVD method (Plasma Enhanced Chemical Vapor Deposition). This layer operates as electro-active passivation that is capable to suppress the electric field even with extreme intensity. Consequently, the framework of the proposed grant was oriented on the design, experimental verification and understanding of physical principles of the non-traditional thin electroactive film deposition on the surface of silicon PN junction. with simple (single bevel) and complex geometric arrangement (double bevel). The goal of the proposed grant was not solely a preparation of the DLC layers of suitable parameters (thickness, structure, hydrogen content, width of the band-gap, etc.), but especially a fundamental research necessary for deep understanding of underlying physical processes that influence the hydrogen contents in the layers and therefore the breakdown voltage in potential /1/.

Results obtained

In agreement with the grant the research was focused on

1. the design of a technological procedure for the DLC layers deposition on the surface of a high voltage silicon diode including an efficient masking of the contact,

2. the verification of the influence of significant technological parameters (voltage of the substrate electrode, the substrate temperature, the deposition time, the methan pressure, mask geometry, etc.) on physical parameters of deposited layers (stochiometric composition, layer thickness, etc.)

3. the performance and evaluation of the physical measurements for determination of structure of the layer, its thickness, and concentration of hydrogen ions in deposited DLC layers,

4. the determination of experimental conditions of the transition between polymer and diamond (DLC) phases.

The measurements performed on about 100 samples of power diodes prepared in POLOVODIČE, a.s. have brought some very interesting and promising quantitative results, among them we would like mention following ones:

1) I-V characteristics were measured before and after the deposition DLC layers. We have observed the influence on layer thickness with agreement with the literature /2 – 4/ 120 – 350 nm. More reliable properties were observed for thicker layers.
2) The measurements of deposition speed have shown significant influence, was found for DC plasma deposition with bias voltage –100 V.
3) The measurements of DC and AC plasma deposition at 13,56 MHz have indicated better sample parameters for DC deposition method due to higher number of bonding $sp^3$ bonds.

Sumarising our observations we can conclude that the quality and reliability of our samples depend not only on the growing speed of the layer but simultaneously on bias voltage: at –100 V is the layer softer, at – 750 - -1000 V it is harder ( more $sp^3$ bonds).

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# Sound Qaulity Evaluation of Areo-acoustic Devices

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Product-sound quality depends on certain factors such as design, appearence, practicality, noise, weight and sensorial modalities. Each of these factors has an effect on the complete quality of the product. Sound quality evaluation is a very difficult and interdisciplinary task, because sound quality evaluation is connected with human perception, we have to acquire knowledge in psychoacoustics and in psychology. Perception of sound quality depends on sensorial modalities and non-sensorial factors. The cognitive influences on Sound quality can be divided into three groups [3]:

- source (product)-related: a source/product usually represents an image;
- situation-related: a product is used in a specific activity situation, the user can interact with the source;
- person-related: people have their personal expectation, motivation, taste, preference or aversions.

Sound quality is consists of three different factor groups:

- physical factors (acoustical signal);
- psychoacoustical factors (describing acoustical sensorial aspects – loudness, sharpness, fluctuation strength ...);
- psychological factors (momentary psychic dispositions of subjects, who evaluate specific products).

Sound quality is product specific. Every criticizable product (or class of products) has its own requirements for sound quality, and it is necessary to select adequate methods of sound quality evaluation for specific product. Time behaviour and measurements of certain psychoacoustic quantities can be imitated by electronic devices, but these results are only an assessment of psychoacoustic quantity, no a psychoacoustic quantities themselves. This is a very important point, because hearing product-sound is an individual process. For evaluation of product-sound we have one difficult task – selecting a representative sample of human subjects to evaluate product-sound. Moreover people should have had experience with the evaluated product.

At the beginning of many psychoacoustic experiments an aurally adequate sound recording is made definite and then this recorded sound is evaluated by the subjects. The evaluation is realized by predetermined and set conditions, all of which depend on the type of experiment. No general or standardized method of evaluating sound quality can be said to. The specific aspects of the product, a well as application and target group, have to be considered in planning and running evaluation experiments. An appropriate evaluation method consists of two blocks:

- a kernel procedure: standard and modified psychoacoustic test methods;
- framework: presentation and documentation of all non-acoustical information.

The most common methods of evaluating sound quality are the absolute and the relative methods. An example of an absolute method are direct-magnituded estimation tests. In these tests, subjects listen to a stimulus and directly quantify the feature to be evaluated. An example of the relative method is a pair-comparison, in which two stimuli are presented as a pair, and the subject has to select the one which better describes the given criterion. Both types of methods have their advantages and disadvantages, and whoever performs the experiments must decide, which of these methods is to be used experiment. Presently,we have available the method termed the "individual" test, which presents a combination of the advantages of both methods without the disadvantages of absolute and relative methods.

A subjective test can be performed with three possibilities: 1) direct testing (subject listening to a sound, emerging a product in actual time), 2) the product is substituted by a sound recording played trough speakers, 3) testing an aurally adequate sound recording (sound is recorded using a dummy head and equalized headphones for playback: the acoustical signal at the eardrums of a listener can nearly perfectly be reproduced). The practice of testing sound recorded by a dummy head brings definite advantages (better systematization of listening tests).

By testing of areo-acoustic devices, we shall apply a pair-comparison method. It employed a reference [3], because the author deals with a sound quality evaluation for a vacuum cleaner. The sound of areo-acoustic devices contain attributes similar to the sound of a vacuum cleaner. In the reference [3], pairs of adjectives are divided into four groups. We have select five pairs of adjectives which best describe the evaluated areo-acoustic devices: 1) disagreeable-agreeable; 2) smooth-ruogh; 3) monotone-varied; 4) uncomfortable-comfortable; 5) atypical-typical. These adjectives will be used in a psychoacoustic test, which will be presented to subjects for evaluation.

The final evaluation of sound quality is assessed with psychoacoustic metrics, which will result in a correlation between subjective judgments and objective quantities. An important part of this theme is the determination of the relation between the subjective evaluation of sound quality and objective measured features of sound. We have to select and modify present psychoacoustic metrics, as best to the sound quality of areo-acoustic devices.

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# Influence of Temperature Gradient on the Function of CdTe gamma Detectors

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Cadmium telluride (CdTe) and cadmium zinc telluride (CdZnTe) have been regarded as a very promising material for the exploitation in imaging detectors for X-ray and gamma rays spectroscopy not only in high-energy physics but also in astrophysics. There are at least two good reasons for such application, namely high atomic number in comparison e. g. with Si ($Z_{Cd}$ = 48, $Z_{Te}$ = 52) and large band gap ($E_g$ = 1,5 eV) which allows to operate at room temperature in contrast to Si detector. Due to recent improvements in the technology of crystals production and in the design of electrodes as well, the above mentioned application is becoming very perspective. As known the problem of small charge collection efficiency in these materials reducing energy resolution is connected with low mobility and short lifetime of holes. For this reason we focused our attention on the influence of temperature gradient on I-V characteristics and on the behavior of Au/p-CdTe contacts. Many our papers [2, 3, 4] were devoted to the measurements of I-V characteristics. Summarizing these measurements we have concluded that the Schottky contact must be described by modified Bethe theory [4].

Other interesting results were obtained on the shift of I-V characteristics with temperature gradient on Au/p-CdTe/Au which were published in [3, 4]. Simultaneously, we have measured Seebeck effect on these structures and a plausible explanation was found in accordance with Gurevich theory [1, 5]. In connection with these measurements probably a question arises - why are we speaking about the temperature gradient? Our detector thickness is about 3 - 4 mm. In our detectors the temperature gradient can appear quite independently of our expectation. The detector can be warmed-up by electronic circuits which produce a certain amount of heat. Moreover it is known that thermal conductivity CdTe is very low, 7,5 $Wm^{-1}K^{-1}$ in comparison with Si, 145 W $m^{-1}K^{-1}$. Dependence of the bulk resistance on a temperature gradient is in Tab.1.

| **Temperature [K]** | | **Bulk Resistance .[MΩ]** | |
|---|---|---|---|
| Left | Right | Positive Polarity | Negative Polarity |
| 298 | 298 | 0.15 | 0.168 |
| 298 | 290 | 0.65 | 0.81 |
| 298 | 315 | 0.112 | 0.138 |

As long as one contact is maintained on a constant temperature, its resistance alone does not change, than the other contact is forward biased, that means it does not contribute to the resistance of the whole sample and all changes appear in bulk resistance only. In agreement with the theory [1] the charge redistribution appears in the semiconductor bulk, which does not represent homogenous distribution but charge accumulation near one of the contacts. In consequence of this the changes appear also in detector depletion layer which can increase or decrease. We have observed such changes also in CdZnTe, similar effects are not known in other semiconductors (e. g. GaAs and Si).

Charge redistribution suport also other our independent experiments with Seebeck effect in CdTe published. Unfortunately Gurevich theory [5] does not assume the existence of depletion layer. It supposes that it has zero thickness and that all changes on the boundary metal - semiconductor are described in boundary conditions where these layers are characterised by such parameters as surface conductivity (resistance of charge surface layer in the direction perpendicular to the surface). But this parameter depends both on the thickness of depletion layer and on the decrease of carrier concentration in the layer. According to [6] the resistance of this depletion layer is more important characteristic than the thickness of this layer. In addition the experiment gives just directly sample resistitance and its changes and the thickness of the depletion layer is secondary deduced quantity. Our analysis of I-V characteristics shows, that we really can wait the changes in noice and energetic spectra.

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# CEDOS – Center for Diffractive Optical Structures

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During the years of 2000-2002, the Ministry of Industry and Trade project "CEDOS – Center for Diffractive Optical Structures" had been solved at the Optical Physics Group at the Department of Physical Electronics, FNSPE CTU in Prague, in cooperation with the holographic company Lightgate, based within the CTU BIC area in Prague, Motol. The project had concentrated on one of the perspective fields of modern optical science - diffractive optics, mainly from the point of view of practical design considerations and fabrication of various optical diffractive structures, mainly for optical document security, hologram production, and laser technique applications. The project had built on the long experience of the research team of the Diffractive Optics Group in the field of interferometry, classical holography, recording materials, diffraction gratings and special areas of diffractive optics. In the frame of this project, several different areas of diffractive optics have thus been covered and studied, mainly microstructural synthesis, i.e. different design, optimization, and analysis techniques for several general classes of diffractive optical structures (Fourier, Fresnel, double and multifocus elements; diffusive type of object, FAN-OUTS), and development of practical design techniques for automatic computer design and optimization of synthetic optical diffractive elements.

Although the detailed analysis and theoretical studies of diffraction processes in periodic diffractive structures (gratings, photonic crystals) as well as the development of the analysis methods and tools (Rigorous coupled-wave analysis, Coordinate transformation method, Effective medium theory, Perturbation theory of waveguide gratings couplers, Plane wave method for photonic crystal band gaps) have been performed separately, under the support of special projects (Research plan Laser systems and their applications, Rigorous analysis of optical diffractive gratings, Electron lithography for relief submicrometer diffractive structures), the CEDOS project has efficiently made the best of their experience and results.

The great interest has been naturally given to studies on efficient design and optimization techniques for various types of diffractive optical structures (DOS), not only from the theoretical viewpoint, but mainly due to the practical interests of the CEDOS project. Several techniques have been developed, modified, and/or successfully implemented for these purposes (Hardclip, Phase hardclip, Error diffusion, Minimum error diffusion algorithm, various forms of Iterative Fourier transform algorithm, Direct binary search, etc.). In such a way, the synthesis problem has been resolved for many practically interesting situations, yielding a set of automated computer tools (HOLOGENERATOR) for an efficient design and optimization of various types of DOS.

Next area of interest within the project covered the R & D of holographic recording media technologies, namely (a) synthesis of silver halide ultra fine grain emulsions, their preparation and coating, together with practical considerations (proper substrates, large formats); (b) spin coating of selective photoresist materials, and preparation of master plates; (c) preparation of promising photopolymer recording media; and (d) preparation of dichromated gelatine (DCG) emulsions.

The main focus, however, has been given to development of special fabrication techniques for DOS. Hence, in the frame of the micrograting synthesis tasks, a new original fabrication technique, called the INTEGRAM, i.e. the integral method and device for optical variable

diffractive structure fabrication, has been successfully designed, developed and tested on several optically variable examples. INTEGRAM represents more efficient, faster, versatile, and last but not least cheaper way of optically variable structures fabrication. Using the INTEGRAM, a master is exposed integrally, in one single exposition, in contrast to classically used techniques. A target image is transferred from a source transparent (spatial light modulator based on nematic liquid crystals) to the hologram plane, through a set of different holographic masks. These masks are used to ensure the requested color and reconstruction angle, by changing grating spatial frequencies and orientations. The SLM (e.g. CRL, SVGA $800 \times 600$ resolution, elementary pixel size 33 μm, as in our case) also provides several advantages, direct addressing from a PC, zero sub-image overlapping, spatial filtration removing pixelated structure of an image. The system has had patent pending, and has also been awarded the Siemens 2001 Award. Other fabrication techniques has been developed as well, and are continuously worked on, i.e. development of laser optical writer, special elektroforming technology for relief diffractive structures for master realization, special DOS recombination technology, technology of DOS for imaging and high-power laser applications, etc.

Finally, based both on our own technologies developed, and on the out-of-house technologies, available through cooperation (e-beam lithography writer, Institute of Scientific Instruments, AS CR), different types of DOS have been successfully modeled, designed, and fabricated. The DOS performance has been demonstrated, and steps to the practical application of selected types have been undertaken (OVDOS and Fourier and Fresnel cryptograms for optical document security and counterfeit protection). In conclusion, we have presented a review of our recent activities under the CEDOS project, covering our R & D in DOE design techniques, in the development of diffractive optics fabrication technologies, and in various application areas.

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# Multi-focus Diffractive Optical elements

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Most commonly used Fourier-domain optical diffractive structures are focused in infinity. For many applications, however, structures with a focal plane in finite distance are needed (s.c. Fresnel-domain structures). Furthermore, in special cases, structures with simultaneous multiple focuses at different distances are of concern. As it turned out, design and optimization algorithms for Fourier-domain structures can be used in such cases, only after some modifications. In this contribution, design procedures based on iterative approaches such as iterative Fourier transform algorithm (IFTA) and direct binary search (DBS), as applied to designing such structures, are presented. Comparison of computer simulated and experimental reconstructions is also included.

Most of the design methods for Fourier-domain structures use simple Fourier transform algorithm for description of light propagation process. In a case of Fresnel-domain structures, it is no more possible to use this simplification. However, there is a mathematical operation, which transforms Fresnel transform to the Fourier transform and enables us to use well-known and effective fast Fourier transform algorithms. In our project, the Fresnel transform has been treated by applying appropriate quadratic corrections on the function and then using simpler Fourier transform. As we found out, this operation can be incorporated into current algorithms for design and optimization of synthetic optical diffractive structures. Here two of them, IFTA and DBS, are presented on practical design problems.

The main idea of the basic IFTA algorithm is well known, and there is no need to go to any details on a general level here. Since we are interested in amplitude-only input objects, the phase freedom (i.e. a random initial phase distribution) within the signal window, as well as the amplitude freedom outside the window are applied. In general, depending on particular degrees of freedom chosen, an input signal, represented within the signal window, is transformed from the object plane to the hologram plane using the relevant transform (i.e. Fourier transform or its modifications). The continuous complex spectrum obtained in the hologram plane is then partially discretised within an each iterative step. This partially quantized signal is transformed to the reconstruction plane using the inverse Fourier transform. Obviously, such partial quantization introduces some noise in the reconstruction plane. This noise is removed by replacing the amplitude of a newly calculated noisy signal within the signal window with the desired amplitude of the original signal. This modified signal is used as an input to the next iteration step. The IFTA model has been successfully implemented and incorporated within the automatic computer design tool HOLOGENERATOR.

The other iterative approach, the DBS algorithm, on the other hand, starts with a random distribution of binary hologram transmittance function. The hologram pixels are then sequentially inverted, and after each inversion, new values of the quality parameters are checked. The inversion is accepted if there is an improvement in the quality, otherwise, the inversion is refused. Also this DBS model has been numerically implemented and tested.

Now, the crucial point is that the above described optimization algorithms can be used also in the case of Fresnel-domain elements. Since, as was discussed above, from a comparison of the kernels of Fresnel and Fourier transforms, a quadratic correction can be derived, the

efficient Fresnel transform computation of the function *f* can be implemented in two steps: firstly the function *f* is multiplied by the quadratic factor and then Fourier transform of the result is computed. Physical meaning of the quadratic correction can be explained as an addition of a negative lens that moves the focal plane to infinity. An inverse transform can be easily derived from the expression for the direct transform as well.

The above-described idea of the Fresnel transform has been incorporated into the IFTA algorithm and used for optimization of the Fresnel-domain diffractive elements. The design results satisfactorily correspond to the Fourier case (from the point of view of quality parameters). Furthermore, several sets of bifocal and multifocal elements were designed, together with estimated results of actual performance. Due to its special nature, the DBS algorithm has been mostly used for designing FAN-OUT type elements because of their lower requirements on the signal sampling and size. The elements with tilted focal plane are the next possible field of perspective applications of the DBS algorithm where the functionality of the algorithm has also been successfully demonstrated.

The designed structures were fabricated using two different technologies. The first one consists of displaying the designed structures on a nematic liquid crystal spatial light modulator, available in the Diffractive Optics Lab. This experiment has confirmed the design results but, unfortunately, the quality of the obtained image was low due to the size and improper shape of the modulator's elementary pixels. The second way of designed diffractive structures realization used was e-beam lithography. Several elements were fabricated with different design and fabrication parameters in e-beam photoresist layer on a glass substrate, with both binary and multilevel microstructure profiles. In this case, correspondence between simulation and experiment was more than satisfactory. In conclusion, based on our research and results presented, the functionality and effectivity of the proposed design process can be stated.

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# Realisation of Selected Optical Transformations

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The Fourier transformation (FT), as a fundamental and easily realizable integral transformation in optics, has continuously gained increasing importance due to many practical applications in the field of Fourier optics and optical information processing. Recently, other more complicated transformations (Fresnel, Hilbert, Mellin, Radon, Wavelet, etc.) have appeared in the optical research due to their unique and specific properties, not obtainable only within the classical FT. These transformations, defined with a specific integral kernel, thus offer new types of invariance, not obtainable within the FT in principle (FT is invariant to translation, but not to scale and/or rotation transformation). Hence, the Mellin transformation is invariant to scale changes while the Radon transformation is invariant to input signal rotation. Moreover, wavelet transformations play a special role due to their ability of signal sampling with automatic self-adaptive resolution.

The optical realisation of these transforms often utilizes the FT experimental setups in a form of Fourier processors, due to their feasibility; and thus transfers a realisation problem to a particular filter synthesis, according to the transformation used. Hence, a problem of a specific filter synthesis becomes a crucial for realisation of more general optical transformations of interest. A Fourier processor is generally based on multiplication of Fourier spectra with transparent functions, providing correlation and/or convolution as the output. There are two elementary correlation (convolution) methods often used in practice, namely Joint transform correlator (JTC) scheme and Vander Lugt correlator, both giving a powerful tools in optical pattern recognition and correlation. Using these setups, different transforms can be realized synthesizing a using a specific filter.

This project, running in our laboratory of Diffractive optics, has build on previous experience in the field of optical information processing and optical correlators, and started a new research in the area of optical filter synthesis and their fabrication.

Naturally, due to their specific functionality, a practical filter synthesis represents the most important part of a problem, placing new demands of improvement into classical fabrication technology of diffractive elements. These practical experimental studies and measurements thus had to represent an important part of our activities. As a recording material for optical filter fabrication, high-efficiency photoresist has been chosen, enabling a preparation of surface-relief type of structures. Based on our detailed testing and comparison, a special SHIPLEY positive photoresist of 1800 series has been selected. For filter recording, spatial light modulator (SLM) based on twisted nematic liquid crystals (LQ) has been used, working in the amplitude modulation regime. Additional problems connected with a conversion of intensity signal to a phase information had to be studied and solved (photoresist is a phase material in principle). This problem has finally been solved by signal numerical pre-processing, based on PC modelling and simulation models of exposed filters.

A separate section of practical problems has posed a recording film preparation, connected with a usage a positive photoresist. A special spin coating manufacturing technique for thin homogeneous resist layers has been experimentally managed and optimized, providing possible filter dimensions of about $200 \times 200$ mm and layer thickness of about 500 – 2000 nm (depending on a particular spin coating rpm used). Additionally, wet etching processes of exposed photoresist have been optimized in order to maximize the output diffraction efficiency. Development of such a fine technology represents an important result itself, with many other promising applications within the field. In general, the optimization of the overall process, has appeared to be absolutely necessary for fabricating of high-quality filters.

Based on Fourier processors considerations, our laboratory setup used for optical filter recording has been optimized for universality and ability to implement various optical transformations. As a coherent cw light source, HeNe laser was used; as a SLM, SVGA CRL LQ with resolution $800 \times 600$ pixels, connected to a PC VGA port as signal source (both for filter fabrication and transformation input signal) was applied. As a coherent processor setup, a typical 4f scheme was used (2f – Fourier transformation, 2f – inverse Fourier transformation) witch performs Fourier spectra multiplications (signals correlations). Some of the transformations discussed above have been realized. The results of realized optical transformations could be further used in linked applications such as optical target recognition, edge detection, and signal compression.

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# Maxwell's Demon Attracts Attention Again

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On the CTU Workshop 1997 we devoted a memory to the so-called Maxwell's demon [1]. It was on the occasion of his 130th birthday. Maxwell mentioned his "heat fairy" for the first time in a private letter to P. Tait 1867. W. Thomson coined the name "Maxwell's demon".

The aim of this thought being was to demonstrate the fact that the 2nd law of thermodynamics has not the same status as e.g. the laws of mechanics but it is valid only statistically. This small "intelligent being" would be able to watch individual molecules and sort them only by opening a door. It would be possible to oppose the 2nd law and to differentiate temperature, pressure or concentration. It would be possible to convert heat into work. A chaotic motion on microscopic level could be changed into a regular motion on the level of macroscopic bodies.

Since his introduction to physics the Maxwell's demon has been a subject of hundreds of various articles. To the list of the most prominent names and ideas in his history belong e.g. Smoluchowski (1913) and his interpretation of the demon as a valve, Szilard (1929) and his one-particle engine with an implicit relation between dissipation (entropy) and information, Brillouin (1956) and his treatment of information as negentropy and the idea that when gathering information the corresponding amount of energy must be dissipated.

Jaynes (1957) studied thermodynamics as a description of a system with an incomplete amount of information. Prigogine was interested in dissipative structures (1971). Feynman's ratchet and pawl (1965) showed how the conversion of heat into work is conditioned by an initial imbalance in a system. Etc.

Landauer and Bennett (1960-1980) studied thermodynamics of computation and a dissipation was identified to be inevitable not in the process of gathering and processing information but in the process of erasure memories. Only for a short period it seemed that demon can work [2].

Nevertheless, articles devoted to demon never stopped and they still continue to appear. Demon presents himself in many incarnations and in different forms. The rich physical culture around the 2nd law and entropy is actually a culture of Maxwell's demon. He is a remarkable teacher of a Socratic type. He doesn't give lectures, he doesn't instruct us. Rather he puts unpleasant and tricky questions. When looking for the answers we learn much.

Of course, the level of articles is not always the same. Some of them are general, some others very specific. The number of them has even increased in the last five years. Recently many different thought experiments have been presented. They involve various situations containing non-equilibrium but stationary conditions somehow opposing the second laws (usually mistakenly). In some of them velocities of molecules in a gravitational field play a role. Some others are based on motions of charged particles, on phase changes, on specific structures in a solid phase etc. Particularly some molecular phenomena near a boundary between living and inanimate structures are of special interest. Some of these articles remain in the realm of classical physics however in the most of them quantum effects may be relevant.

On a general level even the standard quantum formula for entropy and the relation between entropy and information were questioned. Maxwell's demon appeared once in a vicinity of Baron Munchausen [3]. (He also was able to pull himself out of a swamp.) The physics connected with the second law is surely exciting and inspirational. The question how to understand irreversibility of natural events and the asymmetry of time on a macroscopic level in some other way than simply inserting the concept of probability is still a challenge. The second law doesn't deal with a conversion of different kinds of energy only but it is also connected with this fundamental asymmetry and with the concept of information. In physics of the coming century information may be one of the key concepts [4].

Even particular articles dealing with the second law may be useful contributions to a better grasp of all these problems. Unfortunately, many authors of these articles, suggestions and critical essays don't take account of other articles. They differ in their unmentioned and hidden assumptions, and in their formulations of concepts and the questions they are trying to solve, so that these articles are not often mutually well comparable.

To confront them and to search for clearer and comparable expressions with the aim to find the most relevant ideas in these articles is an uneasy but useful program for a research.

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# Laboratory Exercises in Vacuum Technology

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Vacuum appliances are exploited very often in advanced technologies as a means for carrying out production processes demanding high purity environment or well defined conditions. Vacuum technologies have been used more and more frequently in many industrial branches including mechanical engineering. In addition to classical applications as production of electronic and microelectronic elements or production of coating used in optics, vacuum systems and appliances are used in food industry, pharmacy, wood processing, production of decorative coatings. They have fundamental importance in the fast developing field of nanotechnology. In the branch of mechanical engineering are vacuum technologies also used frequently in vacuum metallurgy, in production of hard and wear resistant coatings on cutting and forming tools or on abrasively stressed machine elements.

Due to its importance, vacuum technology is a part of education both at technical faculties and at natural science faculties of many universities: Faculty of Mathematics and Phys od Charles University in Praha, Faculty of Applied Sciences ZČU in Plzeň, Masaryk University and VUT in Brno. Among the faculties of CTU, vacuum technology is a part of curriculum at the Department of Physical Electronics of Faculty of Nuclear Sciences and Physical Engineering and at the Department of Electrotechnology of Faculty of Electrical Engineering. At the Faculty of Mechanical Engineering is teaching of vacuum technology carried out at the Department of Physics in cooperation with the Division of Compressors, Refrigerating and Hydraulic Machines of the Department of Fluid Dynamics and Power Engineering (subject "Vacuum technology") and with the Department of Materials Engineering (subjects "Surfaces and Coatings" and "Plasma Processes". In general, some problems of the vacuum technology teaching are caused with the lack of special books and textbooks on vacuum technology, especially in Czech. At present are there at our disposal only older books on vacuum science [1], [2] or [3] and on laboratory exercises only one textbook [4].

An important part of vacuum technology lessons are the laboratory exercises consisting in measurements of some parameters and characteristics of vacuum systems. Up to now the practical exercises of above mentioned subjects were carried out using the vacuum appliances in the research laboratory of the Department of Physics. This situation was not satisfactory, because the students were disturbing the research activity of the Lab and on the other hand, they had not opportunity to operate the vacuum devices independently.

That was the reason why we took advantage of the CTU grant and decided to obtain a proper vacuum system and to adapt it especially for teaching application. The basis of the device is an older laboratory vacuum system with the following parameters : rotary vane pump with pumping speed 5,6 $m^3 . h^{-1}$ and base pressure $8.10^{-1}$ Pa, diffusion pump with pumping speed 130 l . $s^{-1}$ and base pressure $2.10^{-5}$ Pa, bell jar volume about 15 litres. Pressure monitoring : Pirani and Penning manometers, each with several gauges located in different positions in the vacuum system. Two built-in evaporators enable to demonstrate the thin film evaporation as an example of a classical vacuum process. The device was completed with two new heads that could be connected to the bell jar : a cylindrical pipe for vacuum conductivity measurements and a glass pipe for discharges observations.

In the present state this vacuum system enables to carry out these laboratory exercises :

1. The measurements of pumping speed in dependence on pressure and basic pressure of both pumps.
2. Measurements of vacuum conductivity of a cylindrical pipe in different flow regimes.
3. Study of gas desorption from the bell jar walls.
4. Observation of the glow discharge driven by Tesla transformer independence on pressure, tentative determination of the residual gas composition.
5. Methods of leakage detection and leakage rate measurement in vacuum systems.

The exercises 1, 2 and 3 were carried out already in the winter term 2002/2003 as a part of the subject "Surfaces and Coatings". The whole range of the above mentioned laboratory tasks have been prepared for the laboratory exercises of the subject "Vacuum Technology" in the summer term 2002/2003. The information necessary for students homework preparation and results evaluation are given during lessons and by means of the textbook [4]. The authors of this paper have begun to prepare a digest of basic knowledge and equations of vacuum physics and vacuum technology including brief instruction for laboratory measurements and evaluation of the results. This text will be finished during the summer term and then located at the website of the Department of Physics.

We suppose that the development of this vacuum plant for student laboratory exercises has not been closed and that it will be supplied with other accessories, e.g. with some new types of vacuum gauges or with a small low-voltage magnetron for thin film deposition.

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# Ultrasonic System for Identification of Fluids in Closed Containers

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In research on acousto-optic sensors we had to use a lot of volatile fluids that were not friendly to any environment. We found that the safest way for detecting and identifying these chemical fluids was to let them in their own closed containers and accurately determine their sound speed, sound attenuation and liquid density in a wide frequency range. We started with the pulse-echo time-of-flight technique [1]. In the method, a narrow electrical pulse was used to excite a transducer attached to a container or in direct contact with a mentioned liquid. The pulse generates a pressure pulse that propagates through the liquid, deflects from the opposite wall of the container, and gets detected by either the same transducer or by a second one. By measuring the time it took for the pulse to make the round trip travel over the known distance inside the container, it is possible to determine the sound velocity. By transforming the time domain to the frequency domain, it is possible to gather other physical properties of the liquid (attenuation, density). A nature of some fluids, shapes of containers and the necessity to receive the broadband spectra of the narrow pulses of the pulse-echo time technique, handicaped this method. Therefore different technique was used: acoustic interferometry (AI).
The AI measurement can be described in terms of planar ultrasonic wave transmission and reflection through a multilayer system consisting of the test fluid between symetric layers of transducer crystal, wear plate, coupling gel, and container wall. Almost all multilayer systems can be simplified to basic single-layer model: a volume of liquid between two identical parallel piezoelectric transducers where one transducer is used as transmitter and the one on the opposite side as the receiver. If a sine-wave electrical signal is applied to the source transducer and the frequency is sweeped in time over a frequency range with suitable time, the signal at the receiver transducer is a series of regularly spaced resonance peaks. These interference peaks are observed whenever an integral number of half-wavelengths span the liquid between the two transducers. The sound speed $c$ is then derived from the frequency spacing between any two consecutive resonance peaks $\Delta f$ as

$$c_L = 2 L \Delta f , \quad (1)$$

where $L$ is the liquid path length. The measurement should be done in a frequency range far from the transducer resonance frequency. The width of the peaks is related to the sound attenuation in the liquid. In multilayer systems the received spectrum is much more complicated. The sets of spectra from liquid and walls are coupled together. If the liquid in solid wall container is measured, the spectra can be easily separated in their frequency scale. The measurement in liquid offers us another positive feature – shear wave propagation is missing. In case of single wall system two features were found. First, as the wall peak is approached from other side, the liquid peaks get progressively broader, indicating greater loss. This is because of the stronger sound transmission through the wall near the wall peaks. The second feature is the bunching of the liquid peaks near the wall peak. The liquid peak spacing gets progressively shorter as the maximum of the wall peak is approached due to the coupling between the wall and the liquid. Taking these facts into account, it can be seen that the composite spectrum is very similar to that observed in the simplest mentioned arrangement

where the transducers are in direct contact with the liquid. Only the liquid peak amplitude, liquid width, and liquid peak spacing are function of frequency. In other words, for each observable quantity there is a fixed oscillatory pattern in the observed sound speed data. In practice, the wall-liquid coupling does not affect the sound speed measurement. It does require care in properly extracting (substracting) the sound attenuation value in the liquid. If the right part of the spectra is chosen what is equivalent to a basic one-layer model, the intensity transmission coefficient $T$ of a single fluid layer of thickness $L$, attenuation coefficient $\alpha_L$, and sound speed $c_L$ can be expressed as

$$T = \frac{4}{(2-\sigma\alpha L)^2 + (\sigma^2 - 4)\sin^2\left(\frac{\omega L}{c_L}\right)} \qquad (2)$$

Here, $\sigma = z_W/z_L + z_L/z_W$, $\omega$ is the angular frequency, $z_W$ and $z_L$ are acoustic impedance $(\rho c)$ of wall and liquid, respectively, and $\rho$ is the density. $T$ is a periodic function of $(\omega L/c_L)$ and reaches a maximum (peak) whenever the condition $(2\pi f_n L / c_L) = n\pi$ is satisfied, where $f_n$ is the n-th peak frequency. From this condition, the sound speed $c_L$ (1) can be determined if the frequency difference between any two consecutive resonance peaks $\Delta f = f_{n+1} - f_n$ is measured. The sound attenuation $(\alpha)$ and liquid density $(\sigma)$ can be obtained from the ratio of transmission coefficient minimum $T_{min}$, and maximum

$$\frac{T_{\min}}{T_{\max}} = F(\sigma) + L\alpha_L(f^2). \qquad (3)$$

This equation shows that both $\alpha_L$ and $\sigma$ can be determined from a linear fit of the data of the transmission ratio factor as a function $F$ of $\sigma$ and $f^2$. The intercept at zero frequency is related to the acoustic impedance ratio $\sigma$. If the impedance of the wall material is known, the liquid density $\sigma$ can be determined because the liquid sound speed is determined independently (1). To find liquid sound absorption, if $\sigma$ and $c_L$ are known, is very simple from (3).

We did some starting experiments with AI method. The usage of a narrow band (0.1-100Hz) spectral analyzer filter (in HP8560E) restricted the receiver noise in contrast to pulse-echo method. A signal to noise improvement of five orders of magnitudes was reached. So the much smaller acoustic power and greater acoustic impedance mismatch could be used. The amplitude signal was digitized and recorded in the computer memory for data analyses. Typical excitation power used for measurement was about 1 mW. The broad-band designed piezoelectric transducers with 12 MHz center frequency with element size of 10 mm had only a thin wear plate on the top surface for protection from mechanical damage. The starting measurements were done in polished rectangular glass cells of liquid path length 10mm.

In this paper the measurement setup for identification of liquids in non-invasively way is described. Sound speed, sound attenuation, and density can be determined over a wide frequency range. Some advantages and restriction of the method were discussed. The method is applicable for containers that can be both planar and cylindrical. The accuracy of the sound speed measurements is about 0.5% and that of sound attenuation a bit more than 3%. The density determination is the worst, typically 5%.

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# Powder Neutron Diffraction Study of Ceramic Synthesis of the Pr(1-x)Na(x)MnO(3)

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Complete structural determination of the mixed-valence manganites $Pr_{1-x}Na_xMnO_3$ for samples x=0.025, 0.05, 0.075 and 0.20 was achieved by the powder neutron diffraction on the diffractometer DN-2 in Rez near Prague. (The sample x=0 was studied previously using another facility [1].) The diffraction patterns were taken at $\lambda$=1.362 Å over a range of $2\vartheta$= 5.5° - 67° in steps of 0.1° at the room temperature and 7 K (for x=0.075 and 0.2 also at some intermediate temperatures). The structural refinement has been done by a profile analysis using the program FULLPROF. In order to achieve more significant lattice parameters in the course of the charge ordering transition in the x=0.2 sample, an additional X-ray diffraction measurement has been performed in low temperatures down to 80 K.

Numerous investigations of the mixed-valence manganese perovskites $Ln_{1-x}A_xMnO_3$ (Ln=La or rare-earth cations, A=alkali earth or alkaline cations) show that their properties depend essentially on the actual $Mn^{3+}/Mn^{4+}$ ratio, irrespective whether it is achieved by the Ln-A heterovalent substitution or by a shift of the cation or oxygen stoichiometry. In particular for perovskites rich on $Mn^{3+}$, the compositional transition from the layered (A type) antiferromagnetism in orbitally ordered $LnMnO_3$ to the ferromagnetic ordering in substituted, orbitally disordered systems occurs in a universal way. It appears that up to about 0.05 electron hole per manganese (formal $Mn^{4+}$ content of 5%) the A type matrix hosts ferromagnetic "droplets" which can be directly detected by small angle neutron scattering . With higher hole concentration, the long range ordered components of both the A and F (ferromagnetic) types are observed by neutron diffraction experiments, along with strong indications that these components are in fact coupled and form a canted arrangement. According to our neutron diffraction data on different Pr-based manganites [2], this canted phase exists in the range of 0.05-0.15 hole/Mn. For about 0.15-0.20 hole/Mn there is a two-phase region where the canted arrangement coexists with pure ferromagnetism. An interesting point is the different orientation of the ferromagnetic component in the canted and pure ferromagnetic phases, which manifests itself as an apparent reorientation of moments in the course of temperature. The pure ferromagnetism which may be insulating or metallic in dependence on the size of Ln,A cations, is finally succeeded for samples with 0.3-0.5 hole/Mn by the charge and/or orbitally ordered ground states which are antiferromagnetic and generally insulating.

In contrary to systems substituted with alkali earth cations, there are only few structural reports on the less common systems with alkaline cations. In particular, complete data are

available for the $Pr_{1-x}K_xMnO_3$ series [1] and two brief reports were published also for $Pr_{1-x}Na_xMnO_3$ ($x \leq 0.15$) [3].

Numerous crystallites of the sample x=0.2 used for the neutron diffraction study were characterized using electron diffraction and microscopy. The diffraction study versus temperature and the bright/dark field imaging were carried out with a JEOL 2010 electron microscope using a double tilt cooling sample holder. For most of the experiments, the temperature was firstly stabilized at 92 K and then slowly increased to 300 K, waiting for the temperature stabilization before each recording.

Similarly to related systems with divalent alkali earths, the increasing monovalent sodium substitution decreases the Jahn-Teller deformation of the $MnO_6$ octahedra, lowers the resistivity and changes gradually the magnetic ordering from the layered type antiferromagnetism (x=0) through canted arrangements (x~0.05) to the pure ferromagnetism ($0.10 \leq x \leq 0.15$) with $T_C$~125 K. The samples with the ferromagnetic ground state are not metallic below $T_C$ but show appreciable magnetoresistive effects in a broad temperature region. The electronic localization at low temperatures is further enhanced in sample with the maximum sodium content x~0.2 (actually 36% $Mn^{4+}$). The electron and neutron diffraction evidences that $Pr_{0.8}Na_{0.2}MnO_3$ exhibits a commensurate charge and orbital ordering of the Mn3+/Mn4+(1:1) kind below $T_{co}$=215 K, followed with a transition to the antiferromagnetic arrangement of pseudo-CE type at $T_N$= 175 K, analogous to that of previously studied $Pr_{0.65}Ca_{0.35}MnO_3$. In addition, the present compound $Pr_{0.8}Na_{0.2}MnO_3$ undergoes below ~50 K a spin reorientation and, simultaneously, ferromagnetic clusters in the charge ordered matrix are formed. By application of external field of 2-5 T below $T_{co}$, the insulating charge ordered antiferromagnet is transformed to a metallic ferromagnetic state which is persistent below ~60 K,i.e.temperature close to the mentioned spin reorientation [4].

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# The Study of x-T Phase Diagram of Rb(1-x)(NH4)(x)I Mixed Crystals by Neutron Diffraction

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The study of x-T phase diagram of the $Rb_{1-x}(NH_4)_xI$ mixed crystals has important significance for the understanding of possible influence of inner strain. During last decade x-T phase diagram of the $K_{1-x}(NH_4)_xI$ mixed crystals was studied in detail [1] and it was showed that observed peculiarites of this system at low temperatures can be explained for account of inner straine which are appeared in accordance of the ionic radius difference of potassium from ammonium. This difference can be the cause of the appearance on x-T phase diagram $K_{1-x}(NH_4)_xI$ mixed crystals ε-phase with new crystal structure. Usually KI don't undergo phase transitions up to low temperatures but $NH_4I$ undergoes the series of phase transitions with cooling :

α-phase ↔ 255.4 K ↔ β -phase ↔ 231.4 K ↔ γ-phase

The crystal structures of these phases were investigated by x-ray and neutron diffraction and are known. The cubic α-phase is described by the space groupe $Fm3m\text{-}O_h^5$ with Z=4, ammonium ions are disordered in this phase. The cubic β –phase is described by the space groupe $Pm3m\text{-}O_h^1$ with Z=1, ammonium ions are also disordered in this phase. The tetragonal γ-phase is ordered structure of ammonium ions describing by the space group $P4/nmm\text{-}D_{4h}^7$ withZ=2.

The x-T phase diagram of $K_{1-x}(NH_4)_xI$ at low temperature is presented by following series of phases as a function of ammonium concentrations:

KI ↔ α-phase ↔ OG (orientational glass) ↔ ε-phase ↔ β-phase ↔ γ-phase↔ $NH_4I$.

The ionic radius difference is practically absent between rubidium and ammonium. There are presented results of neutron powder and inelastic incoherent neutron scattering studies of x-T phase diagram of diffraction $Rb_{1-x}(NH_4)_xI$, which were carried out with the purpose to observe ε-phase and the shift of phase boundaries.

The preparations of the powder samples of the $Rb_{1-x}(NH_4)_xI$ mixed crystals with different ammonium concentration was produced by slow evaporation of liquid solutions of corresponding stoichiometric contents. The contents of obtained powder samples were controlled by special chemical methods and x-ray analyses.

The crystal structure of the $Rb_{1-x}(NH_4)_xI$ mixed crystals and ammonium dynamics were studied by the neutron powder diffraction (NPD) and by the inelastic incoherent neutron scattering (IINS) methods. Such complex method of the investigation of the properties of the $Rb_{1-x}(NH_4)_xI$ mixed crystals gives the possibility of more full study of x-T phase diagram by seeking the general dependencies between the crystal structure and the lattice dynamics and structural relaxation of separated lattice units. In the case of the $Rb_{1-x}(NH_4)_xI$ mixed crystals

there is the possibility by the IINS methods to investigate the influence of ammonium disorder on crystal structure with differet order.

The use for the x-T phase diagram study of neutron scattering complex method concluding neutron powder diffraction and inelastic incoherent neutron scattering gives more full possibility for detail investigations. Recent neutron scattering studies allow the determine the concentration region of orientational glass state existence which as it was seen in this report that is difficult using only neutron powder diffraction. The x-T phase diagram of the $Rb_{1-x}(NH_4)_xI$ mixed crystals is not presented in this report in full concentration region of ammonium ions. In recent time the determination of concentration region of β- and γ-phase is continued. There is problem also of the existence of ε-phase on the x-T phase diagram of the $Rb_{1-x}(NH_4)_xI$ mixed crystals [2]. The absence of the ε-phase in the system of $Rb_{1-x}(NH_4)_xI$ mixed crystals can be explained as the result of the absent of inner strains. However it is necessary to continue the search of the ε-phase in the system of $Rb_{1-x}(NH_4)_xI$ mixed crystals with the help of single crystal neutron diffraction because the history of the discovery of the ε-phase in the system of the $K_{1-x}(NH_4)_xI$ mixed crystals confirms to carry out such investigation.

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# Spectrophotometer Calibration Using Common Thungsten Bulb Light Source

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An alternative calibration way of spectrophotomether is discoused in this article. This way is alternative to common calibration way recomanded by National Institut of Since and Technology (NIST). The common way is not as accessebile as alternative one for most lighting laboratory, but some special measurement instrument are nacesary to use.

The calibration objective is to determine measurement system response:

$$\frac{\Phi_{ed}(\lambda)}{\Phi_{ez}(\lambda)} = K(\lambda) \tag{1}$$

$\Phi_{ed}(\lambda)$ is an elementar radiant flux incoming to measurement system [W]*
$\Phi_{ez}(\lambda)$ is an elementar radiant flux emmited by light source[W]*
$K(\lambda)$ is an spectromether response [-]*

* an elementary wavelength interval is given by system construction. The interval is called bandpass B(λ).

Used measurement system make use of mnochromator to difract radiation. Silicon detector is used to determinate energy amount radiate at elementar wavelength interval. Due to detector response calibration is possible to determine energy putting over at proper wavelength interval (bandpass B(λ)).

$$\Phi_{edd}(\lambda) = \frac{MV(\lambda)}{K_d(\lambda)} \tag{2}$$

$\Phi_{edd}(\lambda)$ is an radiant flux detect by silicon detector [W]
$MV(\lambda)$ is an physical quantity measured by system, e.g. for used measurement system photovoltaic current [A]
$K_d(\lambda)$ is an detector calibration function, e.g. for used measurement system [A/W]

This calibration way crucial point is to determine radiant flux emited by light source. For this reason is necesary to choose standard bulb light source which radiant flux is at least during whole calibration constant or alter in preset limit. Than is possible determine light source radiant flux in few steps:

1) Measure clibration light source total luminulous flux $\Phi_{zdc}$ [lm]
2) Determine light source trichromatic coordinates x,y [-] by trichromatic colorimeter.

3) Determine light source temperature $T_z$ [K] using trichromatic coordinates and trichromatic diagram CIE x,y.
4) By the Planck law is possible to determine black body elementary radiant flux coresponding with bandpass wavelength internal $E_{eact}(\lambda)$ [W/m$^2$].
5) Using light source temperature $T_z$ determine wolfram emisivity $\varepsilon_w(\lambda)$ [-] and elementary radiant flux of wolfram body $E_{eW}(\lambda)$ [W/m$^2$]. Wavelength interval is coresponding to bandpass B ($\lambda$).
6) Evaluate wolfram body total luminulous flux $\Phi_W$ [W] at temperature $T_z$.
7) Evaluate spatial constant $S_{ekv}$ [m$^2$] that beyond spatial light source relation with measurement system optical input include all of folowing effects:

   The bulb filament surface and it´s elements proportion on total radiant flux.
   Spatial filament construction, where some filament elements absorb part of emited radiant flux. There is an diference between Planck law and consider calculation.
   Radiant flux multi-reflection inside integrating sphere.

8) Evaluate wolfram body spatial corection and determine total wolfram body radiant flux.

$$\Phi_{ez}(\lambda) = S_{ekv} \cdot M_{eW}(\lambda) \tag{3}$$

$\Phi_{ez}$ is calibration light source elementar radiant flux [W]
$S_{ekv}$ is spatial constant [m$^2$]
$M_{eW}$ is wolfram body elementar radiant flux [W/m$^2$]

9) Evaluate calibration function as it is shown (1).

It is necesary to use integrating sphere during calibration. Integrating sphere is part of measurement system then. It is possible to measure only spectral distribution function of light sources that it could be placed in integrating sphere. There are few principals that is necesary to folow. The first one, the most important, is that source is coresponding with the law of ideal point source, the integration sphere inside surface spectral reflectance is stable for calibration period, spectral reflectance is sufficient enough to transport radiant flux at whole measurement wavelength interval.
This calibration way is only alternative way to common NIST recomanded way. It is very useful for light laboratory with proper equipment. It is very simple way how to calibrate spectrophotometric measurement systém.

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# XUV Spectroscopic Measurement on Carbon Fibre Z-Pinch

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Today, z-pinches are used as effective and intensive XUV and x-ray sources on a wide scale of discharge energies [1]. The aim of the work at CTU in Prague is an investigation of XUV emission generated by a medium size z-pinch Z-150. Z-150 capacitor banks of 12 μF were charged up to the voltage of 20-30 kV. The total stored electrical energy was 3-5 kJ; the current was peaking at 100 kA and the current rise time was 600 ns. The experimental results of the emission from aluminium wires or thicker carbon fibres were presented earlier [2,3]. These experiments were carried out with carbon fibres of 20 and 120 μm diameters and 8 mm length.

For the purpose of diagnostics of XUV radiation there was used different diagnostic tools at the same time, such as a filtered PIN diode, an XUV spectrograph, and an XUV pinhole camera. The laser probing enables the visualisation of density gradient. From one shot we may obtain signals from a PIN diode and electric probes, 4 gated pinhole images, 4 gated XUV spectra and 1 schlieren image. The temporal resolution was carried out with two 4 frame microchannel-plate (MCP) detectors with the exposure time less than 5 ns and the time delay between exposures 10 ns. A 0,8 μm aluminium foil was used to filter visible and UV radiation.

The emission spectrum in the XUV region was recorded by the grazing incidence spectrograph (LSP-VUV1-3S) based on a Rowland circle detection scheme. The gratings with 1200, 600 and 300 grooves per mm provided a useful spectral range of 2-7 nm, 7-25 nm and 25-80 nm, respectively. The emission of the discharge plasma was observed in the axial and radial directions with respect to the axis of the fibre. The detection of longitudinal radiation was enabled by a 5 mm diameter hole in the centre of the upper electrode (cathode). Time-integrated spectra were registered on the photographic film UV-4, while the time-resolved spectra were detected by MCP and CCD detectors.

XUV pulse with FWHM of 10-50 ns occurred approximately 250 ns after the current breakdown. Just prior to this XUV pulse there was a noticeable drop in the time derivative of electric current. After this short pulse, the long lasting emission followed. The most significant difference between the use of fibres of different diameters was the time and duration of the XUV emission: In the case of a thinner fibre, the emission occurred earlier (at 210 ns) and the FWHM of the pulse was substantially shorter (≈15 ns). Other observed properties did not show such huge differences.

The spectrum in the spectral region of 2-5 nm contained the lines of H- and He-like carbon ions. The emission of the C VI Ly-α line was the most intensive usually few ns before the maximum of XUV emission and it lasted for about 20 ns. K-shell spectra were analysed with the aid of non-LTE atomic physics code FLY. The maximum electron temperature and electron density of the "hottest" region were estimated 80 eV and $10^{19}$-$10^{20}$ $cm^{-3}$ respectively.

In the 7-25 nm spectral region they were the spectral lines of Li-and Be-like oxygen that were dominant. The intensities of O VI lines corresponded to Boltzman distribution of excited states. The appropriate electron temperature was 15 eV. The lines of H- and He-like

carbon ions were also present. However, some of the lines have not yet been identified. These unidentified lines could have the same origin as the continuum-like "pedestal" (at 12-18 nm) that changes quite dramatically. This intensive continuum-like "pedestal" was produced during the peak of the XUV pulse, while the intensities of the lines did not show any significant changes in comparison with the time before and after the short pulse [4]. It was observed in some cases that the radiation from the anode could dominate over the radiation emitted by the fibre. Moreover, the evaporated material of the electrodes was visible quite far from the anode and cathode. In order to find a satisfactory answer to this question, the brass electrodes were replaced by the stainless steel ones. After that change the continuum in question disappeared.

In the third spectral range of 25-80 nm the spectral lines of Li-like carbon ions were identified. In this spectral region, the spectral lines of Li- and Be-like oxygen were clearly visible in higher orders of the diffraction.

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# Passively Mode-Locked Diode Pumped Nd:YAG Lasers

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The high repetition rate, compact, pulsed near infrared lasers operating at 1 um wavelength are required in wide range of applications including environment sensing, laser marking, telecommunication, medical diagnostics, range finding, frequency conversion, optical parametric oscillators and Raman laser pumping etc. The most efficient lasers emitting in this spectral range are neodymium host lasers pumped by diode lasers. The best active media with respect to maximum continuous output power are Nd:YAG, Nd:YLF and Nd:$YVO_4$ crystals.

The aim of the present paper is optimization of parameters of passively mode locked Nd:YAG laser under different level of pumping. For mode-locking we have designed and prepared two types of semiconductor saturable absorbers. The first structure is used at Brewster angle inside the laser resonator. We reported succesfull application of this type of semiconductor element for mode-locking of flashlamp pumped Nd:YAG and Nd:YAP laser as a replacement for the liquid saturable dye and also for mode-locking of low power ring diode pumped vanadate laser [1]. The second design is a low finesse antiresonant Fabry-Perot mirror combined with saturable absorber for use as the end mirror of the resonator. We designed structures with either 1, 2, or 25 quantum wells on the top of Bragg mirror. Recently we have demonstrated for the first time the gyroscopic response in ring diode pumped Nd:vanadate laser mode-locked with this type of solid state saturable absorber [2].

Two different laser configurations were investigated. In the first case the laser is pumped with 808 nm laser diode with output power 2 W. Low power diode pumped lasers are typically end pumped with the gain medium at one end of a standing wave cavity. A such configuration easily enables operation in fundamental transversal mode. We designed a five mirror folded resonator similar to the astigmatically compensated cavity used in many diode pumped laser systems. The pump radition from laser diode LD was focussed with three lenses optical system through flat end into the 5 mm long Nd:YAG slab with other dimensions of 1x3 mm. The spot size in the crystal was 80x80 um and contained 75 % of the pump power. The one flat end of the rod was high reflection coated for 1.06 um and antireflection coated for 808 nm (M1). The second end of the rod was AR coated at 1.06 um. The rest of the cavity consisted of a highly reflecting, 500 mm radius of curvature folding mirror M2 , flat folding mirror M3 with reflectivity of 96 % acting as output coupler and spherical mirror M4 with radius of curvature of 100 mm creating the beam waist on the semiconductor saturable absorber combined with highly reflective mirror (HR MQW). The size of the laser mode in the active medium corresponds to the size of the waist of the pump radiation.

Using the MQ10 mirror having low power reflectivity of 97 % and containing two saturable absorber layers, it was not possible to get continuous mode locked (CWML) operation. In Q-switched mode-locked (QML) regime laser generated 100 mW in one beam behind M3 for maximum pump power of 1650 mW. The Q-switched mode-locked train with envelope 800 ns long separated by 10 us (repetition rate of 100 KHz ) were generated. The threshold for mode-locked operation was 900 mW. Using the semiconductor mirror MQ2 with one quantum well and small signal reflectivity of 97 %, it was possible to get stable continuous mode-locked operation for pump power above 1000 mW. The maximum output power in CWML regime in one of two output beams behind flat folding mirror M3 was 120 mW and single pulse duration was 12 ps.

The second laser system is pumped by 20 W diode coupled to the fiber with diameter of 400 um and numerical aperture of 0.22. The coupling optics focused the pump radiation through the flat end into the 10 mm long Nd:YAG rod with diameter of 4 mm. The diameter of the waist of the pump radiation was 400 um. The flat end of the rod was high reflection coated for 1.06 um and antireflection coated for 808 nm. We designed four mirror folded laser resonator consisting of the flat end of the Nd:YAG rod, 500 mm radius of curvature folding mirror M2, another spherical mirror M3 with radius of curvature of 300 mm focusing the radiation on flat end mirror M4. The total length of the laser resonator was 114 cm. In the first part of experiments we have optimized the cavity parameters in the free running mode with dielectric mirror M4 with reflectivity of 91 %. In continuous regime, the threshold was 500 mW of absorbed power and the maximum output power was 4 W for absorbed pump power of 13 W.

Mode-locking of the laser was achieved using MQ2 mirror as the mirror M4. As in the low power case, it was possible to mode-lock laser either continuously or in mode-locked Q-switched regime, but transition between these modes of operation was in both cases different The output power in one beam behind the mirror M2 was 75 mW. Using the slightly misaligned Brewster plate between the Nd:YAG rod and folding mirror M2 it was possible to extract from resonator two beams with output power of 700 mW in each and with pulse duration of 9 ps.

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# Bidirectional Operation of Diode Pumped Nd:$YVO_4$ Laser with Ring Resonator

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The motivation of this work is the development of laser sensors and gyroscopes. So far, most active laser gyroscopes are ring He-Ne lasers. The response of the laser is a beat note between two outputs corresponding to counter-circulating signals, beat note which is proportional to the rotation of the laser about an axis perpendicular to its plane. Scattering from one sense of circulation in the cavity, into the counter-circulating mode, result in injection locking of the two frequencies that would otherwise constitute the beat note. The resulting dead band can only be minimized through avoiding any intracavity element, and using low scatter (usually expensive) optics. A laser gyroscope is generally mechanically biased (given a constant rotational motion) in order to operate outside of the dead band.

It was shown that an alternate way of eliminating the dead band is to use mode-locked lasers, in which the pulses cross only in vacuum or another element that does not introduce any phase coupling between the counter-circulating pulses in the cavity [1]. Solid state lasers are attractive because of their high efficiency and gain and they do not require vacuum technology nor electrodes. Diode pumped solid state lasers are the most promising alternative. For instance, continuous femtosecond pulse operation was observed with an ultralow-pump-threshold Cr:LiSAF ($Cr^{3+}$:$LiSrAlF_6$) laser which could be powered by a few AA batteries [2].

For a first demonstration we have chosen the more common Nd:vanadate (Nd:$YVO_4$) laser. It has the advantage of requiring pump laser diodes at 808 nm, which are more common and have longer lifetime than the 670 nm diodes required for the Cr:LiSAF laser. In first experiments we have shown the gyroscopic response of the ring vanadate lasers pumped by 2 W high brightness laser diode and mode-locked by MQW saturable absorbers either in reflection or transmission configuration [3,4]. The next step reported in this paper is design of more compact laser pumped by low power laser diode.

The vanadate crystal is pumped by a high brightness 0.7 W laser diode LD (emitting area size 1x100 um). The highly asymmetric beam from the diode is collimated with a built in cylindrical microlens and then focused by a spherical lens into the 4.5 mm thick Nd:$YVO_4$ crystal. The maximum available output power from laser diode was 750 mW, incident pump power on vanadate crystal was 515 mW, from which was 98% absorbed. This is substantially lower level in comparison with our previously reported results in ref. [3,4], when the incident pump power was 1400 mW. The five mirror ring cavity is formed by two curved mirrors M1,M2 and three flat dielectric mirrors M3, M4, M5.

With all mirrors highly reflective at 1.064 um the threshold for continuous operation was as low as 35 mW of pump power incident on the crystal. It was possible to observe two output

beams behind each dielectric mirror which indicates the real bidirectional operation. The output power in each of these beams was 10 mW for 500 mW of absorbed pump power. The further possibility to improve the efficiency of the laser is decreasing the spot size of the pump beam in the crystal, which was in our case 150 um. This is substantially larger than is the resonator fundamental mode waist diameter, which is 60 um.

The aim of our work is to get bidirectional mode-locked operation. For passive mode-locking we are using mirror with integrated multiple quantum well saturable absorbers (MQW). The mirror consists of a 0.5 mm thickness GaAs substrate on which is grown Bragg mirror structure consisting of 20-25 pairs of alternating layers of GaAs (75.8 nm) and AlAs (89.9 nm). On the top there are 1- 25 quantum wells layers - 8.7 nm thick (In0.25Ga0.75) spaced by 10 nm of GaAs grown at low temperature (350$^{o}$C) by MBE. The absorbers are designed by a such way that absorbing layers are located in the maximum intensity of the electric field. When replacing the mirror M3 by a semiconductor mirror with low signal reflectivity of 97% containing 2 absorber layers, it was possible to observe that the laser generates continuous train of pulses separated by 3 ns which is the cavity period. The two outputs taken through the mirror M5 have the output power of 5 mW which should be enough to produce the beat signal after the adjustment of relative delays and to interfere on a photodiode.

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# Corona Discharge Interferometric Study

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Today polymer and plastic materials are due to their characteristics often used as a proper replacement of metals for mechanically less stressed parts of constructions. There are intensively studied many perspective materials and methods of polymers and plastics´ mechanical and other characteristics improvement.
It shows, that in analogy with method used decades by metals, when surface hardening of metal made parts improves their mechanical properties (in particular abrasion and strength properties and surface hardness) and durability, a method might be found, that would change characteristics of polymers in a considerable fashion, too and make them possible to be used in more stressed parts – a procedure based on the corona discharge at atmospheric pressure.

Corona discharge is a low energy electrical discharge with non-thermal ionisation. The corona discharge is self-sustained. Corona discharge usually occurs when one of two electrodes, mostly immersed in gas, has a shape causing the electric field at its surface to be significantly greater than that between the electrodes. It can be identified as bright filaments extending from the sharp point electrode towards the substrate. The ionisation region is confined to close vicinity of the discharge electrode and in the remainder of the interelectrode space the ions drift due to the electric field without additional ionisation.
In spite of corona discharge intensive study and due to its complicated behaviour the corona characteristics represented in literature are not fully comprehensive. That is the reason why study of the interaction corona — polymer based material has been started at FEE CTU Prague. For surface treatment technology development and design better understanding of the spatiotemporal behaviour of the corona discharge in the ionisation region near the sharp point electrode is necessary and that is the reason, why discharge optical characteristics were studied by means of optical interferometry.

For studies a newly developed, designed and created experimental system was used [1]. The crucial part of the system was a high resolution Mach-Zehnder interferometer. The corona discharge was generated between grounded large plane electrode and different “single point” electrodes: (a) iron electrode of cylindrical shape, diameter 0.7mm, spike curvature radius about 25μm; (b) bulky copper electrode having cylindrical shape, spike length 17mm, top angle about $10^0$; (c) copper electrode, spherically ended electrode with sphere of diameter 3.85mm. Inter-electrode distance was varied in range of $(7 \div 16)$mm. All experiments were performed in stationary air under atmospheric pressure, humidity $(45 \div 56)$% and temperature $(23 \div 26)^{\circ}$C. Stabilised D.C. voltage was applied to the “single point” electrode via current limiting resistor. Driving voltage was changed between $(5 \div 11)$kV, corresponding current values were $(5 \div 22)\mu$A. The spark discharge ignition limited the voltage setting in some electrode configuration.

Visual appearance of the corona discharge between grounded large plane electrode and different "single point" electrodes in stationary air at atmospheric pressure was observed in each electrode configuration, although with difficulties due to very low irradiance of the discharge. For density distribution measurement interferograms were taken under above described conditions. Interferograms were registered with a camera.
To evaluate registered interferograms, in principle there is necessary to estimate the points of highest optical density in the fringes displayed in the interferogram.
The method commonly used for this purpose is the photometric evaluation of the fringes profile, i.e. determination of equidenses. The evaluation elaborateness was reduced and its accuracy increased by replacing photometric evaluation of the fringe profile with a new method based on the Sabattier effect [3].

Unfortunately for electrode configurations and voltage setting used in experiments evaluated fringe shift revealed to be very small and it was comparable with the error of the measurement. That probably means, that changes of optical refractive index in the interelectrode region were very small and air refractive index in this region was approximately constant. It might be assumed that in the close vicinity of the "single point" electrode any change of the refractive index would occur, but the dimension of this region was too small for the change to be detected.

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# Luminescence of Defects in Undoped Crystals of Incipient Ferroelectrics $KTaO_3$

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Undoped crystals of incipient ferroelectrics $KTaO_3$ with a cubic inversion symmetric perovskite structure down to the lowest temperatures exhibit at low temperatures ($T < 50$ K) phenomena, such as the first order Raman scattering, second harmonic generation of light or dielectric loses, that are characteristic for crystals without inversion symmetry. Because these anomalous properties as well as low temperature photoconductivity are sample-dependent and can be related to crystal lattice imperfections or unavoidable impurities, much attention has been paid to the investigation of defects in undoped $KTaO_3$ crystals in the recent years. Since luminescence enables us to detect low concentrations of defects, we performed a systematic study of luminescence of five undoped $KTaO_3$ crystals. The colorless crystals from different sources were grown by the spontaneous crystallization technique or by the Czochralski method.

Under steady-state excitation with band-gap light ($\lambda < 344$ nm) at low temperatures, all the investigated $KTaO_3$ crystals showed the broad asymmetric emission band of well-known visible photoluminescence (PL) peaking between 488 and 510 nm at 15 K [1]. The weakly sample-dependent emission band shape of all the crystals was fitted well by two Gaussian curves with sample-independent positions and FWHMs at a given temperature. This result indicates that the emission band of visible PL consists of two overlapping bands of nearly Gaussian shape with an individual temperature behavior. The position of 21254 and 19308 $cm^{-1}$ and the FWHM of 3465 and 4286 $cm^{-1}$ were found for the high- and low-energy emission band at 15 K, respectively. The position and FWHM of the low- and high-energy emission band change only slightly with increasing temperature. However, the sample-dependent ratio of integral intensities of the low- and high-energy emission band increases with increasing temperature above 30 K, so that the observed shift of the PL emission band maximum to the lower energy side is predominantly a consequence of this ratio increase.

After an exposure of the crystals to ultraviolet light ($\lambda < 344$ nm) at 12 K, weak thermoluminescence (TL) of undoped $KTaO_3$ crystals was observed within the temperature region from 13 to 65 K for the first time [2]. An analysis of the glow curves of integral TL of all the crystals studied by the thermal cleaning technique revealed five glow peaks with markedly sample-dependent intensities. Three glow peaks near 26, 31, and 58 K at the heating rate of 0.155 K/s, which were common to all the crystals studied, correspond to TL spectrally very similar to broadband visible PL of $KTaO_3$ crystals. Contrariwise, the glow peaks near 34 and 41 K appear only in certain crystals and they are connected with the structureless emission band peaking near 714 nm at 15 K that was observed in the emission spectra of PL and TL of $KTaO_3$ crystals for the first time. The trap depths of 19, 31, 46, 56, and 93 meV corresponding to the glow peaks near 26, 31, 34, 41, and 58 K were determined by the ”initial rise” method. The glow peaks near 26 and 31 K were ascribed to the electron release from photoinduced $Ta^{4+}$-$OH^-$ and $Ta^{4+}$-$V_O$ centers to the conduction band and the glow peak near 58 K to the hole release from photoinduced $O^-$ centers to the valence band.

We proposed a model of visible PL of $KTaO_3$ crystals where a recombination of holes trapped on $O^-$ acceptor centers with electrons from closely situated $Ta^{4+}$-$OH^-$ and $Ta^{4+}$-$V_O$ donor centers gives rise to the high- and low-energy emission band, respectively [1]. Thus TL, spectrally similar to visible PL, appears during heating of the previously irradiated crystal due to the successive thermal release of charge carriers from shallow $Ta^{4+}$-$OH^-$, $Ta^{4+}$-$V_O$, and $O^-$ traps followed by the radiative recombination of newly created pairs of closely situated $Ta^{4+}$-$OH^-$ and $O^-$ as well as $Ta^{4+}$-$V_O$ and $O^-$ centers [2]. Furthermore, this model also simply explains the observed increase or decrease of the integral intensity of visible PL after annealing of the crystal in $H_2$ or $O_2$ atmosphere at 1000 °C in comparison to the as-grown crystal because the annealing in $H_2$ or $O_2$ atmosphere also increases or decreases the concentration of both $Ta^{5+}$-$OH^-$ and $Ta^{5+}$-$V_O$ electron traps [1]. The decrease of visible PL intensity above 30 K with increasing temperature can be assigned to the thermal instability of photoinduced $Ta^{4+}$-$OH^-$, $Ta^{4+}$-$V_O$, and $O^-$ centers in this temperature region and to the nonradiative recombination of charge carriers thermally released from these centers to the conduction or valence band via deep nonradiative recombination centers. The increase of the ratio of integral intensities of the low- and high-energy emission band above 30 K, indicating that the thermal quenching of the high-energy emission band starts at lower temperature, coincides with the lower energy of thermal ionization of $Ta^{4+}$-$OH^-$ centers.

Moreover, $KTaO_3$ samples containing higher concentration of iron exhibited at low temperatures two PL emission bands with the zero-phonon line at 14569 and 15142 $cm^{-1}$ at 18 K, respectively [3, 4]. We ascribed luminescence with the zero-phonon line at 14569 $cm^{-1}$ to $Fe^{3+}$ ($3d^5$) ion substituted in $K^+$ site with the charge compensation by neighboring interstitial $O^{2-}$ ion. The emission band with the zero-phonon line at 14569 $cm^{-1}$ and the corresponding excitation bands with the zero-phonon line at 17225 and 18819 $cm^{-1}$ were assigned to the $^4T_1(G) \rightarrow {}^6A_1(S)$ and $^6A_1(S) \rightarrow {}^2T_2(I)$, $^4T_2(G)$ transitions, respectively. This assignment is supported by the observed "blue" shift of the zero-phonon line at 14569 $cm^{-1}$ with increasing temperature that is in accordance with negative slope of the $^4T_1(G)$ emission level in Tanabe-Sugano diagram. The emission band with the zero-phonon line at 15142 $cm^{-1}$, which was observed for the first time in $KTaO_3$ crystals, was ascribed to the $^2E(G) \rightarrow {}^4A_2(F)$ transition in $Fe^+$ ($3d^7$) ion substituted for $K^+$ ion or in $Fe^{5+}$ ($3d^3$) ion substituted for $Ta^{5+}$ ion. This emission is excited via excitation bands with maximum near 472 and 393 nm.

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# Generation of Ozone by Electrical Discharges

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Atmospheric pressure non-equilibrium plasmas based on the dielectric barrier discharge (DBD), corona discharge (CD), pulsed corona discharge (PCD), atmospheric pressure discharge stabilized by a gas flow (APDFS), etc., which have made recently remarkable progress, are useful for different applications including ozone generation.
Non-thermal plasmas in which the mean energy of the electrons is substantially higher than that of the gas offer advantages in reducing the energy required to generate the ozone. The electrical energy supplied into the discharge is used preferentially to create energetic electrons, which are then used to produce oxygen atoms by dissociation of the molecules of oxygen. These atoms of are used to generate the ozone. When ozone concentration is low enough to disregard the decomposition of ozone by nitrogen oxides, every dissociated oxygen atom is transformed into ozone molecule by three-body collision reaction:

$$e + O_2 \rightarrow O + O + e \quad (1)$$

$$O + O_2 + M \rightarrow O_3 + M \quad (2)$$

When the feed gas is air the letter M substitutes either the oxygen or nitrogen molecule. In case of air the excited nitrogen molecules and atoms contribute to the generation of oxygen atoms, in addition to the above reactions.
DBD discharges are non-equilibrium discharges that can be conveniently operated over a wide temperature and pressure range. At about atmospheric pressure electrical breakdown occurs in many independent thin current filaments. These short-lived microdischarges have properties of transient high-pressure glow discharge with electron energies ideally suited for exciting or dissociating background gas atoms and molecules.
Two types of DBD for the purposes of ozone generation are most frequently used [1]. The first one is a tube-type ozone generator, which consists of a grounded metal tube and concentrically situated inner glass tube. The glass tube inner surface, which is coated with a metal layer, is attached to the high voltage. The glass tube and the grounded electrode form a discharge space between them.
The other type of ozone generator is a plate-type with a grounded metal plate, which serves as a first electrode, and the ceramic plate, which serves as a second electrode.
The grounded electrodes of both tube-type and plate-type generators are water-cooled. The length of the discharge region, the thickness and the dielectric constant of the insulating materials are found to have a considerable effect on the generated ozone concentration. Also, the ozone concentration is several times less when air is used instead of oxygen as a working gas [2].
In case of corona discharge (CD) the volume exposed to the action of the discharge is much smaller than the total discharge volume. Due to the small active volume around the active

electrode, the corona discharge is not very well suited for industrial production of large quantities of chemical species. There are, however, applications where only very small concentrations of excited or charged species are needed. Typical examples are electrostatic precipitators or copying machines where corona discharges are used to produce charged particles.

An interesting application of the pulse corona discharge is the treatment of flue gases or ozone generation. The ozone concentration generated by pulsed coronas is higher than that generated by either dc or ac coronas with the same discharge conditions irrespective of the polarity of the pulsed corona.

We studied of production ozone by DC electrical discharge in air at atmospheric pressure with a single hollow needle to plate electrode configuration enhanced by the flow of air through the needle for both polarities of the needle and different airflow rates. The ozone concentration for the constant airflow rate decreases to zero with increasing current. Discharge with negative polarity of the needle is more efficient source of ozone than the discharge with the needle positive. Concentration of ozone for a given current increases with increased airflow rate.

The ozone production is influenced by the airflow pattern inside the discharge chamber. The velocity field distribution for our electrode arrangement was studied in [3]. It was found that the discharge does not influence the velocity field distribution.

From the experimental results, which are in details described in [4], can be concluded that the maximum ozone concentration depends not only on the discharge current and airflow rate through the needle but it also depends on the geometry of the discharge chamber as well as on the velocity field distribution.

The obtained results can help to understand the mechanism of ozone formation and destruction by hollow needle to plate electrical discharge enhanced by the gas flow through the needle.

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# Modelling of Magnetron Magnetic System

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Most materials used in high technology applications are composites, i.e., they have a near-surface region with properties differing from those of the bulk materials. This is caused by the requirement that the material exhibit a combination of various, and sometimes conflicting, properties. For example, a particular engineering component may be required to have high hardness and toughness (i.e., resistance to brittle crack propagation). This combination of properties can be obtained by having a composite material with high surface hardness and a tough core. Alternately, the need may be for a high temperature, corrosion-resistant material with high elevated-temperature strength as is the case with the hot stage blades and vanes in a gas turbine. The solution again is to provide the strength requirement from the bulk and the corrosion requirement from the surface.

One of the most used method for coatings preparation is a magnetron sputtering. It is a well-established technology, successfully used in wide range of application, due to their high versatility and high sputtering rate. It is also possible to design sputtering source with targets dimension from centimeters up to ten meters and more. In spite of this many problems still remain. One of the main problem in planar magnetron sputtering is nonuniform sputtering of the target. This is caused by non uniformity of the magnetic field and results in decreasing of the target-life, nonuniform growth of the layer and instability of the sputtering process. The target utilization of magnetrons currently produced is low about 20-30 %. It can be increased up to 50-60 % in the case when the magnetron has an optimized magnetic field.

In principle, there are two ways how to improve utilization of the target. Firstly to move magnetic system behind the target so as to expose every surface points to the sputtering discharge and secondly change the magnetic system configuration to achieve better shape of the magnetic field. First method is obvious, but there are a lot of difficulties due to high voltage on the magnetron target (up to 1 kV) and needs of target cooling. The second method is very interesting for practical design of magnetrons due to it's low price and simplicity. There were published a lot of articles on that topic but most of all deal with sputtering in given magnetic field. Our work is aimed to optimization design of magnetron magnetic system.

Modeling of sputtering process include two main parts. As a first step, magnetic field of given magnetic system must be determined. The solution is commonly done using finite element method. It is necessary to minimize the computation expenses because of high number of runs during optimization. In the second step sputtering plasma simulation is done, providing an erosion profile. As the magnetic field is not simple, an analytic solution of plasma motion is not obtained. For our purpose were suggested some Monte Carlo models. They assume time independent magnetic and electric fields which are not disturbed by the magnetron plasma. Basic assumption is that argon molecules are in thermal random motion and argon ions are not affected by the magnetic field. The electron trajectory is traced by integration of the motion

equation and the Monte Carlo technique is used to determine the point and kind of collision because it is necessary to discriminate between elastic and ionization collisions. The erosion profile is calculated from the number of ions, impacting the surface in observed point.

Recently we have been working on the magnetic model. We use the software ANSYS, which is available at our faculty. The computation time is now about fifteen minutes so we have to reduce the model complexity. It is necessary to evaluate influence of boundary condition, elements density and model size. We also compare results obtained from two and three dimensional model. There are also difficulties in corner region of rectangular shaped magnetron. The number of elements must be increase there which brings problems with mapped meshing of the domain.

Future plans are to prepare optimization calculation of the magnetic system configuration. The main problem we have to solve is to find appropriate cost function. Then we will implement some optimization method.

# Implementation of IIR Filters in ANC Controllers

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Digital ANC controllers are frequently based on filtered x-LMS algorithms which, assuming microphones as reference and error sensors, contain many filters that model error and feedback paths. These filters are usually realized as FIR filters. Using FIR filters, multi-channel ANC applications require great computational power for realization of error and feedback paths models. Use of IIR filters can solve this problem, but the IIR filters can be unstable. Consequently, it is necessary to pay close attention to ensure their stability during the process of design.

From the theory of wave-guides of rectangular cross-section, it follows that as the acoustic wavelength becomes comparable with the larger dimension $a$ of the duct, the sound propagates not only in the form of a plane wave, but higher order modes can appear. The first higher order mode can propagate when the excitation frequency exceeds the cut-on frequency given by $f_c = c / 2a$, where $c$ is the speed of sound.

It is obvious that for a relatively narrow duct, the cut-on frequency is high enough and that the single-channel system of active noise control (ANC) is sufficient. Nevertheless, for common air-conditioning ducts the dimensions are of such extend that part of the considerable sound spectrum appears in the frequency range above the cut-on frequency and higher order modes have to be taken into account. Consequently, a multi-channel ANC system is required.

The four-channel ANC system used in this research was an expanded version of the two-channel feed-forward ANC system attenuating the first cross mode realized and successfully tested in previous work [1,2]. This system should in principle enable suppression of zero degree mode and the first three higher order modes. Arrangement of the system was 1x4x4 (i.e. one reference microphone, four secondary sources and four error microphones).

The system is a multi-channel FXLMS, in which there are theoretically sixteen models of error paths. The reference signal is negatively influenced by the acoustic feedback in the same manner as in one-channel systems. This acoustic feedback can be suppressed using various methods. In this case, compensation is included in the control algorithm. Due to the symmetry of our duct (rectangular cross-section), only six different models of error paths are necessary.

As follows from previous text, in the four-channel ANC system at least six different model filters for error paths must be used. Sufficiently long FIR filters spend significant portion of controller memory and computational time. This can be solved by using IIR filters, which can be stable only if their poles lie within the unit circle. Compensation of acoustic feedback is realized by four corresponding model filters, which are likewise IIR filters.

The acoustical system used was stable in time, so the off-line identification method was employed to calculate relevant transfer functions. In the experiments described in this contribution, the controller-generated MLS signals were used for identification of error and feed-back paths of the system.

The IIR filter coefficients can be obtained by solution of Prony equations to minimize a error function. As these equations are nonlinear with respect to both nominator and denominator coefficients, the standard Prony method is used to obtain suboptimal solution. For precision of the filter coefficients, the Steiglitz-McBride method iterative method is used. The

number of iteration is the parameter which influences the quality of the model. For a higher number of iterations, the resulting filter poles are closer to the unit circle. In practical implementation, the filter poles can exceed the unit circle due to the approximation (rounding) error, and the filter is then unstable. This effect has to be considered even for a floating point DSP realization. Therefore, in the presented system, approximately three iterations for error paths models were used and approximately five iterations for feedback paths models. For modeling of error paths, the IIR filters of 15th order were used. For feedback paths, the order of 31 was chosen. The higher order for feedback paths model filters follows from the longer time delay due to distance between secondary sources and reference microphone.

The possibilities of a four-channel active noise control system applied to a rectangular air-conditioning duct were investigated. It was assumed that noise propagates through the duct in even higher modes than only the first one. The control algorithm was implemented in floating-point DSP. The approach used in this research is possible to extend to a larger number of channels. To save memory and computing power of the DSP, filters modeling error and feedback paths were realized using IIR filters. Nevertheless, the due to large computing demand the sampling frequency was lower than the optimal one. In addition for broad band attenuation the increase of number of coefficients of adaptive filters could also be useful.

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# Application of Local ANC in Passanger Seat

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Low frequency noise in various types of vehicular interiors can be attenuated by active noise control systems. Generally, there are two possible approaches depending on the dimensions of the enclosed interior and the type of sound field to be controlled: global and local. In many cases, global attenuation of noise is impractical, and attention is given to the formation of regions with lowered sound pressure levels, which are termed "zones of quiet" [1]. These regions are understandably formed in the areas where human ears would be likely to be positioned.

The arrangement and performance of a two-channel local active noise control system acting in a free sound field is described in this contribution. The active noise control system was mounted in the headrest of a passenger's seat. It can be extended to the usual headrest used in cars, trains, or air-plains cabins. As the diameter of the zone of quiet, within which the sound pressure level is decreased about 10 dB or more, is about one tenth of the wave lenght, the system is useful for low frequencies up to approximately 400 Hz.

The size of zones of quiet depends on the surface of the secondary sources and the distance between the secondary sources and cancellation points which are represented by positions of error microphones.

The spatial distribution of primary sources of sound field is not of crucial importance; therefore, to obtain more definite information about the shape of the resulting zones of attenuation, experiments were performed in an anechoic chamber located in the Acoustic Laboratory of the Department of Physics. The source of noise was simulated by a high-level loudspeaker box placed 5 m away from the artificial head placed in the usual position of the human head. As an artificial head, a head simulator corresponding to the IEC 959 Standard including ear simulator was used.

The headrest contained two secondary loudspeakers with diameter of 10 cm and holes for two error microphones in the back side. The distance between the center of the loudspeaker and the ear channel was approximately 12 cm. The ear channels were at the same height as the centers of the secondary loudspeakers and error microphones. The distance between error microphone and ear channel is approximately 7 cm.

The filtered-*x* LMS algorithm used in the system was very effective and robust, however, it requires models of transfer paths from each secondary source to each error microphone. Identification of these error paths was done off-line by means of MLS signals sent to the secondary sources. To obtain a sufficiently long time response of the model filters with limited number of coefficients, the IIR filters were applied. As the IIR filters can prove unstable, though, the design of the system should take this factor into account.

The control algorithm was implemented in autonomous controller based on floating-point DSP. The sampling frequency was set at 5 kHz, the order of IIR filters used for error paths modelling was chosen as 20. Antialiasing and reconstruction filters were set at 1 kHz.

No symmetry of the sound field is assumed, and consequently four different error path model filters are included in the algorithm. On the other hand, acoustic feedback from secondary sources to the reference sensor was not take into account and therefore the reference signal was picked up from the output of the signal generator.

For testing of the ANC system two band pass noises were used. The first band noise was chosen from 100 Hz to 900 Hz to find relevant region of attenuation. Results measured by the error microphone show that the system operates well for all frequencies. From measurements performed by the microphone located in the artificial head's ear it is evident, that minimum sound pressure is reached at the position of the error microphone which is in certain distance from passenger ear. This effect is not important up to approximately 600 Hz. Therefore, a useful frequency range is from 100 Hz to 500 Hz. Attenuation from 10 to 15 dB is reached for the regions of typical position of human ears.

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# High Energy Radiation Delivery by Hollow Waveguides in Mid-infrared Spectral Region

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Disposition of lasers in many applications – medicine, industry, communications – and also in the basic laboratory research often requires delivery of laser radiation from the laser source to the place of the radiation activity. The main requirement on radiation delivery is small transmission losses, flexibility, and mobility. For the reason of mobility, an articulated arm is not convenient. Especially for the medical endoscopy treatment the method of radiation delivery by the articulated arm is impossible. The current fibers (due to their material) cannot be used for radiation below 0.3 μm and above 2.5 μm. Some problems with conventional fibers become more serious even with the wavelength in a visible region, when the extremely high power laser radiation is to be delivered. Therefore, new possibilities of high power laser radiation delivery are highly appreciated. We are reporting about special hollow glass waveguides with an internal coating formed by silver and cyclic olefin polymer (COP) layers with the help of which the high energy radiation of Er:YAG laser ($\lambda$ = 2.94 μm) was successfully delivered.

Each waveguide consists of a supporting fused-silica glass capillary tube on the inner surface of which a reflective silver layer as smooth as possible is deposited. For lowering the reflection losses, special cyclic olefin polymer film about 0.1 - 0.3 μm thick coats this silver layer. During fabrication, the thickness of the COP layer is set for the optimal transmission properties at each required wavelength. For our case the COP layer was prepared for 2.94 μm wavelength. Dimensions of the waveguides were 1 mm – an inner diameter and 0.5 m – a length. The maximum delivered energy and transmission of the investigated waveguide were measured in our work. For comparison an analogous measurement was made for near-infrared Nd:YAG laser radiation ($\lambda$ = 1.06 μm); the special waveguide this wavelength was used with the dimensions: 1 mm (inner diameter) and 1 m (length). Radiation coupling into the waveguide was optimized for both cases using a proper lens and a special protector.

The source of laser mid-infrared (2.94 μm) radiation was a powerful laboratory built Er:YAG laser system. The laser head of this system consists of an Er:YAG laser crystal of 5 mm diameter and 100 mm length placed along with a xenon flashlamp into a diffused ceramic pumping cavity (Laser Modules Inc.,1620). A resonator 265 mm long was composed of mirrors with a reflectivity R1 = 100 %, and R2 = 80 % for the 2.94 μm radiation. The laser was working in a free-running long-pulse mode regime. The maximum output energy reached was 2.35 J; the length of the generated pulses increased with higher energy from 110 μsec up to 550 μsec (FWHM). The repetition rate of this laser system ranged from 1 Hz to 4 Hz.

A double mode-locked (active and passive) oscillator plus three amplifiers was used for powerful near-infrared Nd:YAG laser (1.06 μm) radiation. The maximum energy (used in the experiment) behind the third amplifier was 80 mJ for the single pulse; its profile was a near-Gaussian and the measured full divergence angle was 0.8 mrad, beam diameter 7 mm. The

length of the individual pulse (FWHM) measured by a streak camera was 50 psec; the repetition rate used was 2.5 Hz.

The maximum delivery system transmission, mean power, and peak power obtained for Er:YAG laser radiation were 92 %, 5 W, and 3 kW (550 μs pulses), respectively. The maximum delivered power of 1.58 GW was reached for the 50 psec Nd:YAG laser pulses (188 mW of mean power).

From our investigations follows that the COP hollow glass waveguides are appropriated delivery systems for powerful mid- and near- infrared radiation and that they can be used in a medical or industrial applications.

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# Interactive Physics via Java Applets

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Web browser technology now in general supports Java applets (http://java.sun.com/), usually small flexible programs written in Java and embedded in HTML documents and allowing flexible and extensive interaction with the user. Such applets are ideally suited for physics instruction, allowing animation, changing of parameters, taking measurements etc. One disadvantage of programming directly in Java is the necessity to write complete Java programs for all new problems. But in combination with a scripting language like JavaScript (http://javascript.com/) Java applets can provide us with very flexible interactive programs that can be easily adapted to various pedagogical activities. To emphasize the physics content, W. Christian introduced the term Physlets for such small specialized Java applets driven by JavaScript [1]. Physlets are easy to use since they are based on standard non-proprietary Internet technologies. Depending on the degree of sophistication, they are also fairly easy to develop. Moreover, many physics instructors are making available downloadable versions, free for non-commercial purposes, so even those without Java skills can benefit. All necessary information about freely available Physlets can be found on Physlets resource page (http://webphysics.davidson.edu/Applets/Applets.html). There are many very useful Physlets available. We can mention several of them, the names of these Physlet modules are mostly self-explanatory: Animator, EField, BField, DataGraph, DataTable, Circuits, Eigenvalues and QM Wavefunctions, Hydrogenic, Molecular, Optics, Poisson. Extended documentation to existing Physlets is available. We have written several small applications using these basic modules and we are sure that Physlets represent very nice and perspective tool for writing interactive Java applets.

Java technology is now also frequently used as an interface to general purpose scientific programming packages. For instance general purpose computer algebra systems like Maple and Mathematica are designed to solve mathematical problems and produce high-quality technical graphics. They are relatively easy to learn, but powerful enough to calculate difficult problems. Maple and Mathematica incorporates their own high-level programming languages which allows the user to define his own procedures. However for some users, learning Maple (Mathematica, Matlab ...) syntax is a chore, and may distract from the task at hand. In Maple by using Maplets package (http://www.maplesoft.com/products/Maple8/) one can create custom Java-based graphical user interfaces to access the Maple library or user-written Maple functions. Maplets (and equivalent technology in Mathematica, Matlab ...) enable these users access to the part of Maple relevant to their needs while shielding them from any problems connected with Maple syntax. By using Maplets one can write compelling educational applications and we are highly interested in using these promising technologies in our pedagogical activities, too.

We have written also several small Java applets directly in Java language. In developing some of these applications we have been strongly influenced by interesting package CUPS (The Consortium for Upper-Level Physics Software, http://www.physics.gmu.edu/~cups/). CUPS consortium has developed a comprehensive series of nine Book/Software packages that have been published by Wiley (http://www.wiley.com/). All of the computer simulations in package CUPS have been provided in executable form and the source codes of the programs are also

available. Unfortunately CUPS programs are written in Turbo Pascal for DOS programming language and this limits usefulness of the package in these days.

Short description of several Java applets written in our group and by our students follows. All these programs will be available on our website (http://vega.fjfi.cvut.cz):

*Fourier Analysis and Synthesis*: Investigation of Fourier analysis and one and two dimensional Fourier transforms. In Fourier analysis users can choose from several predefined functions. The build-up of a periodic function is illustrated as successive terms of the Fourier series are added in, and the effects of dispersion and attenuation on the evolution of the synthesized waveform can then be investigated. One and two dimensional discrete Fourier transforms can be produced for a range of standard and user-entered functions. The effects of filters on the inverse transforms are illustrated.

*Diffraction*: This applet simulates some of the fundamental wave behaviors in Fresnel and Fraunhofer diffraction, and other interference effects. In particular students can study Fresnel diffraction phenomena associated with a slit or set of slits. The transition from Fresnel to Fraunhofer can be investigated.

*Electromagnetic Waves*: Illustration of the behavior of electric and magnetic field in a polarized plane electromagnetic wave. The user can choose to observe the wave in free space, or to see the effect on the wave of incidence on a material interface. The polarization state of the incident wave can be changed by specifying its Stokes parameters. Standing electromagnetic waves can be simulated by combining the incident traveling wave with a reflected wave of the same amplitude. This can be done by choosing appropriate values of the physical properties of the medium on which the incident wave impinges.

*Rutherford Scattering*: Numerical solution and visualization of scattering of fast alpha particles by atoms, an experiment leading to discovery of atomic nucleus.

*Quantum description of the Hydrogen Atom*: Stochastic visualization of electronic probability density, analytic solution of the Schrödinger equation for various quantum states of the hydrogen atom.

In conclusion some of our pedagogical activities associated with project supported by internal CTU grant CTU0214834 were presented on international conference PTEE 2002 [2,3,4].

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# Using Point Source Array for Modeling of Oblique Wave Impact on Liquid-Solid Interface

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New approach to generation of an incident wave for numerical modeling of wave reflection on a liquid-solid interface is reported. The plane incident bulk wave is generated by means of the phased source array. Single sources in source array are represented by short external force pulses. An incident angle of resulting plane wave can be controlled by changing time delay among the single sources. In our study we paid attention to incident critical angles. Reflection and refraction coefficients of bulk wave on water-glass interface were both derived analytically and computed numerically. Correspondence between analytical and numerical results is discussed.

Ultrasound is widely used in industry, material sciences as well as in medicine for nondestructive material characterizations. The multiply transducers are used in modern multi-channel ultrasonics systems for real-time measurements. The elements of electro-mechanical transducers are arranged in an array and input signals are time delayed among single transducers. The transducers can be arranged in a group of a general shape. For example, the linear source phased array can be created by ordering transducers along a line.

We have used this approach to generate incident oblique plane wave in our two dimensional numerical code [1]. With this numerical code we can study the propagation of ultrasonic pulses of arbitrary shape in arbitrarily complex media. Recursive relationships yielding the time evolution of the displacement field are derived on the basis of the Local Interaction Simulation Approach (LISA) [2]. Cross-points at the intersection of orthogonal interfaces separating media of different physical properties are treated in the framework of a sharp interface model (SIM) [2]. SIM assumes that any relevant variable is constant within any cell but possibly discontinuous at any cell interface. The displacements and stresses are then matched at each interface. A comparison with conventional finite difference techniques shows that sharp interface model avoids the ambiguities due to the smoothing of the physical quantities. This smoothing procedure may cause severe numerical errors, when the variations of the physical properties across the interface are large.

In our numerical studies incident plane wave generated by a group of sources is scattered on a water-glass interface. This interface can represent for example boundary of a glass specimen immersed in water. The linear array of ultrasonic quasi-point sources is considered. The sources are distributed equidistantly. Each of the sources generates a short pulse with phase delay proportional to the distance from the first source. The incident bulk wave is generated in this way and it propagates toward the interface. The generated wave strikes on the water-glass interface. Part of the energy is reflected backward into the water and the rest propagates in glass as a compressed and transversal wave.

An analysis of impact of plain wave on water-glass interface is essential in evaluation of the computed numerical results. We have performed in detail analytical analysis of the problem considered, the similar solution can be found in [3]. When plane harmonic bulk wave impacts on the interface, one part of the energy is reflected backward into the water in the form of harmonic bulk wave and the other part of energy is transmitted into the glass as a longitudinal

and transverse plain waves. By solving corresponding equations we get for example three critical angles. If the incident angle is equal to the first (second) critical angle, the refraction angle of longitudinal (transverse) wave is equal to 90 degrees. Leaky Rayleigh wave is generated for third critical angle. Solution can be also expressed in the form of reflection coefficient and refraction coefficients of longitudinal and transverse waves. Similarly, we can determine reflection and refraction coefficients of kinetic energy densities.

We have compared amplitudes and kinetic energy density reflection and refraction coefficients numerically computed with theoretical values. Differences for reflection and longitudinal wave refraction coefficients are up to 1% for amplitudes and about 2% for energy for wide range of incident angles. The main source of errors originates from numerical approximations, namely dispersion of solution on computational mesh. Differences for refraction coefficient of transverse wave are up to 12% for amplitudes and 22% for energy in the case of critical angles. It is because there is in addition an interference of transverse refracted wave with longitudinal refracted wave.

In conclusion, we succeeded in generation of a plane wave by means of the linear phased source array. This technique however results also in generation of spurious waves propagated from point sources. Consequently we have to follow solution only in time and space where the spurious waves do not arrive or where they have negligible effect.

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# Stimulated Raman Scattering in Crystals Nd:$SrWO_4$ and $SrMoO_4$ in Picosecond Region: Comparative Study

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The aim of our experimental work was the investigation of the SRS properties of two new nonlinear crystals Nd:$SrWO_4$ (Raman shift of 921.5 $cm^{-1}$) and $SrMoO_4$ (Raman shift 887.7 $cm^{-1}$). The results were compared with measurement of known Raman crystals $BaWO_4$ and KGW.

Stimulated Raman scattering (SRS) has become a standard method for shifting laser radiation into various spectral regions. SRS in solid-state materials was developed into a promising technology enabling generation of laser radiation in up-to-now uncovered spectral regions. Suitable crystals for Raman frequencies generation include KGW ($KGd(WO_4)_2$), $LiNO_3$, $Ba(NO_3)_2$, $CaCO_3$, and $BaWO_4$ [1-3]. $BaWO_4$ crystal was found to be useful for the frequency conversion of either nanosecond or picosecond pulses [4]. Previous results on spontaneous Raman spectroscopic study have revealed the essential advantages of the series of tungstate and molybdate single crystals with isolated $[WO_4]$ and $[MoO_4]$ groups for Raman lasers. They exhibit intensive lines in the Raman spectra, which correspond to symmetrical vibrations in $[WO_4]$ and $[MoO_4]$ molecular ionic groups. Among these tungstate and molybdate crystals, in $BaWO_4$ and $BaMoO_4$ was observed the narrowest linewidth ($\Delta\nu_R$). This linewidth is approximately three times broader than that in $Ba(NO_3)_2$. Due to a 2.5-3 times larger integral Raman scattering cross-section, these materials exhibit approximately the same values of the peak cross-section as that observed in $Ba(NO_3)_2$ crystal. Other tungstate and molybdate crystals reveal approximately the same values of the integral Raman scattering cross-section, while $\Delta\nu_R$ value is essentially increased from 1.6 to 6 $cm^{-1}$ at 300 K in the series of tungstates ($MeWO_4$) and molybdates ($MeMoO_4$), with changing the $Me^{2+}$ cation from Ba to Sr and Ca. The $SrMoO_4$ crystal is promising Raman medium. Active Raman vibration in this crystal has lower 888 $cm^{-1}$ frequency and larger 2.8 $cm^{-1}$ line width compared with $BaWO_4$. This crystal is attractive due to simple growth conditions using Pt crucible on the air with the 9 $cm^3/h$ growth speed. It was shown that for both crystals integral Raman cross-sections, obtained from spontaneous spectroscopy data are equal, but peak cross-sections differ essentially due to a large difference in line width.

SRS of picosecond pulses was investigated for new nonlinear crystal Nd:$SrWO_4$ and $SrMoO_4$, and for previously investigated $BaWO_4$ and $KGd(WO_4)_2$ tungstate crystals. As pumping source Nd:YAG double mode-locked oscillator-two amplifiers laser system. The output parameters of the system were 50 mJ/50 ps in a single pulse at 1.06 um. The output beam diameter was 7 mm, and the full divergence angle was measured to be 0.12 mrad. Nd:YAG output laser beam diameter was decreased by a telescope to increase the pumping intensity for Raman generation and was directed into the investigated Raman crystal. The beam shape at the Raman-active crystal input face was circular of 520 μm diameter. Scattered radiation energy was divided into individual spectral components by two prisms (STF3 and

flint-glass prisms). Generated Raman energy was measured by the Molectron energy meter behind these two dispersing prisms, collimating lens, and movable slit. Losses of the cascade of optical elements were evaluated and the values of the measured energy recalculated.

Two independent measurement sets of stimulated Raman scattering of picosecond pulses in Nd:$SrWO_4$, $BaWO_4$, $SrMoO_4$, and KGW ($KGd(WO_4)_2$) crystals were performed. For first experiment the crystals' dimensions were: Nd:$SrWO_4$ - length 45 mm, diameter 4 mm, $BaWO_4$ – length 39 mm, profile 6x6 mm, KGW – length 40 mm, profile 7x7 mm. From measured data, the threshold of RS generation can be estimated as 3.5 GW/cm$^2$ for Nd:$SrWO_4$ and $BaWO_4$ crystals, and 3.8 GW/cm$^2$ for KGW crystal sample. The maximal conversion efficiency $\eta$ was 25% for Nd:$SrWO_4$, 15% for $BaWO_4$, and 10% for KGW while the maximal first Stokes energy was 1.2 mJ, 0.5 mJ and 0.6 mJ for Nd:$SrWO_4$, $BaWO_4$, and KGW, respectively. For second part of measurements the following crystals were used: $SrMoO_4$ – length 33 mm, diameter 4 mm, $BaWO_4$ – length 33 mm, profile 6x6 mm, KGW – length 40 mm, profile 4x4 mm. The threshold of SRS was estimated to 3 GW/cm$^2$ for $BaWO_4$ crystal in this measurement. The difference between threshold values in two measurement sets can be caused by a better quality of the crystal used in the second set. This fact is also indicated by higher conversion efficiency (25%) achieved in the second set. Two orientations of $SrMoO_4$ crystal yielded different threshold values. The orientation "a" exhibited SRS threshold at approx. 3 GW/cm$^2$, while for the orientation "b" the SRS action started at ~ 2.8 GW/cm$^2$. KGW crystal performed similarly as in the previous measurement and the SRS threshold was estimated to 3.5 GW/cm$^2$. The highest conversion efficiency of 25% was obtained with the $BaWO_4$ crystal, the other crystals yielded conversion efficiency of about 20%. Using a monochromator (Oriel 77250) the measurement of spectral lines position was performed. For 1. Stokes line generated in Nd:$SrWO_4$ crystal was measured to be 1180 ± 1 nm and for $SrMoO_4$ it was 1175 nm. The calculated frequency shifts (923 cm$^{-1}$ for Nd:$SrWO_4$, and 888 cm$^{-1}$ for $SrMoO_4$) were in very good agreement with the shifts obtained previously in spectroscopic analysis of these crystals.

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# Nd:$SrWO_4$ Raman Laser

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The aim of our research was to investigate the operation of a newly built $Nd^{3+}$:$SrWO_4$ Raman laser coherently end-pumped by pulsed flashlamp pumped alexandrite laser radiation. Tungstate materials doped with $Nd^{3+}$ ions are known as an efficient laser [1] media for stimulated Raman scattering (SRS) [2]. Their great advantage is that they can combine SRS and laser properties simultaneously in the same crystal. Recently neodymium doped strontium tungstate crystal ($Nd^{3+}$:$SrWO_4$) demonstrated efficient laser and SRS operation under flashlamp pumping [3]. Strontium tungstate crystal has an intense $A_g$ Raman mode that corresponds to symmetrical vibrations of molecular ionic $(WO_4)^{-2}$ groups. The SRS-active mode frequency $\Omega_R$ equals to 921 $cm^{-1}$ [4]. The concentration of $Nd^{3+}$ ions doped in $SrWO_4$ crystal is sufficient for obtaining laser operation at wavelength 1057 nm.

Cylindrical rod of $Nd^{3+}$:$SrWO_4$ crystal (diameter 5 mm, length 45 mm) was tested in our experiments. A FNSPI laboratory-made alexandrite (chromium-doped chrysoberyl $Cr^{3+}$:$BeO.Al_2O_3$) laser was used as a pump source for $Nd^{3+}$:$SrWO_4$ laser. The generated spectrum of the alexandrite laser without tuning elements had maximum at 752.3 nm. It well overlapped with the absorption line of $Nd^{3+}$ ions in $SrWO_4$. The pump laser worked in the free-running multimode regime with the pulse repetition rate of 5 Hz. The pulse duration was about 40 μsec. The output laser energy was up to 200 mJ. Laser beam parameter $M^2$ was equal to approximately to 10. The pumping radiation was focused into the active sample by single lens (f = 166 mm).

The cavity of longitudinally pumped $Nd^{3+}$:$SrWO_4$ laser was composed with two mirrors. The entrance mirror was concave with 0.5 m curvature and with high transmission at alexandrite laser wavelength and high reflectivity in the range from 1000 nm to 1250 nm; the reflectivity of the output coupler varied from 10 to 90%. The maximum generated energy (90 mJ) from the free-running $Nd^{3+}$:$SrWO_4$ laser at 1056 nm wavelength was obtained with the output coupler $R_{1056}$ = 52 %. The slope efficiency reached $\sigma$ = 0.52 for this cavity. With Fabry-Perot double reflector used as the output coupler the laser output energy reached 67 mJ. The beam characteristic parameters were $M^2 = 2.5 \pm 0.1$ and divergence $\theta = 1.5 \pm 0.1$ mrad in this case.

The Q-switching operation of $Nd^{3+}$:$SrWO_4$ laser was realized with LiF:$F_2^-$ color center saturable absorber. The output radiation consisted of the fundamental radiation (1056 nm) and SRS shifted Stokes component (1170 nm, corresponding Raman shift 923 $cm^{-1}$). Basically the experiment was separated on two parts – at first, the output coupler of the Nd:$SrWO_4$ laser was partially transparent for both the fundamental and Raman frequencies. At second part, the fundamental wavelength was reflected back into the Nd:$SrWO_4$ laser oscillator and only Raman frequencies were transmitted through the output coupler. In both parts of the measurements, the resonator output coupler and nonlinear saturable absorber initial transmission were changed with the goal of optimization of the output Raman radiation.

At first, we optimized the scheme for operation at the fundamental wavelength. The optimal laser operation in the cavity with double Fabri-Perrot as the output coupler (R = 48 %) was obtained with saturable absorber with $T_0$ = 5 % and provided maximal output energy of 1.46 mJ for the fundamental wavelength. The emission band of $F_2^-$ color centers in LiF crystal spreads from 1 till 1.3 μm and includes the first Stokes wavelength in $Nd^{3+}$:$SrWO_4$ laser. This emission worked as a seed for the first Stokes component operation that resulted in the existence of the first Stokes component together with the fundamental in the Q-switched operation. Up to 0.74 mJ was registered at the first Stokes frequency. The pulse duration was 5 ns and 2.4 ns for the fundamental and Stokes radiation.

In the next experiment, a Raman Nd:$SrWO_4$ laser was built. As a output coupler was used dielectric coated mirror which has 100 % reflectivity for base 1056 nm wavelength and 46 % reflectivity for supposed generated Raman frequency. The resonator length was 142.5 mm. The maximum output Raman energy in the second part of the experiment was reached when the initial saturable absorber transmission was equal to 5 %. In this case, the output energy in single pulse was 1.25 mJ at 1170 nm. The energy conversion from pump (750 nm) to Raman (1170 nm) radiation was 1.6 %, length of the generated pulse was measured to be 2.9 ns, and peak power reached 430 kW. Parameters of the output 1170 nm beam for the repetition rate 5 Hz were following: $M^2$ = 9.8, and divergence θ = 3.1 mrad.

We can conclude that properties of laser operation and simultaneous stimulated Raman scattering in the new SRS-active neodymium doped $SrWO_4$ crystal coherently end-pumped by flashlamp alexandrite laser were investigated. Maximal output energy at 1057 nm reached 90 mJ in the free-running mode. When this laser was Q-switched by LiF:$F_2^-$ crystal, SRS self-conversion was achieved with maximal output of 1.23 mJ at 1170 nm in single pulse (FWHM 2.9 ns). The influence of various Raman laser output couplers reflectivity as well as initial transmission of LiF:$F_2^-$ crystal saturable absorbers were investigated with the goal to maximize output energy at the Stokes wavelength. Our results could serve as a base for the future development of diode pumped $Nd^{3+}$:$SrWO_4$ Raman laser.

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# Difference Schemes for Conservation Laws and Hydrodynamics Modelling in Plasma Physics

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We report here on the development of finite difference schemes for numerical treatment of conservation laws and their applications in plasma physics hydrodynamical simulations.

Composite schemes perform several times steps of higher order dispersive (e.g. Lax-Wendroff) scheme followed by one time step of first order diffusive (e.g. Lax-Friedrichs) scheme which serves as a filter removing dispersive oscillations around discontinuities which is consistent with the solved partial differential equation. We have extended composite schemes to unstructured triangular meshes which allow arbitrary solution domain. For plasma compression problems involving big changes of volume and shape of computational domain one needs to use Lagrangian formulation with mesh moving with the fluid. Composite schemes on Lagrangian unstructured triangular grid have been developed.

Hybrid schemes combine numerical fluxes of second order dispersive scheme and first order diffusive scheme by weighting in such a way that in areas of smooth solution only second order scheme is applied while around discontinuities first order scheme adds enough dissipation to treat shock and contact waves. Hybrid schemes have been developed in different geometries in 2D and 3D. They have been applied in polar geometry to black hole accretion disc simulation [4]. Hybrid schemes remain second order for smooth solutions while composite schemes are only first order however with much smaller truncation error coefficients than that of standard first order diffusive schemes.

We have preformed a study comparing representative set of ten finite difference schemes used for numerical solving of Euler equations on a set of 1D and 2D test problems [1]. Most popular schemes are covered in this study, including composite, hybrid, centered with limiter, positive, Clawpack wave propagation, WAF, WENO and PPM schemes. Some methods appear to work better than others on a specific test, but no one scheme has shown itself to be superior on all tests.

Our further work in the designing of finite difference schemes for conservation laws includes development of dimensionally non-split optimally stable second order scheme of Lax-Wendroff type in 3D [2] and fully 2D HLLE (Harten-Lax-van Leer-Einfeldt) type approximate Riemann solver.

Plasma compression simulations involve large changes in computational domains for which Lagrangian formulation is better than Eulerian one. In 2D however plasma instabilities often tangle the Lagrangian moving grid so that it becomes degenerate, e.g. edges of cells intersect. At such stage one needs to apply Arbitrary Lagrangian Eulerian (ALE) approach which first untangles the grid into a new regular one, remaps the conserved quantities to the new grid and then continues the Lagrangian simulation until the moving grid keeps its regularity. As a preparation to the development of ALE code basic mesh untangling and conservative remapping algorithms have been developed.

Mathematical and algorithmical grounds described above have been applied to a variety of plasma physics problems. We have simulated plasma compression of homogeneous and inhomogeneous, layered targets to high densities [3]. Two different one-fluid one-temperature

models, Lagrangian and Eulerian, are employed for modeling target compression to high densities. Numerically, Lagrangian model is treated by support operator method and Eulerian one by composite schemes on a moving grid. Both models also include heat conductivity with Spitzer-Harm or Rozmus coefficients. The quotidian equation of state (QEOS) by More is used. This equation of state is valid for a very wide range of plasma parameters. It is fast, reliable and consistent. Several particular configurations including targets with several layers from different materials have been simulated. Results for compression of cold liquid/frozen hydrogen by gold flyer correspond reasonably well with fully independent calculations performed by others. We have also simulated a real experiment performed in Lawrence Livermore National Laboratory where liquid hydrogen contained between two sapphire anvils was compressed to a metallic state by a high speed impactor. Reasonably good agreement of our simulation including six layers with experiment has been achieved.

Other applications to plasma physics include simulations of Rosby wave instability of thin accretion discs surrounding a black hole [4] where the instability produces an efficient outward angular momentum transport. Also simple magneto-hydrodynamical models and plasma instability appearing during compression have been studied numerically.

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# Application of an X-Ray Fluorescence Method for Analysis of Inks and Pigments in Medieval Manuscripts

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This study is a part of a project aimed at investigating the types and chemical composition of inks and pigments used in medieval manuscripts. The X-ray fluorescence apparatus set up and operated by the Laboratory of Quantitative Methods in Research of Ancient Monuments (FNSPE, TU Prague) has been used to detect photons from the sample. The Si(Li) detector measures the numbers and energies of the photons emitted from the specimen. The energy and the number of photons detected are characteristic of each element and indicate its concentration. These results give data for qualitative and quantitative analysis of the samples. XRFA is a relatively simple and nondestructive method. Its capability for *in situ* measurement is one of the great advantages of this method. Appropriate radionuclide sources for exciting XRF radiation have been used (e.g., $^{55}$Fe enables excitation of elements with Z up to 23, $^{238}$Pu is used for elements in the interval 20 to 39, etc.) A Si(Li) semiconductor detector with a 5 l Dewar vessel and a portable spectroscopy system has been used to enable *in situ* measurement. Narrow collimation of the exciting beam makes it possible to select an area of interest in the manuscript.

XRF results have greater significance when applied within a statistical framework. Measuring the semi-quantitative elemental composition of a single area, which itself may be of heterogeneous or layered structure, would generally be carried out for a specific purpose, such as establishing the presence of a particular element. The intrinsic non-destructiveness of the XRF technique allows large numbers of measurements to be taken and analyses to be carried out even on areas or samples from which sampling is not possible.

A set of standards corresponding to many types of pigments used in medieval manuscripts was prepared in the laboratory of the National Library. These standards were measured by the XRF technique. The X-ray spectra of standard samples were compared with the X-ray spectra of the pigments used in manuscripts. Each pigment is characterized by the specific content of various elements, allowing the pigment to be identified. The use of individual pigments and inks was characteristic of different periods, different areas or different workshops.

Suitable analysis of pigments enables identification of the types of inorganic pigments used by medieval artists, detection for potential restoration, evaluation of changes in the pigments and proposals for useful procedures for conservation and restoration.

Within a series of manuscripts produced contemporaneously in the same scriptorium around the middle of the 13$^{th}$ century ( “S. Bernardi Claraevall: Sermones varii” ) different inks were identified. In the first folio the ink was characterized by iron alone, whereas in the ink used for the second folio the iron was accompanied by zinc. These results indicate that for the latter a hydrated iron sulphate rich in zinc impurities was used to produce the ink.

In most hand-written documents iron-gall ink was used. This ink was prepared on the basis of a mixture of $FeSO_4$, gallic acid extracted from the spherical protrusions formed in leaves,

caused by local damage inflicted by gall-wasps and a viscous medium such gum arabic. The dark-brown black colour of the ink is caused by the oxidation of $Fe^{2+}$ to $Fe^{3+}$ and the formation of $Fe^{3+}$ -gallic acid complexes. Hand-written documents written with iron gall ink present a serious conservation problem, as the ink slowly oxidizes the paper it is written on, thereby gradually disintegrating the document. Two mechanisms were put forward to explain this behavior. Either the strongly acidic components of the ink hydrolyze the cellulose in the paper and cause it to disintegrate or $Fe^{2+}$ residues act as a catalyst for the oxidation of the organic compounds present. This oxidation involves the intermediate formation of radicals ($O_2$, HOO). The reaction of $Fe^{2+}$ with HOO in an acidic medium leads to the formation of $H_2O_2$, which in turn can further oxidize the paper and the $Fe^{2+}$ present in the ink. Local measurement of the $Fe^{2+}$ to $Fe^{3+}$ ratio in handwritten letters of historical documents can therefore enable objective monitoring of the damage potential of the ink in a document.

Narrow collimation of the exciting beam to determine the $Fe^{2+}$ to $Fe^{3+}$ ratio is necessary. Narrow collimation of the radionuclide sources presents a serious problem. The volume activity of the exciting sources does not enable the collimation necessary for these purposes. The new collimation system with an X-Ray tube was built and tested in the Laboratory of Quantitative Methods in Research of Ancient Monuments.

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# Temporal Variability of Several Radon Charakteristics of the Soil

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Exposure to the radon and radon decay products in some residential areas and at workplaces constitutes one of the great risk from natural sources of ionizing radiaton. According to UNSCEAR (United Nations Scientific Committee of the Effects of Atomic Radiation) these radionuclides share almost 55 % of all causes of irradiation on population. Statistical investignation in the last decades showed that people loitering in areas with increased volume of radon activity tend to suffer more likely from lung cancer than the rest of the population. Contribution to exposition of man depends on the transport of radon from the soil to the atmosphere. That is the reason why to estimate the radon area as precisely as possible, and also determine the best approach to evaluating radon risk. By measuring and studying radon volume activity in various media we can better understand the processes influencing the concentration of $^{222}$Rn, test models describing the variations of $^{222}$Rn, identify and quantify the sources of $^{222}$Rn in residential areas, correct procedures in measuring concentrations of $^{222}$Rn by integral methods and also control the efficiency of counter-radon measures.

The volume activity of $^{222}$Rn in the soil air is not stable. It changes with the depth as well as with time. Radon concentrations are influenced especially by the atmospheric pressure, by the temperature and moisture of the soil, by the wind velocity and by the state of the soil surface.

The daily and seasonal variations of the volume activity of $^{222}Rn$ were observed in the soil air [1]. These variations must be taken into account for example in case that the soil's radon is used for the earthquake prediction. But mainly the seasonal variations of the radon concentration are also the source of the uncertainties at the radon classification of the soil for the purposes of the radiation protection. Therefore we must search such radon characteristics of the soil, that are as little sensitive to the soil's state as possible during their determination. Further the new approaches to the expression of the radon potential of soils could be developed too because of the more unique indication of the radon indoor levels.

Therefore the time variability of the volume activity of $^{222}Rn$ in the various depth of the soil, the variability of the diffusion radon length, of the radon exhalation's rate from the soil surface are studied in our contribution.

The sampling place – the place where the seasonal variability of the radon characteristics of the soil was studied – was situated in the area of Faculty of Mathematics, Physics and Informatics in Bratislava. The soil of this place is middle permeable [2]. The mean specific activity of $^{226}Ra$ up to the depth of 1,5 m is equal to 37,5 Bq.kg$^{-1}$ in this soil. The emanation coefficient of $^{222}Rn$ in the surface soil is approximately 14,5% at the weight content of the soil moisture in the range of 5 – 20 % [3].

The soil air samples were collected from different depths by using of the stainless steel tubes and the syringes [4]. For the determination of the $^{222}Rn$ activity concentration the soil air

was sucked from the syringes into the pre-evacuated scintillation cells of Lucas type the volume of which was 125 mℓ. The accumulation method was used for the determination of the exhalation rate of $^{222}Rn$ from the soil surface. The air from the accumulation vessel circulated continuously by means of the membrane pump in the closed circuit. The increase of the $^{222}Rn$ activity in the accumulation vessel was continuously recorded by the radon monitor [4].

The volume activity of $^{222}Rn$ in the soil air in the depth' interval of <0,15 m; 1,6 m> was observed from June to March. Altogether 29 depth profiles of radon were measured. The higher radon concentrations were found out during winter months than in summer months in all depths. The highest temporal variability of the volume activities characterized by the relative range of the measured radon activities $(A_{Rn,\max} - A_{Rn,\min})/A_{Rn,m}$ and by the variation coefficient $S_A/A_{Rn,m}$ ($S_A$ is the standard deviation) was found out in the small soil depths. The exponential decrease of the relative variation range and of the variation coefficient was observed with the increase of the depth. Meanwhile in the depth of 0,15 m the volume activity of $^{222}Rn$ oscillates round the mean value up to 150 %, the seasonal fluctuation of the volume activity of $^{222}Rn$ in the depth of 0,80 m was only 30 %. The seasonal increase of the volume activity of $^{222}Rn$ was connected with the increase of the soil moisture. While the volume moisture of the soil was only 5 % during dry summer days up to the depth of 0,80 m, from autumn to spring months was this moisture in the surface layer of the soil 28 % and successively it decreased up to the depth of 1 m where reached the value of 5 %. The short-time increase of the volume activity of $^{222}Rn$ up to the depth of 0,6 m was found out also in June after the rain when the increase of the volume moisture of the soil was 15 % but only in the surface layer of the depth about 0,10 m.

The measured depth profiles of the volume activity of $^{222}Rn$ were fitted by the exponencial function and then the values of the saturated radon volume activity $A_{s,Rn}$ and values of the diffusion length $L$ were obtained from these fits [5]. The determined values of $A_{s,Rn}$ are higher in winter than in summer months and the diffusion length has just reverse course. The relative variation range is 0,26 for $L$ and 0,6 for $A_{s,Rn}$, that is the same as for the volume activity of radon in the depth more than 0,8 m.

The time variability of the measured exhalation rates was smaller than the variability of the other parameters. The relative variation range was only at the level of 0,21.

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# Transient Absorption of a Bichromophore

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The transient absorption of a bichromophoric molecule 2-(3-benzantronylamino)-4-(1-pyrenylamino)-6-chloro-1,3,5triazine (APyTCABa), and of corresponding model compounds that behave as an acceptor and/or a donor sub-unit of the bichromophore was measured in dimethyl sulfoxide (DMSO) solvent at room temperature. 2-(3-benzantronylamino)-4-(phenylamino)-6-chloro-1,3,5-triazine (ABaTCAn) as model acceptor compound and 2-(1-pyrenyl)-4-(methoxy)-6-chloro-1,3,5 triazine (APyTCM) as model donor compound were used. The time resolved pump-probe absorption spectroscopy instrumentation used for measurements described here had time resolution 150 fs approximately. To excite the bichromophore and the model donor compounds, fs pump pulses at 349 nm were required. Typical average pump intensity was of the order of 10 μW, repetition rate was 1 kHz. The probe pulses were generated in range from 580 to 930 nm. A synchronized chopper blocked every second pump pulse in order to exclude eventual slow drifts of the instrumentation as well as of the background absorption. The pump and probe pulses were collinearly focused into the 0,7 mm flow sample cell. The measured signal was obtained as a difference between the absorbance of the sample after the excitation by pump pulse and the absorbance without the previous excitation. High sample concentrations, almost at the limit of solubility, were necessary for pump-probe absorption spectroscopy: typical concentration was about $4*10^{-4}$ M.

Positions of possible transient absorption bands for S1→Sn transition were not known yet for the substances studied here. Therefore, the model donor compound APyTCM was excited by laser pulses at 349 nm and probed in the range from 580 to 780 nm in order to find a transition from S1 state to a suitable higher electronically excited Sn state. A strong transition was found around 610 nm. In the following step the bichromophoric molecule and the model acceptor compound ABaTCAn were pumped by laser pulses at 349 nm and probed by pulses at 610 nm. Observation of no transient absorption of ABaTCAn at this wavelength indicated that the donor part of the bichromophore APyTCABa was locally excited.

The bichromophoric molecule was subsequently probed by laser pulses in the range from 610 to 930 nm to find an expected transition from S1 (localized) state of the acceptor part of APyTCABa to the higher electronically excited Sn state of this part. We proved in our previous work [1] that S1 state of the acceptor part of APyTCABa is populated after selective excitation of the donor part via an intramolecular electronic excitation energy transfer.

A noticeable difference was observed in kinetics of the time resolved transient absorption when the sample was probed at 610 or at 930 nm. The absorption at shorter wavelength was assigned to transition from S1 state of donor part of APyTCABa to its higher electronically excited Sn state. Fast decay component was observed here that probably corresponds to S1→S0 transition of the donor part and a very slow decay component that may correspond to fluorescence from S1 state of the acceptor part of the bichromophore. The transient absorption at longer wavelength (930 nm) probably corresponds to a transition from S1 state of the

acceptor part to a higher electronically excited Sn state of this acceptor part. Again, a very slow decay of absorbance was observed that has probably the same reason in fluorescence as the slow decay component when probing at 610 nm. The very fast initial increase, detected under these conditions, could provide more information about fast energy transfer from donor to acceptor part which was indicated in previous experiments to happen on 150 fs time scale.

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# Bichromophoric Molecule with Vibrational Probe – Computational Study

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One of the intensively studied phenomena is the intramolecular electronic excitation energy transfer (IEEET) because of its importance e.g. for understanding to photosyntetic light harvesting systems or development of molecular electronic devices. In our previous work [1] we introduced a new approach to the monitoring of electron density redistribution in the course of such a process as e.g. IEEET, based on attachment of a vibrational probe to a corresponding model compound, in our case a bichromophoric molecule. As the vibrational probe, the nitrile group was selected, since the frequency of its stretching vibration was expected both to be sensitive to the electronic density in the vicinity of the group, and not to severely interfere with vibrational modes of the rest of the bichromophore. For this purpose, a compound consisting of 4-aminobenzonitrile (donor), 1-aminopyrene (acceptor) and 2-chloro-1,3,5-triazine (bridge) (2-(4-cyanophenylamino)-4-(1-pyrenylamino)-6-chloro-1,3,5-triazine, ABN-TC-APy) together with a model donor subunit compound consisting of 4-aminobenzonitrile and 2,4-dichloro-1,3,5-triazine (2-(4-cyanophenylamino)-4,6-dichloro-1,3,5-triazine, ABN-$TC_2$) were synthesized and investigated using UV-Vis absorption, fluorescence and FT-Raman scattering spectroscopy. For better understanding to the behavior of the vibrational probe we performed the following computational study of benzonitrile (BN), 4-aminobenzonitrile (ABN), 1-aminopyrene, ABN-$TC_2$ and ABN-TC-APy using *Gaussian98W* software.

The optimization of the geometry of the studied molecules and consequent calculation of their vibrational frequencies was performed by restricted HF (Hartree-Fock) and B3LYP (Becke three parameter formulation of hybrid functional and Lee-Young-Parr correlation functional) methods. As the starting geometries for the optimization, geometries resulting from semiempirical AM1 (Austin Model 1) method were taken. For both methods, the basis sets 3-21G(d), 6-31G(d) and 6-31+G(d) were employed. The calculated frequencies were, after scaling by corresponding factors, compared to those observed in the FT-Raman scattering spectra. As an example, the comparison of experimental and calculated (using 6-31G(d) basis set) values of nitrile group stretching frequency is shown in Table 1. Both methods, particularly the B3LYP, yielded a good agreement with experimental data including the sensitivity of the nitrile group stretching vibration frequency to the changes of the electron density on the vicinal

Table 1. Nitrile group stretching frequency in $cm^{-1}$

| Sample | Experiment | RHF | RHF (scaled) | B3LYP | B3LYP (scaled) |
|---|---|---|---|---|---|
| BN | 2232 | 2604 | 2325 | 2349 | 2258 |
| ABN | 2213 | 2594 | 2316 | 2339 | 2249 |
| ABN-TC2 | 2233 | 2603 | 2324 | 2347 | 2256 |
| ABN-TC-APy | 2219 | 2600 | 2321 | | |

benzene ring that is influenced by the electron donating / withdrawing character of the substituent in para- position.

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Section 3

# INFORMATICS
# &
# AUTOMATION ENGINEERING

# Simulated Enterprise Integrated System (SEIS)

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**Annotation**

The main aim of the "Simulated Enterprise Integrated System (SEIS)" project is an enrichment and improvement of contemporary way of teaching in different courses in the field of IT by systematic inclusion of the trend of the system integration on the information level. This trend reflects the real circumstances in complex IT applications such as CAD (Computer Aided Design) systems [1], PDM (Product Data Management) systems [2], web based information systems [3], etc. The complexity of such systems is growing up and its position is considerable in the computer science and there is a serious interest of scientific community to find the technology of teaching such kind of teaching subjects.

In our project we specialize in complex EIS (Enterprise Information Systems) and we design a Simulated Enterprise Integrated System – SEIS, as a solution of the missing pedagogical base. A simulated system allows both improvement of the teaching of integrated systems' problems and above all to practice them. Students should take the lessons in the all-possible roles to manage the system - the role of the users, administrators and mainly in the roles of the members of integrated system's realization team.

**Observation**

During the last ten years the world has been living through the unexpectedly rapid growth of the information technologies across all spheres of a human activity. Thanks to the Internet – a worldwide public network – the fundamental revision of the views on the information, the way of exchange of information and the time continuity has been done. There are following consequences in the commercial world. The globalisation trends have been deployed, the commercial organizations started to collaborate more and they started to make use of new methodologies of collaboration and trading. Since the universities should above all prepare students for solving problems of real use, the teaching cannot be out of this evolution.

Contemporary teaching system still emphasizes individual students' work in the boundaries of more or less isolated courses. Of course, there are courses that are going in for teamwork yet, but the integration of human potential is covered only. There is not emphasized the integration of information on the level of the software systems.

The environment of the integrated information systems is very heterogeneous. This heterogeneity can be classified into two basic layers:

- Logical heterogeneity – on the information level
- Physical heterogeneity – on the system level (heterogeneous software components or systems and variety of used hardware platforms)

The bridging of the gaps of described heterogeneity induces sets of specific problems, which are not being satisfactory taught, now.

The live cycle of these complex systems always calls for maintenance and support, which is a weak point of the teaching. Students do not have any chance to practice these aspects of using of integrated software solutions. Only theoretical base as a rule tends to under valuation of problems of designing and using of real integrated systems.

As well as there is an aspect that the information from systems for support of some design process can be reused in the system for support of live cycle of designed artefact, and what not. The aspects of the coherence of information in the integrated system make the next sector, where systematic practicing is missing in the academic approach.

As today's university graduates are looking for the job, they are finding, that they are good in algorithmization and they know principles, the information technologies are based on, but they do not know anything about trends, technologies, techniques and methodologies that are used in the integrated heterogeneous environment.

We are going to develop and start the system in following steps: system design (students would participate on), system creation (primarily as a supervised students' teamwork), testing of the project (partly outside teaching process), inclusion to the teaching process and using, administration and maintenance of developed system (we propose to use it in several heterogeneous appropriate courses).

Designed simulated system consist from the next modules:

- Opened interface for communication with "enterprise software" (such as CAD systems)
- Support of PDM and PLM (Product Lifecycle Management)
- Integrated web-based user interface

There are two levels of students' benefit. First, we are going to engage students to develop of the simulated system. Second, designed system will be useful to practice all aspects of using of integrated system. Students will be able to alternate the roles of the users, administrators, system developers or service engineers.

**Conclusions**

The contemporary teaching of information technologies and computer sciences needs the tools for supporting of information integration's problems teaching. As a solution, we design a simulated enterprise integrated information system.

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# Some Theoretical Problems of Plate Digital Terrain Model Construction

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Digital terrain model is a programme equipment for terrain relief describing as 3D model form. Digital terrain model is available to provide some operations by this model. The basic activities that the programmes usually are available to provide can be distributed to several sections:

1. Digital terrain model date extraction
2. Digital terrain model constructing
3. Digital terrain model browsing
4. Interpolation on the model
5. Editing of terrain and modelling

Not only a terrain relief itself compose a cultural landscape but also some more components. The landscape layout is influenced by buildings and areas for various purposes (fields, meadows, ponds). We must use other computer modelling tools and join together results from different methods to be able to model any landscapes.

The raster model is the easiest type of digital terrain model . A terrain relief is described by array of vertical coordinates of points. The points are located in a regular raster. Raster model data usually is not taken by right measuring in a landscape but by interpolation of points measured in a nonregular raster.

The polyhedry model is the next type of digital terrain model . For polyhedry model a landscape is parceled in smaller plane areas. Usually triangles, quadrangles so as to adjoin to a terrain relief to the nines. The terrain relief is replaced by regular polyhedron with triangle or quadrangle faces.

The plate model has many attributes alike the polyhedry model. A terrain is parceled smaller areas. No only plane ones. They can be anyway curved. Most frequently used areas are ones describable by polynomical functions what to continue one another enough fluently that there is warranted derivatives continuity up to default a order.

The plate model is constructed gradually by several steps. The first step is a triangulation. It is merging a input index of points to a triangle net. Such triangle net can be constructed by many way. Some of the way are more available for next operations that others ones. A result of the triangulation is the terrain model described by a available data structure. A member of terrain model construction can be optimization of single plates. Needless edges of triangle net are cut out during the optimization. Then the model is composed quadrangles and more compound polygons.

The last phases of the model creation is treatment singularities. The singularity is a place, where a terrain goes on different way as it is expected from going on a around of the singularity. E.g. it can be an edgy ridge or a coast of a lake.

A lot of theoretical problems rises during a creation of the plate model. The first of them is the triangulation itself. An effectiveness of whole programme package for the terrain and landscape digital model is highly influenced by triangulation algorithm effectiveness just. This algorithm must be enough fast and withal offer a good duality of triangulation.

The next problem is curvature of the terrain plates so as to continue one another fluently. This problem is missed
in a many commercial programmes. Because a visual image is the most important for a practical work. Sometimes approx fluently continuity of the polyhedry plates is enough. Another time fluently continuity of the plates specially polyhedry ones with various numbers of apexes is a large theoretical problem.

The last set of problems is a treatment of singularities. There are different types or the singularities. Sometimes we can apply for some edges a fluently continuity a terrain itself but no fluently continuity of the plates (derivatives continuity). E.g. ridge. Sometimes neither terrain itself as a function of two variables (hight Z is assigned to position coordinates X and Y) do not have to be continuous. The terrain can include a break (a vertical brow what two plates do not continue fluently on), or even a cornice (a place what two plates overlap partly and the terrain does not make a function). Because the types of singularities (break, cornice) affect rather rarely and their programme treatment is very difficult, a lot of programmes for digital terrain model go about a those singularities solving. The break is often realized by a plummeting plate what to be still a graph of a function of two variables. A plummeting brow appears instead of a vertical brow in a resultant model.

The staffs team of the department of applied informatics, college of civil engineering, Czech Technical University in Prague, deals with digital terrain model more 15 years. A lot of the indicated theoretical problems were resolved and their resolution was tried in practice, others problems wait for a complex resolutions.

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# Rule Extraction using Artificial Neural Networks

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Due to ever increasing amount of collected data, automatic knowledge acquisition has become a key concern in artificial intelligence. An important type of representation, in which knowledge is represented, is sets of symbolic IF…THEN rules, as it is well understood by humans and amenable to symbolic manipulation and inferencing techniques. *Rule extraction using neural networks* presents an attractive approach to knowledge acquisition because it combines the straightforward manner in which neural networks can learn from training data with the above given advantages of rule sets.

**Using Neural Networks for Rule Extraction**

The process of rule extraction using neural networks proceeds by first training a neural network on the data being analyzed, followed by transformation of the resulting network into a corresponding rule set representation. By means of this transformation, rules implicitly represented by numerical connection weights and topology of the trained neural network are expressed in an explicit form. In general, several types of symbolic rules exist, the most important types being propositional, M-of-N and first-order Boolean rules, as well as various types of fuzzy rules. In our project, we focus on propositional classification rules as they are the most comprehensible, yet offer sufficiently good accuracy for a wide range of tasks. They are of the form

$$\text{IF } x_1 \in S_1^{(k)} \wedge \ldots \wedge x_N \in S_N^{(k)} \text{ THEN } Class(X) = c_k \,,$$

where $x_1 \ldots x_N$ are values of attributes for a given object $X$, $S_1^{(k)} \ldots S_N^{(k)}$ are intervals or sets of discrete values and $c_k$ is the class to which an object $X$ is possibly classified by the rule.

In comparison to several well-known algorithms that extract symbolic rules directly from data, such as C4.5/C5.0, CN2 or AQ-family algorithms, neural network based rule extraction techniques posses several advantages:

- **straightforward handling of continuous attributes**, as neural networks can be trained directly on real-valued data
- **universal approximation**, which entails the ability to accurately represent a wide class of input-output relationships
- **multivariate search**, i.e. the ability to examine combinations of attributes simultaneously during the search for optimum network weights
- **wide-margin classification**, which improves generalization accuracy of learned solutions
- **high tolerance to noise**

Methods for rule extraction using neural networks can be categorized according to numerous criteria [3]. Perhaps the most important criterion is the quality of extraction, which is measured in terms of accuracy, comprehensibility and fidelity of extracted rules. Another important issue from the user's perspective is *scalability in comprehensibility*, i.e., a possibility to choose preference between highly accurate rules on the one side and easily comprehensible rules on the other, as these are often competing goals. Many rule extraction algorithms proceed by first extracting rules at the level of individual network units and subsequently aggregating them to

form global relationships. This process is, however, usually quite complicated and requires some ad hoc mechanism to approximate network unit functions by Boolean functions, so that they can be subsequently expressed as formulas.

**Structural Learning**

As a possible solution to this problem, *structural learning* methods, which aim at producing networks that simplify the rule extraction step, have been proposed. A prominent example of such methods is *rule extraction by successive regularization* proposed by M. Ishikawa [2]. In comparison to other techniques for rule extraction using neural networks, this technique has the following advantages:

- **general-to-specific hierarchical rule extraction,** which agrees with human tendency to interpret data and improves rule comprehensibility
- **scalability in comprehensibility** through the choice of regularization parameter of structural learning
- **robustness** with respect to different initial network weights

In the network-to-rule conversion process, Ishikava uses manual Karnaugh map method, which is suitable only for a low number of input attributes. To overcome this limitation, we employ Quine-McClusky minimization method, which does not impose any limit on the number of inputs and is easily automated. The resulting method has been applied to several benchmark problems from the UCI machine learning repository. In these experiments, the method exhibited ability to extract high quality rules; in several cases, it extracted the simplest rule set known for a given level of accuracy [4]. The quality of extracted rules, however, goes at the expense of the extraction time, which is generally several orders higher than in case of the fastest symbolic rule extraction algorithms.

**Conclusion**

The experimental results demonstrate that neural network rule extraction techniques are a promising approach to the problem of symbolic rule extraction. The proposed method allows the user to control the scalability-comprehensibility trade-off of rule extraction, which was an important objective of the project. Nevertheless, the issue of scalability in comprehensibility requires additional research, especially from the theoretical perspective. In the future, we would like to focus on neural network methods for extracting rules from data with continuous attributes, as this is a domain where neural networks could fully unleash their potential [1]. Moreover, as the method becomes more mature, we would like to apply it to several real-world knowledge discovery problems, some of which are solved in the Gerstner laboratory by means of other data mining techniques.

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# Implementation of DNEP information databases in IS of CTU

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The DNEP database program was designed for two main purposes as they follow, namely:

- As a tool of decision making and control for the management of CTU, for the Department of Science and Research, managements of particular faculties and selected parts of CTU (namely BIC with its Patent Centre). Hence DNEP is utilized in such a way for internal needs in managing the University.
- As an information and orientation tool for lecturers, scientists and students at the CTU and naturally for interested wide public and another interested people outside of CTU, e.g. for specialized journalists. Hence the DNEP is here directed for the internal as well as for the outer usage.

The program is for both groups of users, inside or outside of the CTU, accessible freely.

The DNEP database program saves and shares with all above mentioned subjects an overview and detailed data as well in records of:

- Offers based on results in the field of scientific and research activity and in the teaching process as well for the industry in frames of a transfer of technologies and for a cooperation with other universities and research institutions in the Czech Republic or abroad. The range of offers is relatively wide. Let us mention an application of computers, an application of technology, expertise, project/design activity, oponenture of projects, support of innovation of SME, translation of technical texts, invention/patent, etc.
- Experts in different technical and non-technical fields raised at CTU.
- Unique instruments/devices which are at disposal at faculties and parts of CTU.

The DNEP database program can be briefly described by main features as they follow:

- DNEP consists of three databases - some records in different databases are connected one to the other ones. These are records which share the same author (an offer of a result), who is recorded possibly as an expert or a responsible person for an instrument/device.

- A maximal extent of particular databases in a steady state after being filled in is supposed to be hundreds of records.
- The approach to databases is implemented by means of a web page to which exists a link at the CTU Homepage - Science and Research.
- DNEP program is an integral part of the CTU Information System.
- The program is implemented on the server located at the Computing and Information Centre of CTU, Department of Information Systems.
- The Department of Science and Research, Rector's Office, takes care of editing of the records, namely: Doc.RNDr. K.Lejčková, CSc. (Mrs.), Phone 224 353 463, **lejckova@vc.cvut.cz .**
- The data acquisition is guarantied from multiplied sources (submitting of records from faculties and another parts of CTU via Web, existing databases, lists of patents and another sources).
- Submitting forms are tailored with respect to particular databases.
- Consistency of records created by different authors is supported by a system of pop-up menus at key items of the record (e.g. the title of a faculty or a part, its address etc.).
- Particular databases are filled in by data in an off-line way. The author uses a submitting form and sends it to the server. By this act he agrees that a description of his offer, or his person as an expert, or an instrument/device, which is he responsible for, together with contact data are able to be displayed on web pages of CTU, or to be distributed by other suitable ways.
- The editor of the database edits this submitted record to keep the consistency of the database as a whole, or he or she corrects the submitted record and after that he or she displays it in the web accessible database. In case of an offer a record will be displayed there for a time interval submitted by the author. A prolongation is possible after a treaty of an author and the editor based either on a wish of the author or on knowledge of the editor about the frequency of interest of users. At the both other databases (experts and instruments/devices) the interval of displaying is not limited in forward.
- The access to displayed records is free - with respect to the nature of displayed personal data, offers or results it is necessary to handle the records with an etiquette common in the field of science. That means at least, when quoting a record, to publish also the name of the author and the source, to respect authorship and to handle thoroughly all sensitive information and data with the etiquette, which is common in this field of creative scientific activity.
- The DNEP database program is located at the URL http://inforek.cvut.cz:8085/

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# Arrangement of Access Networks and Properties of Subscriber Lines

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The present trends in the area of teleinformatics lead to combination of various information sources and so-called multimedia services. If we want to provide the required services, we must ensure transmission of necessary information as a digital data stream with quite high transmission speed.

In the long-term perspective, satisfactory transmission capacity should be provided by optical fibers that will be used for implementation of all access network sections towards subscribers (i.e. to subscriber wall outlet). At present time, the optical fibers are usually terminated at curbs or in buildings and the signal is distributed towards subscribers through original metallic telephone lines; this situation will persist until all the metallic subscriber lines are replaced by optical fibers.

Exploitation of the existing metallic subscriber lines is possible thanks to xDSL technology. ADSL and VDSL connections preserve the original functionality of the analog telephone (or digital ISDN) lines, and besides that they provide fast data channels for multimedia services. ADSL offers downstream transmission speed up to 8 Mbps, which is enough for compressed video signal (digital TV broadcast). VDSL, on the other hand, satisfies demands for higher transmission speeds – up to tens of Mbps. The network infrastructure, however, must reflect the fact that the maximum distance will be only few kilometers and that there must be enough optical access network terminations with subsequent signal distribution through metallic pairs.

One of the crucial problems accompanying implementation of high-speed digital subscriber lines is their topology (arrangement), nonhomogenities and nonlinearities and their influence on other parameters, especially maximum possible transmission speed. Our goal is to examine the influence of nonhomogenities and nonlinearities on digital transmission over digital subscriber lines and to prepare theoretical framework that would enable optimum utilization of symmetric pairs in access networks; one of the most interesting issues in the said area is that of so-called bridged taps, i.e. entities bringing tree and star topologies into subscriber lines. Another problem is coexistence of several xDSL systems in one multi-pair cable in access network, in the presence of crosstalk. The existing applications often use solutions, which are suitable for particular conditions but not after any significant change of circumstances.

Access networks implemented using cables with symmetric pairs usually have tree topology with hierarchical structure of distribution units, from an exchange towards subscribers. The resulting structure in particular cases may be very complicated; thus, for the purposes of simulations and comparation of basic VDSL application methods, simplified model with linear arrangement of cable lines is used where individual lines with modems come out from particular nodes (distribution units).

When ditributive topology of the subscriber access network is applied, the structure of traffic in the direction from provider towards subscriber (downstream) is dramatically different from that of traffic in the opposite direction (upstream). In the first case, the transmitters (LT) of individual systems are concentrated in one place; in the second one, on the other hand, the

transmitters (NT) are distributed along the cable. Hence, the conditions of transmission are different for each direction.

If we try to analyze possibilities for simultaneous operation of various xDSL systems in one multi-pair cable, we need to know power spectral density (PSD) of all coexisting transmission systems. For VDSL, maximum PSD value is set to –60 dBm/Hz in the entire frequency band used. This value, however, may be lower due to limitation of transmission power (Power Back-Off – PBO) which is used for prevention of mutual interference among individual VDSL systems or, possibly, ADSL systems operating in the same cable. Interference between VDSL and ADSL may be prevented by shifting the lower VDSL band margin above 1.1 MHz.

Without limiting the output power, constant PSD of –60 dBm/Hz is presumed. The transmitted signal is weakened by attenuation of the line resulting in various level of received signal PSD in various distances from line termination (LT). Moreover, noise caused by crosstalk from all other VDSL systems operating in the same cable is added to signal. PSD of the received signal and PSD of the received noise, i.e. signal to noise ratio, influences the maximum possible transmission speed of the VDSL system in the specific location, i.e. specific distance from line termination.

Line terminations (LT) of all VDSL systems in one cable are situated in a single point. Thus, PSD of signal received in a specific distance from LT will be equal for all systems, providing that initial output PSD is equal as well. In the case of distributive topology will line terminations (LT) in a longer distance receive signal with lower PSD than the closer ones. The crosstalk from other systems, on the other hand, will be also lower because it is attenuated due to transmission function of the cable as well. Maximum possible transmission speed in the downstream direction will decrease along with increasing distance between line and network terminations of the examined system (it is influenced by increasing attenuation of cables especially for higher frequencies). It would be possible to increase the transmission speed of far systems by decreasing disturbance from other VDSL systems – we could decrease the transmission output power of the near systems, while line terminations of far systems would continue transmitting with maximum output power; this would decrease signal to noise ratio of the nearest systems and subsequently their transmission speeds, but the overall transmission speed of all engaged systems would remain virtually constant. Thus, limiting the transmission output power in the downstream direction does not introduce any significant benefit.

The situation in the upstream direction is different. Without limiting the output power, the network terminations (NT) of all VDSL systems will transmit with maximum power. The values of PSD for signals received by particular line terminations (LT) will be in the case of distributive topology quite varying. While the signals from near VDSL modems will have almost original level, those from far modems will be significantly lower because of line attenuation. If the nearest modem would really transmit with maximum output power, the far modems would be drastically disturbed as their signals come to LT inputs already substantially attenuated; their function would be significantly affected – almost disabled – due to small signal to noise ratio. Thus, it is desirable that near modems transmit with that output power which just ensures the required transmission speed.

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# Presentation of Results in Impulse Noise and Education

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## 1. Introduction

Within last two years, extensive scientific works dealing with problems of impulse noise in xDSL systems originated at the Department of Telecommunication Engineering. Our team consisting of three members has been active in the said field. The research is partly supported by various grants. Thanks to this support, we could perform a series of measurements besides theoretical work, using modern (and expensive) equipment. Some of the research results have been implemented to education in the engineering and doctoral stages.

## 2. ADSL Systems

The metallic access networks have been recently using a variety of technical means that enable fast data transmission. The whole family of such systems is called xDSL. This category covers especially the following systems: ADSL (Asymmetric Digital Subscriber Line), VDSL (Very High-Speed Digital Subscriber Line), HDSL (High Bitrate Digital Subscriber Line) and other similar ones.

The following discussion is focused on ADSL technology, since ADSL (and derived VDSL) systems exclusively have implemented a special protection against effects of impulse noise.

## 3. Impulse Noise

Impulse noise is another component of interference in modern transmission systems. It is generated by various sources that undergo short transient states (for example in electric distribution systems for lighting, home appliances etc.) and also by telephone subscriber lines realized within one cable (because of loop interruptions and ringing). The impulse noise from telephone sets connected to the same pair as ADSL device and separated only by filter (splitter) may be extremely strong. These negative effects may cause error bursts by digital transmission. Methods employing forward error correction (FEC) and data interleaving are used to lower the negative impacts of impulse noise.

Most important sources of impulse noise are various electric devices installed in the same building as the subscriber part of ADSL (ATU-R) - motors (in elevators, air conditioning, ventilators) and other equipment (faders etc.). The key parameter of these sources of impulse noise (and the subsequent error rate of influenced ADSL system) is their position relatively to ATU-R. We have verified experimentally that impulse noise injected into data link close to ATU-R (about 100 m) causes major rise of error rate, but the same impulse noise injected at the distance of about 2 km has no effect on the data.

## 4. Action against Impulse Noise

There are three independent actions commonly undertaken in ADSL systems for error detection and correction, two of them intended especially for protection against impulse noise.

Common error detection employs cyclic redundant code. This is a universal solution that guarantees protection of a data link against errors originating under various influences.

Application of Reed-Solomon code enables error correction in data receiver. We can say, in simplified way, that the number of bytes that may be corrected using Reed-Solomon code is

half then the number of used control bytes. For example, within 16 control bytes there can be 8 erroneous, while the errors may be of burst nature. This method of error correction is very effective thanks to its low redundancy (about 7 per cent in this case). The efficient protection against error bursts determines the Reed-Solomon code for use in ADSL systems where undesirable effects of impulse noise must be eliminated.
The third method - interleaving - is universal one, based on distribution of data elements in time; thus, probability of error burst is substantially decreased.

**5. Impact on Education**

Our team has prepared quite extensive series of laboratory measurements that are based on the research results. These measurements have been taken into regular syllabus of "Transmission Systems" curriculum and we consider their application to the "Fundaments of Electromagnetic Compatibility". Besides that, semester and diploma works are being prepared. Thus, students can profit from the scientific research results and use them for their own work and engineering education.
From 1998, we have been implementing new scientific knowledge concerning xDSL access systems into education. The first one was HDSL, followed by other development steps according to successive standardization. The curricula, however, had only informative character without theoretical analysis or practical laboratory measurements. We were able change that situation thanks to deep theoretical study of the area, which became a part of several dissertation theses and subsequently of some innovated curricula. Purchasing the appropriate equipment for our laboratories became the second milestone.
Practical education employing xDSL systems will be possible thanks to supplementary equipment from ZyXEL company (particularly concentrator, switch, router and ADSL modems). Besides that we have HDSL converters and SHDSL devices for peer-to-peer LAN connection. We also dispose of necessary measuring technology, cables (approaching real conditions) and noise simulators.
In this academic year we update education in xDSL area on the base of experience from the mentioned project. We have obtained support from the Fund for Development of Universities. Let us explain the further innovations in the following paragraphs.

**7. Conclusion**

By joining scientific research with practical measurements in the area of high-speed data technologies we gradually succeed to innovate and update the respective curricula, especially in their practical parts. In the future we expect even more support (technical, personal and financial) from our industrial partners and grant agencies, so that we can introduce our students to the most current trends.
Tělo příspěvku

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# Simulation of Natural Environment in Virtual Reality

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Our project is focused on an experimental web-based physical environment for teaching and testing. The application named Nautilus has been developed using Virtual Reality Modeling Language (VRML) and Java language with two special libraries: DILEWA [1] and Vrmlworld [2]. Although the resulting system is intended for low-level virtual reality systems without any specialized hardware support, it is powerful enough to accurately simulate various situations and scenarios. Currently implemented multi-user environment for training and testing of yacht captains serves as an experimental workbench for creation of general applications where a developer combines a simulated environment of simpler simulation elements. Design and implementation of the system are presented together with several practical observations concerning efficiency of the real-time rendering and the level of implementation difficulty.

There are many web-based applications that visualize 3D environment. This paper describes the main innovative characteristic of our application which is fusion of four features into one product: Web-based 3D visualization, multi-user environment, simulation process preprocessing, and possibility to extend or change the scene using plug-in system (our product is not just a yacht simulator; if we change physical objects and effects, we can get for example a train simulator). It is quite difficult to find a comparable web-based 3D system as various authors often focus on description of the visualized effect and the visualization itself (to make it as good as possible), but do not pay attention to other problems (management of a scene, computation etc.).

Related application presented by Humusoft [3] company uses Simulink for computation of simulation and VRML for visualization. Both parts are interconnected through their Virtual Reality Toolbox (sold worldwide by The Mathworks, Inc.). This solution, however, does not take advantage of VRML scripts, does not support multi user scenes and requires special software.

The novelty of our approach is the architecture of scene plug-ins and their universal interface that allows to create models of objects or effects independently from the development of the Nautilus environment itself (teamwork design). Next asset is splitting of computation of the simulation into two phases (preprocessing of samples and their use). The developed application uses standards (VRML, Java), publicly available software tools (editors, compilers) and libraries developed at our department (some parts are used for pedagogical purposes too). Thus, the final program is very cheap, portable to various platforms and easily extendable for new models and functionality. Currently, our goal is to rapidly increase the number of plug-in modules (new physical objects, swinging on the waves, sun traveling on the sky, wind effects – especially to yachts) and to make preprocessing phase more user-friendly.

Architecture based on plug-ins is advantageous from the point of simple scene management, easy extensibility and large adaptability. Plug-ins communicate with the base through an interface that is represented by a table of variables. These variables are divided into four categories: static variables (convex envelope), variables for simulation (dependence of

speed on the speed of wind), variables with low frequency of changes (sun intensity), and finally variables with high frequency of changes (position and orientation of physical objects).

Plug-in of type "Object" is determined for representation of a physical object. It contains two types of data. The first one is the model of this object. All these models are described in VRML language. The second one is information describing the object from the perspective of simulation (parameters concerning physical property of objects: trajectory, speed, dynamics, formulas for simulation of effect on object, etc.) The data are in form of n-dimensional matrixes of constants. All of these parameters are obtained from preprocessing of full simulation of ship model in standalone application Dynast [4]. All of these parameters are used for real-time but also very precise simulation.

Plug-in of type "Effect" is determined for representation of nature phenomena. It contains three types of data. The first are models of the effects (model of cloud etc.). Such models are written in VRML language again. The second one is information that describes phenomena from the viewpoint of simulation (specialization of effect behavior). These data are in the form of matrix of constants. The third type of data is expression of dependencies among the phenomena (e.g. how the wind influences waves). Simulated environmental effects can be divided into two basic groups - Global effect affecting all objects in the scene, and local affect with impact only on some objects. By force of local effects can be solved interaction between two objects as well. Simulation of the complete natural environment is very demanding on computation so that it is not usable for our real-time visualization purposes. So that we implemented a tool similar to LOD (Level of Detail) – tool called Level of Simulation Precision (LOSP) that we use for faster visualization. It is based on this idea: The smaller the impact on the simulated object, the bigger inaccuracy can we make in computation of this effect, which means the smaller computations demands. Modification of the accuracy of computation can be also used for compensation of demand of the simulation computation so that the visualization of simulation would run in real-time, even if at the cost of lower authenticity of the simulation.

To make physical modeling easier, Herman Mann and his team have many years ago developed a simulation package called Dynast. Now it can be easily used as a physical modeling toolbox for MATLAB, even through the Internet. Dynast allows to set up models of engineering systems from system parts in a kit-like fashion. Models are based on a mere inspection of the real systems in the same way in which the systems are assembled from real components, without forming any equations or graphs. Dynast formulates all the equations respecting the physical laws governing mutual energetic interactions between the components automatically.

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# Optimized Mobile Robot Path Planning Methods

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The path planning task belongs to the basic class of problems solved by autonomous mobile systems (robots) expected to execute motions through an operating environment. Motion planning problems can be classified into three major categories: go-to-goal, mapping, and coverage. Go-to-goal task presents planning a path between two pre-determined locations in the environment to achieve the goal position. This task is fundamental for accomplishing the higher level tasks (e.g. object manipulations, assembly tasks, etc.) The mapping (environment exploration) refers to an incremental construction of a geometric structure (map) which the robot uses later while planning it's actions. Coverage path planning (also referred to as the autonomous cleaning task) has to design a a path that the robot has to pass in order to completely cover all points of a given region .

The typical target fields for application of such intelligent autonomous systems are supermarkets, large office buildings, industrial and production spaces, etc. However, these may also contain a wide variety of static objects (obstacles) different in size and shape. Moreover, these spaces can also be accessed by humans, which brings up a problem of moving objects. The situation setup has also specific constraints (given by purely economic reasons). Usually there are not allowed any additional installations which might support the localization of the robot like active beacons, passive markers or any other "artificial" landmarks. Therefore, the robot has to be navigated autonomously, and rely purely on environment features during the localization process. These features can be obtained from observations of the environment. However, just the navigation combined with planning in the working space with a known structure is not sufficient for a successful operation of the robot. The Robot also should be able to take into acount various types of obstacles while travelling in the environment. This mainly incorporates problems of handling situations with unknown obstacles, which can modify the path plan execution.

Our research was originally motivated by the path planning task. Later we found interesting a more specific problem of the path planning with a complete coverage, thus our research activities were focused on this topic. The path planning and path tracking strategies for a mobile robot navigation are highly dependent on the target applications. Most of those applications,(e.g. floor cleaning in large public places or industrial areas etc.), when required to be carried out by autonomous mobile robots, raise very interesting research challenges. The cleaning task requires a special kind of trajectory, in order to cover all the unoccupied areas in the specified environment. Paths that comply with this requirement are known as the paths of complete (total) coverage. Some methods of generating the path of complete coverage based on a map of the area to be covered, have been presented recently . From the general point of view, the complete coverage path planning involves not only the cleaning task, but also many other applications i.e. spraying car coachwork in automobile industry, pocket milling in NC machining, gardens lawn mowing , automatic cropping in agriculture, bridge inspection, demining missions etc.

In literature, we found a variety of coverage algorithms that use different approaches and operate with certain assumptions about the structure of the environment and the sensors utilized by mobile robot. Based on the knowledge obtained from numerous publications, we were able to formulate and implement our own ideas in a form of the border expansion method. The border expansion algoritm was designed for mobile robots which are able to perform forward and backward motions and to turn on the spot (i.e. turning around its vertical central axis of rotation). The border expansion method uses expanding the object boundaries to generate a set of roads, that subsequently provide the complete coverage of the given free area. Each contour represents a simple closed trajectory (road) of the robot. Contours are approximated by connected straight-line segments (polygons). In such polygonal contour, each point that connects two lines represents a possible transition node between two roads. By defining a limited distance between two nodes, (with each of them on a different road), we can obtain a set of possible transitions between two neghboring roads for each roadHowever, the issue is how to find an optimal sequence of transitions between the roads.

Therefore, the present research has been focused on optimizing the border expansion method, aimed to reach an optimal sequence of transitions between the roads and more optimal path plan in comparison to the other known methods.

To compare the quality of path plans generated by different methods, we also established a "PC" (past cost) criterium that mathematically describes the path plan quality in sense of path segment lengths, number of turns, size of turning angles etc.

Suggested methods and their optimizations were implemented in MATLAB and experimentaly verified on real data sets gathered by experimental mobile robot (GL-bot), utilizing laser rangefinder sensors and camera.

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# Simultaneous Localization and Map Building for Intelligent Mobile Robotics

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In order to explore a work environment and to build a model of the environment, a robot has to fulfill two fundamental tasks: (1) to localize its position based on observations and (2) to recover the environment shape and structure. Both of the mentioned tasks are complementary and usually can not be solved separately.

Local navigation systems (e.g dead-reckoning system based on odometry) of mobile robots typically provide sufficient accuracy only in short-term periods; therefore an independent localization technique has to be applied. Most localization techniques use some existing maps of the environment, which can be obtained either in the form of a CAD model or can be automatically built by a mobile robot itself during exploration of the work environment.

The map building methods usually rely on range-measurements (laser range-finder, sonar, etc.) of the environment. In the local sensor-based map, environment of the robot is often represented by an occupancy grid. It is a regular grid, where each cell represents a probability that the particular space is occupied. The probability is updated by accumulated sensor readings.

The motivation of our work is to increase robustness and reliability of environment sensing. Sonar sensors have usually low precision, while laser range-finders provide information about surrounding environment and obstacles only in one horizontal slice. Our effort has been targeted on utilization of a visual image of an environment using a camera for obstacle detection detection of obstacles and free space marking via color of the floor. The inverse perspective transformation is used to get a 2D map of the environment. This map is transformed to the occupancy grid using a color probability model of the floor. The probability model is a matrix in which each color of HSV color space represents a certain probability of a free space. Updating of the occupancy grid is performed by the Bayes formula.

Furthermore, the occupancy grid can be easily used for fusing the camera data with the range finder measurements. On the other hand, the range finder data can be also used to calibrate the probability profiles for the camera preprocessing or for building very accurate 2D maps of the robot environment.

An important precondition for a successful building and updating robotic maps is the accurate determination of the actual position of the robot. A common sensor for the mobile robot localization is usually considered to be the odometry measurement. Unfortunately, the odometer itself suffers from large and cumulative errors due to wheel slippage. Therefore, there have been developed many approaches for detection and correction of the odometry errors. Localization methods are usually based on laser range-finger scan matching technique. Scan matching techniques estimate robot motion by computation of shift and rotation between two succeeding range-scans.

Our method for correction of odometric data errors employs inertial sensors, specifically accelerometers. The designed method solves in particular some issues associated

with the wheel slippage. The core idea of the approach is based on a different essence of errors, which both the odometry and the accelerometer provide. The odometer typically fails in relatively short time intervals mainly during acceleration or slowing down. On the other hand, these situations can be successfully handled by an accelerometer because the current sensor parameters for double integration of acceleration are known at the time (in particular its offset).

The requirement of a double integration is necessary for usage an inertial sensor (accelerometer) as a supporting position sensor. The determination of the actual sensor offset has a direct impact on the precision of the computed position. Therefore, a crucial part of our approach is to estimate the sensor offset. The estimation of the offset is performed by means of continuous fitting integrated trajectory to odometry. If odometry slippage appears, the estimated offset is meaningfully deviated. If an extremely deviated offset is detected, the current odometry measurement is marked as an odometry-unreliable and the evaluation of traveled distance in a certain time interval is completely switched to the accelerometer. The accelerometer offset has to be evaluated differently in this case; an extrapolation of the last reliable offset values before slippage is applied.

The odometer and the accelerometer can serve as supplementary sensing tools, substituting each other if desired. The long-term precision depends on calibration of the odometer, nevertheless the local odometer error induced by wheel slippage could possibly be successfully detected and treated using the accelerometer.

Practical behavior and experimental results of the designed methods were obtained with the experimental mobile robot (GLbot) in real indoor environments. There have been performed trials in the hall with artificial obstacles, office and similar indoor environments. Results of the localization method were also tested using the data gathered from a real train navigation system. The used dataset includes not only odometric and accelerometric data but also GPS data, which can be utilized as very good reference information for evaluating the precision of the designed method.

Further research is supposed to be targeted on improvement of the estimation mechanism for the acceleration sensor offset with the objective to achieve a higher precision in path integration.

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# Next Generation Network

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In the present-day world of telecommunication networks the problem of convergences especially dominates (the integration of voice, data and multimedia transfers). Convergence presents three seemingly independent areas of integration: electronic media, telecommunications and computer networks. By means of the combination of information technologies there is a rise in number of terms and conceptions like ICT (Information and Communication Technology), NGN (Next Generation Networks) or teleinformatics. The rise in integrated sector of information and communication technology has many reasons. Among the most important reasons belong to the fast development in the areas of information technology, coming new program instruments, new systems of speech and image processing (digital TV and IP telephony), setting-on of third generation mobile systems or broadband services exploitation for multimedia transfers.

The term NGN may be understood like a high-speed data network that works on the switching principle of packets or cells and is intended for providing voice, data and multimedia services. In principle there are three possible ways to create Next Generation Network:

- To continue creating separate networks without their active change, which means lower investment exploitation, providing less flexibility for value-added services, and lower competitive advantage.
- To continue creating separate networks with their adaptation according to transformative conditions in the market. Technology changes separate platforms should provide larger flexibility and establishing rate, and modification of existing services. This solution can hardly offer quick preparation and establishing of added-value services.
- To build the Next Generation Network and fully use the technologies convergence. Existing technologies and platforms must be integrated into NGN so that they can fully use their strong aspects. This will also ensure the former investments of the telecommunication providers in this case, but they will also offer essentially larger value both for the provider and for the customer.

NGN is possible to define in many ways. In light of the technical aspect it is possible to define NGN like a system whose part is a network transport, an integrated access network, a multiservice network, a mediation network, an operating system, a service part, and an application part. The function of the transport network is providing a high-speed connection among single localities namely both within a wide network type WAN (Wide Area Network) and within a large agglomeration. The most important technologies in the transport network are SDH (Synchronous Digital Hierarchy) and WDM (Wavelength Division Multiplex). The integrated access network provides a transparent access point for the customer in any locality, with any rate, namely with using of optical, metallic, wireless or mobile systems. The main technologies in this network are e.g. xDSL (x Digital Subscriber Line), FTTX (Fibre to the …), PSTN/ISDN (Public Switched Telephone Network/Integrated Services Digital Network), plus wireless and mobile systems. The multiservice network must provide transparency, appropriate quality, security and reliability for single services. Key technologies in multiservice networks are IP (Internet Protocol), ATM (Asynchronous Transfer Mode), MPLS (MultiProtocol Label Switching), and Frame Relay. The mediation

network provides converting voice and packet services, converting signalling protocols, switching, address protocols etc. It is created by gateway type components. The NGN operating system is one of the most important parts of NGN, which is created by components. By means of the components, the establishment of the connection is controlled through the network infrastructure. The component Session/Control Manager is intended for this purpose. It controls the mediation network and by means of the SS7 (Signalling System, number 7) gateway type equipment, it cooperates with the STP (Signalling Transfer Point) within the SS7 network. The main NGN control infrastructure features are its logic and in a large extent its physical independence on multiservice data network, meditation network, and PSTN/ISDN network. The service and application part provides support of controlling services and interfaces towards customers. Furthermore for single customers it provides services such as setting-up a personal profile of service without provider interference through a web interface.

The main technologies of the multiservice network are ATM and IP. Quality of services (QoS) in IP technology is not fully stabilized so far and it is continally developing.

Earlier there was the aim to establish analogy for QoS in ATM, however it brings considerable problems in regards to the principle difference between conception IP and ATM, which is in that ATM is in contrast to an IP connection oriented environment and thus it is possible to explicitly identify a concrete data stream and consequently to allocate certain parameters to it. Currently there are two main accesses for the implementation of QoS for a computer network: Integrated Services (IntServ) a Differentiated Services (DiffServ). Another possibility is the design of protocols that do not require a guarantee of transfer quality (constant delay and bandwith). The base for security traffic of the audiovisual transfer is the H.323 standard in networks like Ethernet or Token Ring. The next possibility is the usage of ATM technology and its services for transfer of IP protocol. There are some methods to solve it: emulation link layer transferring IP packets – LANE (LAN Emulation), simple transfer of IP protocol in ATM cells (Classical IP over ATM) or transparent transfer of any protocol in a network layer or higher – MPOA (Multiprotocol Over ATM). MPLS (resp. MPλS) is another very prospective method for usage of better properties of ATM technology and IP protocol. The disadvantage of MPLS technology is that the standardization has not been finalized.

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# Depth-of-Field Rendering for Point-Based Object

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The ability to render the depth-of-field effect is an important feature of any image synthesis algorithm. Depth-of-field increases the naturalness of the image, since both optical systems in cameras and in human eye have lens of final aperture and do not produce perfectly focused images. Depth-of-field is also an important depth cue that helps humans to perceive the spatial configuration of a scene and is also important in stereoscopic image generation.

Depth-of-field is inherent to camera models with lens of finite aperture, however in computer graphics the most commonly used camera model is the *pinhole camera,* where the lens is supposed to be infinitely small. The pinhole camera model produces images that are in sharp focus in any distance from the viewer. This can be a desired feature (e.g. for technical visualizations), but often a more realistic 3D image including depth-of-field is required.

The effect of depth-of-field is, that out-of-focus points in 3D space form circular patterns (circle of confusion) in the image plane. The most common, *post-filtering* algorithms for depth-of-field rendering [2], generate the depth-of-field in a post-processing step: first a pinhole-camera image is generated and then a post processing step turns the out-of-focus pixels into the circles of confusion. This algorithm suffers from the *intensity leakage* (*e.g.* blurred background leaks into focused object in foreground) and does not handle the *partial occlusion* (visibility of objects changes for different positions on the lens of final aperture). Several algorithms that solve those problems exist, but they are currently slow, especially for large amounts of depth-blur.

We present a new, fast depth-of-field rendering algorithm for point-based objects. The *point-based graphics* has recently gained a lot of research focus. In point-based modeling the 3D objects are represented by a cloud of points in 3D space with no connectivity information among them. The reasons for using a point-based representation are manifold. For example the point-based representation is a natural output of the 3D scanning devices that are becoming to a widespread use not only in the research, but also in practical applications. Also the rendering is faster for points than for triangles if the modeled shape is highly detailed.

There are more approaches to render the points as continuous surface. Our algorithm builds on top of *surface splatting* [3,4]. In this method, every point of the point-based representation of a 3D objects is displayed as a “splat” or “footprint” on the screen. The splats overlap in screen space and the weighted averages of splats’ contributions to different pixels are used for *high*

*quality texture antialiasing*. Another features of surface splatting that we can directly profit from are order-independent transparency and edge antialiasing.

Our algorithm generates depth-of-field by a filtering, as the post-filtering algorithms do. However, we filter the individual splats before producing the final image. This actually decouples the visibility determination from the depth-of-field rendering and allows us to handle the partial occlusion and to avoid the intensity leakage. The algorithm also allows for depth-of field rendering in presence of transparent surfaces.

To speed-up the depth-of-field rendering, we use the concept of level-of-detail. We profit from the fact, that the level-of-detail hierarchies prefilter the surface representation for coarser levels. When a large amount of filtering is required to produce the depth-of-field, we use the coarser level-of-detail hierarchy level, thus saving the computational resources. With this technique the speed of the algorithm is practically independent of the amount of depth-blur. This is a big advantage over the existing algorithms, where the rendering speed drops down with the square of the aperture diameter used for simulating the depth-of-field effect.

In our work [1], we present a mathematical analysis extending the surface splatting to include the depth-of-field rendering ability. We also present an analysis allowing to use the level-of-detail as the means for depth-of-field rendering, including the criterions for level-of-detail selection. We give the implementation of the algorithm, and a discussion of practical issues arising from the implementation as the normalization of the splats' contributions, surface reconstruction from the depth-blurred splats and shading. The timings obtained from the implementation confirm the independence of the rendering time on the amount of depth-blur.

The drawbacks of the algorithm are high sensitivity to the regularity of sample positions on the surface of point-based object and occasional artifacts due to the incorrect surface reconstruction.

As a future work we want to implement the depth-of-field rendering algorithm for volume rendering, which should be a straightforward extension of the algorithm we developed for point-based surfaces. We also want to develop a specialized point-processing tool, which could be used for normalization of point-based objects.

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# BR(1) Scheme for Fault-Tolerant Multicast

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Tree-topology structures are often used to connect distributed components of decentralized systems and applications. As trees are sensitive to even single node failure disrupting the connection, it is usually necessary to deploy efficient protocols to achieve higher reliability of communication. In this paper, we present a fault-tolerant scheme for repair of single node failures in multi-directional trees. The scheme is based on cyclic structures providing alternative paths to eliminate faulty nodes and reroute the traffic. Our scheme is independent on message source and direction in the tree, provides basis for on-the-fly repair and can be used as a platform for various strategies of reconnection of tree partitions. It only requires an underlying infrastructure providing reliable routing service. The scheme can be used universally in all systems using tree-based overlay networks for communication among components.

**Model and notations.** The underlying network we consider here is a network providing routing service modeled as a graph $SN = (V, E)$ where $V$ is a finite set of vertices representing nodes; $E$ is a finite set of edges, representing links between nodes in the network. A multicast group $MG$, i.e. set of nodes receiving multicast messages, is an arbitrary subset of nodes from $V$; $MG = \{n_i; i = 1, \ldots, k; n_i \in V\}$ where $n_i$ are nodes from $SN$ that are to exchange information and $k = |MG|$ is multicast group size. The overlay multicast tree is modeled as a graph $MT = (MG, CE)$ where $CE$ is set of *core tree edges* - virtual links (built on top of $SN$) connecting nodes in $MG$. We expect that multicast group (thus either multicast tree) dynamically adapts to current network state and user requirements.

Besides $SN$-unique ID, each member of multicast tree $MT$ may be assigned with $MT$-specific *hierarchical identifier* HID. Identifier $HID_n^c$ of node $n$ related to node $c$ in $MT$ tree is concatenation of IDs of nodes on the only path in $MT$ from node $c$ to $n$. Functions *pref* (i, $HID_n^c$) and *suff* (i, $HID_n^c$) denote prefix and suffix of length i of identifier $HID_n^c$ and *gcp* ($HID_{n_1}^c$, $HID_{n_2}^c$) denotes *the greatest common prefix* of HIDs of nodes $n_1$ and $n_2$.

**Bypass ring *BR*(1).** Let $MT = (MG, CE)$ be the tree-topology communication network. Bypass ring $BR_c(1)$ of radius 1 centered at node $c \in MG$ is a circuit consisting of sequence of nodes $n_1, n_2, \ldots, n_{t+1} \in MG$, $n_1 = n_{t+1}$ such that: (1.1) For all $n_i$, $i = 1, \ldots, t$, distance $d(n_i, c) = 1$ and (1.2) $HID_{n_i}^c < HID_{n_{i+1}}^c$ for $i = 1, \ldots, t$-1.

A directed *bypass edge* $be_i = (n_i, n_{i+1})$ (for all $i = 1, \ldots, t$) is virtual link from node $n_i$ to node $n_{i+1}$, where $n_i$ is the initial node and $n_{i+1}$ the terminal node of $be_i$. Integration of all bypass rings and $MT$ graph creates an *extended multicast tree* $EMT = (MG, CE \cup BE)$ where $CE$ is set of core tree edges of original $MT$ and $BE$ is set of all bypass edges. $MT$ is then a spanning tree of $EMT$.

**Failure repair.** The aim of node failure repair is to create new core tree edges to connect tree partitions using bypass ring and restore the multicast tree $MT$ to connected and consistent

state. Let node $c$ be the faulty node in $EMT = (MG, CE \cup BE)$ and $BR_c(1)$ its bypass ring consisting of nodes $n_1, \ldots, n_t$. Define function $R(n_i)$ for all $n_i$, $i = 1, \ldots, t$ as follows: (2.1) $R(n_i) = HID^c_{n_f}$, if node $n_i$ has been first notified about node $c$ failure by node $n_f$; (2.2) $R(n_i)$ is undefined if node $n_i$ does not know about node $c$ failure yet. Define relation $\rightarrow$: $n_i \rightarrow n_j$ if and only if: (3.1) $(n_i, n_j)$ is bypass edge of $BR_c(1)$ and (3.2) $R(n_i)$ is defined and (3.3) $R(n_i) < R(n_j)$ or $R(n_j)$ is not defined.

The basic idea behind the repair process is that each neighbor $n_i$ of faulty node $c$ detecting the failure consecutively iterates along the ring $BR_c(1)$ through nodes $n_{i_1}, n_{i_2}, \ldots \in BR_c(1)$ ($n_{i_1}$ is right ring-neighbor of $n_i = n_{i_0}$) until it reaches a node $n_{i_p}$ that has already been notified about failure (i.e., $R(n_{i_p})$ is defined). At each hop $n_{i_q}$, $1 ? q ? p$, it is determined if $n_{i_{q-1}} \rightarrow n_{i_q}$ and $n_{i_q}$ is notified about failure of node $c$. After node $n_{i_q}$ has been notified and if $n_{i_{q-1}} \rightarrow n_{i_q}$ then a new core tree edge $ce_{i_q} = (n_{i_q}, n_{i_r})$ is constructed with properties (4.1) $r < q$, (4.2) $n_{i_{q-1}} \rightarrow n_{i_q}$ and (4.3) there is a path $n_{i_q}, n_{i_r}, \ldots, n_i$ in new $MT$.

After all nodes $n_1, \ldots, n_t \in BR_c(1)$ have been notified, the relation $\rightarrow$ between incident nodes of all bypass edges $e_i$ is known. With the $BR(1)$ definition of bypass ring and $\rightarrow$ relation, it can be proven that relation $\rightarrow$ on bypass ring has the following properties (5.1) relation $\rightarrow$ is not cyclic and (5.2) there is only one bypass edge $be_i=(n_u, n_v) \in BR_c(1)$ such that $n_u \rightarrow n_v$ is not true. With this lemma and properties (4.1) – (4.3) of newly constructed core tree edges, we can get the result: (6.1) the repaired $MT$ connects all partitions induced by a node failure; (6.2) the repaired $MT$ is a tree graph.

**Conclusion.** We have described $BR(1)$ scheme for failure recovery in multicast tree based on redundant bypass rings constructed at the distance d=1 around nodes in the tree. The scheme is independent on message source and direction in the tree We have formally defined $BR(1)$ rings and shown how single failure repair is done providing two important properties: all tree partitions induced by faulty nodes are reconnected and repaired network does not contain cycles. The $BR(1)$ scheme is a special case of general $BR(r)$ scheme capable of multiple failure repair in tree-based structures. $BR(r)$ scheme is described in [1], for example.

Our future work in this area will include simulation of standard tree traffic patterns, evaluation of performance of the scheme under various workloads and comparison of effectiveness of various strategies for partition reconnection in terms of extern tree optimization requirements.

This work was elaborated as a part of Gaston project at the Czech Technical University in Prague. Gaston [2], [3] is peer-to-peer large-scale file system designed to provide fault-tolerant and highly available file service.

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# Implementation of Standardized Processing of Personal Data

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The organisation system of CTU isn't similar to common hierarchical systems of commercial firms. University is partly directive institution and partly servicing organisation for faculties. This is the main reason for difficulties with collecting of information in this heterogeneous structure of university. The working process brought a lot of new experiences for members of project team and will help us in future projects.

It is necessary to describe situation in CTU before starting of this project. CTU is a system of 6 faculties, 3 institutes and 7 additional research and service bodies. All of them used different systems for presentation of contact data. They were based on different technologies and different organisational principles. The functionality and actualities of system depended on importance for faculty management. There was not any central system for collecting, analysing and presenting contact information on university level.

The objective of the project was to analyse original systems, technological designs and designs of database structures. It was necessary to connect new system to present information components and design user-friendly system of administration. The next objective of the project was to offer relevant information to the IT administrators of CTU for theirs local systems. Due to receiving no incoming information from higher levels of organization local administrators built up local duplicate and independent systems with different ways of receiving information. The consequences were different data in the systems, higher cost of administration system and mess for users because there is not any simple way to change data records.

Due to different technologies and data models used in faculties was impossible to design system for collecting data only. There was another basic problem with combination of identical personal records from different primary independent systems. Our team decided to employ existing system of SSU (Composed System of Users Administration) as a base for new database. The SSU is based on LDAP (Light Directory Access Protocol) with tree structure. This type of database is ideal for quick access to data searching and reading. The slow access to recording into database is not important. This technology was used at FEE (Faculty of Electrical Engineering) and was plan to be used at Faculty of Civil Engineering and Faculty of Mechanical Engineering.

The system is based on reading and combination of personal data from four components of IS CTU (Information System of Czech Technical University) where primary personal data are recorded. It is PMSV (Personality, Sales and Social Relations) application with all CTU staff records and KOS (Study Application) with records of all students at CTU. The KOS has three independent installations. They are administrated by CIC (Computer and Information Centre), FME and FEE. The data are linked with unique identifier and record in SSU. We collect Name, Surname, Head Title, Back Title, Personal number, Position at university (student,

staff), Position at Faculty Department and validity of data. The system of priorities for combination of duplicity information was installed. The SSU system can read information from local authorization systems. We used predominately information from NDS in faculty Novell systems and Microsoft-Exchange system as exception.

Room, telephone, e-mail data and linkage to personal web presentation are common contact data presented with Internet by CTU. The analysis of local system detected that contact data were kept in the form of text entry in databases and were used in different data formats. Our team decided to base contact information on system of centrally administrated dials. These dials will be used as the node of IS CTU. We used primary sources of information from all segments of CTU. Unfortunately sometimes no information had been recorded at all or in any consistent formats. The information was not always up-to-date.

We built up two access types for receiving information, direct records to the database and imports from local LDAP databases. We programmed an access by web protocol for local administrators of contact information. Users can select items from dials and assign them to the personal data that have been read up before from personal systems. The uniform structure of records enable reading up of data form local LDAP databases and uniform linkage to the records of the central dial system. Users are allowed to join their own e-mail addresses from unconnected CTU mail servers.

We programmed the scripts for data export from SSU in xml format and in excel table format. It is used by accredited IT administrators for their local systems, by CTU management, for switchboard operators, for creating of all university reviews, for paper lists of telephone numbers and predominately for CTU web presentation.

The contact information in SSU system was fully integrated into IS CTU. The working process over this project brought a lot of new experience for our team. It is necessary to built up not only good technical solution of the task but also to find an optimal way for implementation of the new system and substitutions of current systems.

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# Extension of Parametric Design in Knowledge Modelling

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Knowledge modeling is a modern approach to writing intelligent computer programs that emphasizes preserving the structure of knowledge the program handles during its runtime and thus supports the so called *knowledge reusability*. Knowledge reusability has been under an intensive development in past decade. One of the products of this stream of investigation is the model of *parametric design*.

The parametric design methodology (see [1]) can be described by the following terms: *parameters*, *dependencies*, *constraints*, *requirements*, and *fixes*. Parameter values can be selected from the set of admissible values for particular parameter or computed by means of particular parameter dependencies $d_k$, i.e. the following holds $p_k=d_k(p_i, p_j, \ldots)$. Parameters can be limited by constraints $c_l$ in the form $c_l(p_i)\leq 0$, and/or by requirements $r_n$ in the form $r_n(p_i)\leq 0$. In case of violated parameter constraint or requirement, particular fix $f_m$ is applied to find the sufficient value for the parameter, i.e. $p_i=f_m(p_i)$. The set of all these subjects (i.e. parameters, dependencies, …) we refer to as *design network*. The goal is to find an assignment of values to all the parameters such that no constraint is violated and all requirements are satisfied. If any of the constraints is violated, i.e. the value of left-hand side of the constraint expression is greater than zero, or any of the requirements is not satisfied during the progress of the design procedure, appropriate fix is applied. The fix procedure modifies certain parameter's value in order to satisfy the violated constraint. Basically, this is a *task* definition from knowledge-level analysis point of view; it states *what* has to achieve. An algorithm from the *Propose&Revise* class of *problem solving methods* (PSM), for instance, can serve as one of the methods to satisfy this task goal; it specifies *how* the goal should be achieved.

A PSM can pursuit one of several strategies, e.g., a) *propose&check* (conclude a value for a parameter, then, if the parameter is constrained, check its constraint(s) and possibly evaluate appropriate fix), or b) *complete&revise* (conclude the values for all the parameters, then check the constraints and possibly evaluate fixes). However, in practice, the following two bottlenecks usually go in hand in both cases.

**Multiple fixes.** Often, to provide the model with sufficient power in resatisfying the constraints process, multiple fixes are coupled with a constraint. In such case, some fixes priority ordering must be specified. Usually, this priority ordering must be specified by an expert according to his/her experience.

**Type of fix.** The fix procedures can update the design network in various ways. For instance, *step-like* fix changes particular parameter from one value to another value and cannot be recalled to attempt at resatisfying the constraint. On the other hand, the *incremental* fix gradually sets the modified parameter to values generated very often by a simple linear strategy with a fixed step size until the relevant constraint is satisfied.

To overcome these aspects we propose the so called *sensitivity analysis* (see [1]). Sensitivity analysis allows to gain some more information on the dynamic behavior of the design network that can be exploited in designing a new PSM with more sophisticated algorithm. The sensitivity information can be stored in two kinds of a *sensitivity matrix*. First, let us designate all the parameters that does not depend on any other parameter, or whose

value can be directly modified by a fix by the term *key parameters*. Then the first matrix can be called *parameter sensitivity matrix* (Psm). Its columns correspond to the key parameters and the rows correspond to all the parameters. Its elements represent the sensitivity of a change of a regular parameter on a small change of particular key parameter. The column norms then show how the particular key parameter affects the rest of the design network. If we suppose that the more the design network is changed the more additional work will be necessary to satisfy all constraints (this is quite common and reasonable heuristics) then we can formulate the strategy for automatic fix rating based on sensitivity analysis: "The smaller the norm of a Psm column the smaller the rate of the fix that corresponds to that column and the more the fix is preferable."

The second matrix is *constraint sensitivity matrix* (Csm) with columns corresponding to *key parameters* and rows corresponding to all the constraints. The elements of this matrix represent the sensitivity of particular constraint on a small change of particular key parameter. If we regard the problem of satisfying the constraints dependent on parameters as $\mathbf{c}=f(\mathbf{p})\leq 0$ where **c** is a vector of constraints, **p** is a vector of key parameters, and $f$ is an unknown nonlinear function that underlies the design network, we can use e.g. a Newton method and locally rewrite the problem as $\mathbf{c}=\mathbf{Mp}$ where **M** is the Csm, i.e. the Jacobian. With this approach the linear strategy of proposing a new values for fixable parameters by incremental fixes can replaced by the direct utilization of Newton method that is certainly more relevant for dealing with nonlinear systems like real-world engineering design problems.

Both, automatic fix rating and utilization of Newton have been successfully tested on various engineering design cases: hydrodynamic pump design, bearing design, and well-known VT-elevator design (see [1, 2]). For example, when the automated fix rating was applied to the VT design, the number of iterations performed decreased from 625 to 218, and when applied to the bearing design it decreased from more than 8000 with fixes rated randomly to 32 with fixes rated according to our strategy.

Moreover, constraint sensitivity matrix can reveal effective combinations of fixes that, for example, affect only a subset of constraints leaving the rest of constraints untouched. The fix combinations correspond to the linear combination of the Csm columns with certain features. However, the method for systematic identification of such sufficient fix combinations is of a combinatorial type. To avoid a combinatorial explosion further research effort is necessary to develop a powerful strategy. However, the usefulness of such strategy is evident: it would provide one with a tool for partitioning the sensitivity matrix into diagonal set of smaller submatrices. In other words, it would enable one to decompose the whole engineering design procedure into a smaller and more easily tractable subtasks that could be possible to evaluate in parallel, i.e. it would provide a methodology for turning the traditional engineering design procedure into a concurrent one. The sensitivity analysis appears to be one of the promising approaches to the extremely complex problem of an engineering design process concurrentization.

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# Generalization of Min Cut Graph Algorithm for Concurrent Engineering

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Different people usually understand the term *concurrent engineering* in a different ways. Some researches regard this issue as a problem of communication and negotiation between groups of subject involved in the design process. This approach is known as multi-agent. Mono-agent approach studies the inherent structure of the design process, for example the nature of the iterative loops. Nevertheless, all these approaches have in common the statement that concurrent engineering design of a new product emphasizes shortening of initial and final phases of the product life-cycle. By initial phases we mean especially preliminary design computation, manufacturing and testing of prototype, production process design, the product manufacturing itself, assembly, distribution, etc. Final phases of the product life-cycle usually involves disposal and recycling, and possibly repair.

This paper discusses some aspects and provides some new ideas from the mono-agent approach to the problem of transforming the traditional design into a concurrent one (concurrentization). It is based on the knowledge level description of a engineering design process and it utilizes the so called *sensitivity analysis* as proposed in [1]. The objective is to find a robust methodology of partitioning of the whole portion of a complex design process into smaller more tractable subparts that could be possibly evaluated in parallel.

As the knowledge level model of the engineering design process the *parametric design* is used (see again [1] for its definition). Let us briefly summarize: the parametric design uses the terms *parameters*, *dependencies*, *constraints*, *requirements*, and *fixes* to describe and model the process of design; all these units form the so called *design network*. The sensitivity analysis is an extension to the parametric design knowledge model that includes information of the sensitivity of the rest of the design network (i.e. parameters and constraints) on the small changes in values of special parameters called *key parameters* (i.e., parameters that are not affected by any other parameters, or whose values can be affected directly by a fix). The sensitivity information can be stored in a *sensitivity matrix* whose columns correspond to the key parameters and the rows to the constraints. The elements of such matrix represent how the small change in a key parameter will affect a constraint.

The paper [1] provides some ideas on finding certain linear combinations of the sensitivity matrix columns to construct effective combinations of fixes that would influence only certain subset of constraints leaving the rest of them unaffected. Basically, this approach is in certain respect an attempt to decompose the sensitivity matrix (i.e., the design process itself) but possesses difficulties with the combinatorial explosion. Here, we will try to investigate an analogical approach that has the same objective but comes along a different way. We are looking for a partitioning of the original sensitivity matrix $\mathbf{M}$ into a small number $n$ of disjoint submatrices $\mathbf{M}_i$ that if all placed in one new matrix $\mathbf{A}$, it would be equivalent to the original sensitivity matrix $\mathbf{M}$ and the submatrices $\mathbf{M}_i$ would form a diagonal of the matrix $\mathbf{A}$. And since we suppose that the original matrix $\mathbf{M}$ approximates the behavior of the design network, the

partitioning of **M** would mean decomposing the whole design process into several design subtasks mutually separable with respect to the problem of satisfying the design constraints.

The question arises, how to partition the matrix **M**? Instead of trying to find sufficient linear combinations of the matrix **M** columns (i.e., the fix combinations) and building up the fix combinations from single fixes, which is combinatorically dangerous, we decided to explore the somehow inverse approach that lies in successive splitting of the matrix **M** into parts according to some criteria. We utilize the possibility of representing the sensitivity matrix **M** by a bipartite graph where the columns (i.e. the key parameters) are represented by one set of vertices, and the rows (i.e. the constraints) by the other set of vertices. Generally all the vertices from one set are connected by an edge to all the vertices in the other set with weights corresponding to the appropriate elements in **M**. Then using the algorithm of minimum cut (see [2]) we split such graph into two connected subpraphs removing edges such that the sum of their weights is minimized. However, this algorithm allows only positive real numbers as the weights of the edges. To develop an efficient and robust methodology for partitioning the engineering design process approximated by the sensitivity matrix, we need to reflect some other aspect relevant to our problem.

Let us imagine an simple situation: the matrix **M** could be partitioned very efficiently but there is an edge (or a small number of edges) in the underlying bipartite graph with a strong weight (i.e. matrix **M** possess an element indicating a strong sensitivity of the particular constraint on the particular key parameter). The edge with such weight cannot be neglected because there would be strong influence of one partition to another that would be "forgotten" by removing this edge. However, such influence can be modeled by some nonlinear function that can be embodied in the other partition. Then the partitioning would be possible without the loss of information. The trade off to be paid for this is an necessary extra computational effort to estimate the coefficients of the nonlinear substitute function. On the other hand, the benefits from dividing the complex design process onto two parallel subtasks are obvious.

The simple min-cut algorithm have been adapted to meet the needs of the concurrentization investigation and the enhanced min-cut algorithm have been developed. To construct the partitioning of the original matrix **M** into more than two partitions is straightforward by applying the enhanced min-cut algorithm successively. The initial framework of automated dividing of the engineering design process into smaller subtasks by means enhanced simple min-cut algorithm from graph theory has been presented here. The framework is based on the knowledge level description of the design procedure and utilizes the sensitivity analysis.

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# Interactive Creation and Retrieval of Graphical Information by Visually Impaired Users

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Introducing the Internet into every day life significantly expanded the opportunities for communication and information retrieval by people with disabilities. In the case of visually impaired people it is possible to gain access to the textual information provided for example through the Web technologies by enlarging text or converting the information to speech.

The problem arises for the visual based multimedia data (pictures, photographs, movies etc.) or very complex data structures (maps, 2D pictures, 3D models, scenes etc.). Providing the access to these types of data using only existing "classical" technologies and methods is in general very complicated and usually not very user friendly for the given class of users.

As the share of complex graphical information on the web steadily increases it is necessary to develop new methods that will provide an easy access to this type of information to visually impaired users. Our focus is placed on complex 2D pictures. The complexity of the description is based on the fact that besides the description of geometric properties of objects also additional non-geometric information (semantic description) is provided.

In all currently existing approaches mainly the geometrical description of 2D picture is processed and the semantic description of the picture is utilized very rarely.

Our solution to this problem is the extension of the solution to the problem of communication of visually impaired users with 2D information by means of a semantic description of pictures. The geometric description of a picture is more closely connected to the semantic description. The description itself is more complex - it describes miscellaneous object properties (object name, material etc.) including visual ones (color etc.) and relations between objects (room A is connected with room B; object X is situated in room Y etc.).

The semantic information can be very complex and comprehensive - even for small pictures containing only a few objects. For geometrical description of objects the SVG [5] format is used. This is XML-based format, which allows much easier manipulation by the system and by visually impaired users. As a suitable format for implementing additional semantic information, we use the MPEG-7 [6]; the ISO/IEC standard for description of multimedia content. This is also XML-based format.

During the description creation process the visually impaired user has two roles - "author" when creating the description and "browsing user" when checking the picture and finding objects and relations. To allow the visually impaired user to efficiently edit and create the 2D pictures we must provide special tools for description creation and for browsing through the picture. The creation tool is based only on text and keyboard interaction. The context sensitive listboxes are used as much as possible to speed up the user's input. To

increase the efficiency of the creation process the browsing through created picture must be easy and intuitive. This means that the browsing tool must allow the user to virtually walk through the picture by means of following different relations between objects (e.g. get form room A to room B by following the relation "connection" between these two objects).

The problem is that this browsing in the picture can lead to overloading the user with information (e.g. neighbor object, relations). To avoid this overloading the reduction of picture complexity by means of filtering out unnecessary information is provided. These filters are based on XSLT transformations [7] and are applied on both the geometrical (SVG) and semantic (MPEG-7) description.

With the implemented experimental system we have made several tests with visually impaired users with satisfactory results. The main problem that arises during the tests was quickly decreasing efficiency of orientation in more complex pictures. Particularly searching for object the user cannot identify precisely seems to be serious problem.

In the future we will focus on improving the orientation of the visually impaired user in the complex structure of the picture by developing more powerful information filters and query tools.

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# Efficiency of Distributed Object Interface

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In the area of distributed systems standard interface CORBA (Common Object Request Broker Architecture) is used for several years. This standard provides interface for communication among objects written in different programming languages. This standard has many advantages, but also several disadvantages. The first of them is concentration on statically typed languages. It means that type of each variable and each argument has to be known and written manually by programmer in advance. There is enormous manual work increase and long compilation in opposite to type checking and following optimization features. The second disadvantage is omitting efficiency of this interface. We can face big gaps in this sense in many implementations of CORBA interface, despite the fact that there are known optimization techniques from other areas of computer science. The third disadvantage is absence of behaviour passing, it means that only data parts of objects are passed. Behaviour of object is usually presented as methods closely connected with object and allows to perform basic operations with data fields. This behaviour is is completely ommitted, there is neither checking of equivalency of behaviour on both sides of communication nor any automatic behaviour passing together with data fields.

Our work is concentrating on the area of dynamically typed pure object oriented languages (Smalltalk, Self). Mainly because of their simplicity and easy implementation and testing of techniques described later. These are full dynamic systems. Programmer is released from writing types of variables and arguments, type information is present only in runtime. Classes and methods can be created and modified without limits when the program is running. Compilation is performed incrementally, separately for each method. Strict type checking is performed when messages are passed to target object. It is not possible to call undefined method. Access to all objects is indirect, it is not possible to modify data with direct pointers in non-object way.

In the area of efficiency we have concentrated on several basic key points that should be provided by each implementation. The first optimization technique is creation of cache as a defend against unnecessary repeated passing of same data or against their repeated creation. Cache can be created on both sides of communication – sending and receiving. Whole objects can be stored or only their parts. We can also store linearized forms for transport after marshalling procedure. The main idea is to transfer useful information only once, the rest should be done via some kind of references. Known techniques of keeping consistency can be also applied here.

The second point is incremental passing and dynamic changes of passing mode. Instead of passing whole large hierarchical structure, we can pass only the most important parts. The others can be replaced by references and can be passed later if they are required. Determination of all factors or in other words setting of granularity is performed dynamically during runtime. It means to define which parts will be passed for the first time and which parts will be passed later. Inverse process is to set which parts are no longer required on target side and can be substituted by reference or removed completely. Further attention has to be paid to the possible load of keeping consistency in case of passing objects by value.

The third point is to join requests (messages) and answers (return values) in larger blocks. This comes from fragmentation on lower levels of communication system where not only maximum but as well as minimum size of messages has to be met. Therefore it is advantageous to send one bigger message instead of sending separately several small messages that contain the same information. Useless increase in load is avoided in this way. Time factor of communication has to be also kept in mind, because it is not possible to add unproportional delay to joining elements.

In the area of behaviour passing we can take full advantage of dynamic Smalltalk environment. Classes and methods can be crated, modified or removed during runtime and classes themselves are represented as objects. Therefore we can look at the blocks of code as a common data fields. Interesting problems come from passing their context. Block of code can include different kinds of references – local as well as global, absolute as well as relative. The optimization techniques that we described above can be also applied here.

In the future this work can lead to a system that will provide automatic behaviour transfer among several programming languages in a similar way as CORBA interface does for typed data fields of objects. This approach requires to work on the level of definition of programming language and is also dependant on specification of environment where programs are running. We plan to develop such a system between Smalltalk and Java.

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# Intelligent Hypermedia

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Intelligent hypermedia is a relatively new direction of research on the join of hypermedia and user modeling. One limitation of traditional hypermedia applications is that they provide the same page content and the same set of links to all users. This is often very objectionable, because every user has different requirements on given hypermedia system. For example, a traditional educational hypermedia system will present the same static explanation and suggest the same next page to students with widely differing educational goals and knowledge of the subject.

An intelligent hypermedia enlarges the functionality of a hypermedia system. The aim of this system is to personalize hypermedia system to the individual users. Thus, each user has an individual view and individual navigational possibilities for working with the hypermedia system.

An intelligent hypermedia system combines ideas from hypermedia systems and ideas from intelligent tutoring systems. It belongs to the group of user adaptive systems, which are, for example, user adaptive interfaces or user model based interfaces. Intelligent hypermedia systems use a model of the user to collect information about his knowledge, goals, experience, etc., to adapt the content and the navigational structure. For example, a student in an intelligent educational hypermedia system will be given a presentation that is adapted specifically to his or her knowledge of the subject and a suggested set of most relevant links to proceed further. Here, the choice of the right information at the right time is the task of the user model.

Intelligent hypermedia system is also an attempt to overcome the "lost in hyperspace" problem. The user's goals and knowledge can be used for limiting the number of available links in a hypermedia system.

Typical applications of intelligent hypermedia systems are educational hypermedia systems where the user or student has a certain learning goal. In these systems, the focus is on the knowledge of the students, which might vary enormously. The knowledge state changes during the work with the system. Thus, a correct modeling of changing knowledge, a proper updating, and the ability to make the right conclusions on base of the updated knowledge estimations are the critical parts in an educational hypermedia system.

We differentiate two distinct areas of adaptation:

- the content level adaptation (adaptive presentation)
- the link level adaptation (adaptive navigation support)

By adapting the content for a user, the document's content is tailored to the needs of the user, for example by hiding too specialized information or by inserting some additional explanations. We identify the following methods for content level adaptation:

- additional explanations - Only those parts of a document are displayed to a user which fit to his knowledge or goal.
- prerequisite explanations - Here the user model checks the prerequisites necessary to understand the content of the page. If the user lacks to know some prerequisites, the corresponding information is integrated in the page.

- comparative explanations - The idea of comparative explanations is to explain new topics by stressing their relations to known topics.
- explanation variants - By providing different explanations for some parts of a document, those explanations which are most suited for the user can be selected. This extends the method of prerequisite explanations.
- sorting - The different parts of a document are sorted according to their relevance for the user.

By using link level adaptation, the user's possibilities to navigate through the hypermedia system are personalized. The following methods show examples for adaptive navigation support:

- direct guidance - Guide the user sequentially through the hypermedia system. The following two methods can be distinguished:
  - next best - Provide a next-button to navigate through the hypertext.
  - page sequencing or trails - Generate a reading sequence through the entire hypermedia system or through some part of it.
- adaptive sorting - Sort the links of a document according to their relevance for the user.
- adaptive hiding - Limit the navigational possibilities by hiding links to irrelevant information. Hiding of links can be realized by making them unavailable or invisible.
- link annotation - Annotate the links to give the user hints to the content of the pages they point to. The annotation might be text, coloring, an icon, or dimming.
  - traffic light metaphor - The traffic light metaphor is the most popular method for link annotation. Here the educational state of a link is estimated by the system according to the user's actual knowledge state. The link pointing to the page is then annotated by a colored ball.
  - traffic lights and hiding – A mix of traffic light metaphor and adaptive hiding is also used in some systems.
- map annotation - Here, graphical overviews or maps are adapted with some of the above mentioned methods.

Techniques for content level adaptation and link level adaptation are discussed in [1] and depend on the specific system. Here, the system's assumptions about the user play an important role to decide what and how to adapt.

At first I define a general hypermedia structure in order to create pages dynamically using a structured description of the domain knowledge and a model of the current user. And then I implementate an experimental system using this structure. This system will be implemented by using the functionality provided by XML in order to emphasize the separation of the information content from presentation.

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# Distributed Shared Memory: Home Based Consistency Protocol

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Shared memory is one of the programming models for parallel computing. Shared memory offer a general and convenient programming model that enables simple data sharing through a uniform mechanism of reading and writing shared structures in the common memory.

A distributed system use message-passing model as main communication layer. The scalable nature of distributed systems makes systems with very high computing power possible. However, this programming model requires explicit use of send/receive primitives. Most programmers find this model difficult to use.

Distributed Shared Memory (DSM) system logically implements the shared memory model on a physically distributed system. The DSM system hides the remote communication mechanism from the application writer, preserving the programming easy and portability typical for shared memory systems. DSM is a very interesting way, how to easily design powerful computation clusters.

DSM system can be implemented in many different ways. They are basically divided into hardware and software implementations. Software implementations are based on general-purpose networks and standard computers with common memory structure. Software implementation is easy to get and use and is easy to adapt for specific environment.

The most important part of each DSM system is a memory consistency protocol. This protocol maintains memory consistency between nodes in the DSM system. There are two main pure software DSM consistency protocols: Lazy Release Consistency (LRC) and Home Based Lazy Release Consistency (HLRC).

LRC systems synchronize memory only when it is needed. It is very important feature for system performance. But software overhead is a very problem in LRC. System memory consumption and size of data transferred during execution of an application significantly grows. This leads towards garbage collection and thus even more software-processing overhead.

HLRC systems assign home node to each memory block. This node maintains consistency of the block and always contains valid data of this block. Other nodes send its modifications to memory blocks to home nodes and synchronize their own copies from home nodes. This approach minimizes size of data to transfer, reduces system memory consumption and reduces software overhead. On the other side, communication between nodes is performed although it is not needed.

Which of these approaches is better depends on application. I developed consistency protocol that takes advantages from both LRC and HLRC. A home node is assigned to each memory block as under HLRC. Home node maintains consistency of the memory block, but data of the block are synchronized only when it is needed. Size of data transferred between nodes is the same as under HLRC and also software overhead is similar to HLRC. Communication between nodes is performed only when it is needed as under LRC. System memory consumption is similar to LRC. Garbage collection is not needed because memory consumption has acceptable boundaries. This protocol is especially designed for DSM systems implemented on top of standard local area networks.

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# The Study of the Properties of Independent (decentralized) and Centralized Control of Redundant Parallel Robots

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The fundamental task of parallel robot constructions, especially redundantly actuated, is to provide effective and safe cooperation of all drives - actuators. This paper summarizes the set of the available control approaches adjusted to redundant case: from simple decentralized control ( PID (/PSD) controller with reduction of the unproductive part of $I_{ntegeal}/S_{um}$ channels), to the simple centralized control ( PID (/PSD) control with redistribution of adequate resultant fictitious force effects to really - used redundant actuators), and one example of the high level control approach ( Generalized Predictive Control - GPC ).

The parallel robot constructions, in comparison with serial open-loop types, achieve higher stiffness, high load capacity, lower mass inertia etc. These properties, among others, predetermine the robots to the use within more powerful industrial applications performing accurate machining and positioning. This paper discusses and investigates the following approaches of control adjusted to the redundant robots:

- simple decentralized control ( the independent PID (/PSD) control with reduction of the unproductive part of I/S channels of the controller ),
- simple centralized control ( the independent PID (/PSD) control with redistribution of adequate resultant fictitious actuators to the really used redundant drive configuration ),
- and one example of the high level control approach (Generalized Predictive Control - GPC) ensuring the optimal cooperation of all actuators both adequate and redundant ).

The first approach, the simplest control strategy [1], which can be taken into account, is view on the robots-manipulators, powered by group of the independent systems (drives-actuators), controlled separately, as a set of single-input / single-output systems. The mutual interactions among all actuators due to varying configurations during the robot motion are involved
as disturbance in each system. The graphical representation corresponds with the classical PID/PSD feedback control. However, in case of the parallel robots, mainly redundantly actuated, some problem of the unproductive part of integral/sum control channels must be solved. It does not occur in serial open-loop structures.

Undesirable unproductive part of I/S channels is caused by inaccuracies in mechanism. It means that the drive coordinates designed from independent (Cartesian) coordinates in certain cases cannot be attainable. It causes unpredictable increase of I/S channels, which does not contribute to the motion. Moreover, It leads to instability of the whole robot system. Therefore, some block must be added to the control circuit to reduce this undesired property.

In the ideal situation, the integral/sum part leveled off at certain magnitude, which was integrated during the whole control process. In opposite case, the integration/sum part increases unpredictably. This situation appears from geometrical inaccuracies in parallel construction. To solve the problem the block based on virtual work and projection method is used.

■ The next approach, simple centralized control [1], is based on the control in the independent Cartesian coordinates. The controller designs fictional actuators acting directly to the fix point of the tool. These fictional actuators are consecutively recomputed to the appropriate values. They are expecting from the drives, in order to perform the desired movement.

Utilization of the centralized control has one important advantage. The all-independent Cartesian coordinates within workspace of the robot are always achievable and they do not depend on any recomputation. Thus, there does not occur any unpredictable increase of I/S channels, which can damage the drives.

■ The last approach, high level control, is represented by Generalized Predictive Control algorithm (GPC). The Predictive control [4, 3] is a multi-step control based on local optimization of the quadratic criterion, where the linarized equation or state formula is used (i.e. only the nearest future control signal is evaluated). This approach admits combination of feedback~feedforward parts. As mentioned above, for the quadratic criterion, the nonlinear model must be linearized and converted from continuous to discrete form.

The base of predictive control is the expression (prediction) of new unknown output values from actual topical state. Then, the quadratic criterion is optimized at certain time instant, with use of mentioned prediction. Obtained control can be already used.

Setting of parameters of the controllers of mentioned approaches is not the same task. Number of the parameters is different. For tested parallel robot construction, the decentralized control has three parameters. The second approach, simple centralized control is not so simple for setting, because it generally represents the biggest number of parameters (in our case 12 parameters). The last approach (GPC) is the simplest from the all. Since it represents generally only two parameters (horizon of the prediction and penalization) and their choice is not difficult as in the previous methods. Moreover, the approach achieves the best compliance of the planed trajectory, but it requires linear or linearized dynamic model of the robot.

The simple decentralized control and high level control (GPC) were successfully tested on the real robot application.

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# Data-Mining and Decision-Support Systems Integration

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Data mining (DM) is the analysis of often large observational data sets to find unsuspected relationships and to summarize the data in novel ways that are both understandable and useful to the data owner. The relationships and summaries derived through a data mining exercise can vary from complex models of the analyzed domain to fractional patterns describing particular characteristics. In general, extraction of non-trivial and actionable knowledge makes one of the main outputs of DM. Decision Support Systems (DSS, DS for Decision Support) are a specific class of computerized information systems that support business and organizational decision-making activities. DSS are aimed to improve or speed up (more often) decision making, they can be based on expert system, data warehouse or other well-known architecture. Typical DSS applications areas are in the evaluation and selection of management scenarios (e.g., production, personnel), assessment of projects and investments, evaluation of companies and business partners, land-use planning, medical diagnosis and prognosis.

Our research is focused on integration of data mining and decision support. A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions. It follows that the functionalities of DM and DS are complementary and oriented towards solving difficult practical problems. First, quality of decisions and policies can be significantly improved if both knowledge of experts and knowledge extracted from data by DM methods are used appropriately in DS systems. Second, DSS can be used in DM processes when selecting among several data models, i.e., consistent sets of domain knowledge. Similarly, DSS can influence data aggregation process, generation of secondary attributes etc.

The theoretical concepts developed in the frame of this project are based on two case studies. The case studies represent practical examples of integration of both discussed fields. The first study refers to scheduling and resource allocation in a spa. The spa offers a set of various health procedures to heal medical problems of the patients who are arriving into the health farm for a restricted period. Obviously, each patient obtains an individual treatment, i.e. a set of procedures assigned to the patient by the spa physician, who makes his recommendation after careful inspection of the patient upon his arrival. But a recommendation of the spa physician is not enough to ensure that the patient gets exactly those procedures he or she is supposed to get. To reach such a goal, it is important to ensure that necessary resources are available in appropriate quantity. Resource allocation has to be planned several days or even weeks in advance which makes timely prediction of resource requirements vital for the spa administration.

That is the reason why the company running the administrative system of spa decided to utilize the available history data as a basic source for a DM/DS project. The project resulted in development of a predictive module, which is able to forecast treatment requirements four weeks in advance. The main asset of the project from the point of view of DM/DS integration lies in development of the mining strategy that outputs knowledge easily understandable and applicable in terms of the DS predictive module. As the process of knowledge acquisition often

leads to significant amount of data pre-processing, a newly developed pre-processing tool SumatraTT [4] has been integrated into the general strategy. The SPA task and one of the obtained solutions is described in [1].

The second case study concerns with data mining and decision support in telecommunications. History data describing the operation of a telephone exchange in a commercial company were analyzed to reconstruct understandable event descriptions. The event descriptions are processed by an algorithm inducing rules, which describe regularities in the events. The rules can be used as decision support means (supporting the exchange operator / receptionist) or directly to automate the operation of the exchange.

The principal step towards a systematic cloning of data-mining with decision support relied on the following approach. A considerably heavy body of background knowledge relevant in this application (such as the encoding of 'hard-wired' principles of the exchange operation) was formalized in such a way that it could be exploited by both the DM and DS algorithms.

Technically, the language of first-order logic (namely its restricted set called Prolog) proved to be an excellent foundation for building all necessary algorithms and encoding the background knowledge. The following reasons thereof are foremost: (a) background knowledge representation in Prolog is *declarative* (the semantics can be easily interpreted by a semi-qualified human) and can in principle express arbitrary concepts (its expressive power is equivalent to that of the Turing machine), (b) a vast quantity of data mining algorithms (namely falling into the category of *inductive logic programming* systems [2]) are available to assist in the DM phase, and (c) decision-support mechanisms implemented in Prolog are transparent and allow for seamless debugging and upgrading. Relative inefficiency of Prolog would hinder its deployment in time-critical applications; response times were fortunately not a crucial factor in our application.

The result of our implementation is a system able to interpret the exchange logging data together with the background knowledge into a understandable form describing the past telecommunication traffic (sequences of events), to induce predictive rules and interpret them in conjunction with the background knowledge and thereby serve as a DS device.

A detailed treatment of all technicalities inherent to the materialization of the above outlined principles is provided in [2].

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# Computational Stereoscopic Vision

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Computational stereopsis has traditionally been one of the most investigated research topics in computer vision. The core problem of stereoscopic vision is to compute a disparity map of the captured scene, which means (1) to find correspondences between binocularly visible points in the input 2-D images, (2) to detect half-occluded regions (regions, which are not visible in all the input images).

To find the correspondences correctly even in the hard scenes containing repetitive patterns, noise, thin objects at the foreground, specularities, etc. is considered as one of the most difficult problems in stereo vision, because in such scenes standard approaches generally fail. The local stereo methods typically find the correspondences based only on small image windows. Pixels having the most similar neighbourhoods in the input images (computed by various statistics, such as SSD, SAD, NCC, etc.) are assigned as the corresponding pair. In order to obtain accurate results, the matching features---contents of the windows---have to be as stable and discriminable as possible. By stability we mean independence on projection distortions, by discriminability the ability to recognize the correct correspondence. Consequently, the key-problem in area-based stereo is the proper selection of matching windows over which the statistics is computed.

In our research we have come to the conclusion that to produce results of a good quality it is essential to assign the matching over jointly discriminable and stable features; by jointly we mean that both the input images contribute to their definition. However, to obtain such features in the input images is impossible due to projective image distortions. Consequently, we pose the problem in the disparity space, which is a set of all tentative matches. Every point in this space represents a binocular correspondence and has defined a similarity value computed by a matching statistics. From our experience we have concluded, that the quality of features is often more influenced by the window shape that its size. Since the window shape cannot be selected without having any matching hypothesis, we propose a pre-matching to find a good quality matching hypothesis in advance. To ensure the windows cover the same parts of the scene, we define them in the disparity space. The windows adapt to connected structures of points with high similarity values in disparity space---matching hypotheses, which we call disparity components. To capture even small disparity variations in the scene, the disparity within one disparity component is allowed to differ for two neighbouring points by at most one. This results in windows of non-constant disparity (unlike standard approaches). For such windows there exists an equivalent pair of admissible "windows" in the input images, which typically would be non-rectangular. The adaptive windows in the disparity space are then used to re-compute the similarity statistics over which the final matching is performed. The proposed algorithm is independent on the selection of matching algorithms, although it is desirable to use a pre-matching algorithm that guarantees low false negative error and a final matching algorithm that guarantees low false positive error.

We have tested our algorithm in various experiments using benchmark real or artificial images. To study the properties of our algorithm we also performed the rigorous ground-truth evaluation experiment, introduced below. In this experiment we compared results produced by the same matching algorithm, ones using standard rectangular windows and ones using our

adaptive windows. The experiments demonstrated that by applying adaptive windows approach the overall quality of disparity maps can be improved four-fold, while the accuracy remains comparable.

In order to be able to study stereo matching algorithms properties and qualities, in our research we have concentrated also to a different topic, the design of the evaluation methodology for this purpose. Our method is based on known ground-truth and focuses on failure due to insufficient signal-to-noise ratio (SNR), because the data uncertainty is never totally avoidable. Different error mechanisms are than studied in detail to discover specific weaknesses of various algorithms. The designed scene is artificial and consists of three thin textured stripes in front of a textured plane. Ten stereo image pairs of the scene have been captured under varying SNR to create a dataset for the evaluation. We assume half-occluded regions are identified.

For the sake of evaluation, eight types of errors were considered. They are all mutually related and all of them are important for assessing the quality of a matching algorithm. Failure rate measures the overall quality of the disparity map. False positive rate measures the quality of detection of half-occluded regions. The matching quality in binocularly visible regions is measured in two characteristics: sparsity (false negative rate) and accuracy (mismatch rate). The preciseness of detection of occlusion boundary is monitored by three errors: overall quality (occlusion boundary accuracy), the case when the object narrows the half-occluded region (occlusion boundary false positive rate) and the case when the half-occluded region is widened (occlusion boundary false negative rate). The last error measures if the studied matching algorithm exhibits any bias towards large objects. All the errors for all ten image pairs are depicted in relevant plots, where the behaviour of algorithms can be studied in detail.

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# 360x360 Omnidirectional Camera

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We generalize simultaneous linear estimation of multiple view geometry and lens distortion presented by Fitzgibbon at CVPR 2001 [4] for and omnidirectional (angle of view larger than 180°) camera. The standard camera is replaced by a linear camera with a spherical retina and a non-linear mapping of the sphere into the image plane. It is shown that the new camera model is capable, unlike the previous distortion-based models, to describe a camera with the angle of view larger than 180° at the cost of introducing only one extra parameter. A suitable linearization of the camera model and of the epipolar constraint are developed in order to arrive at a Quadratic Eigenvalue Problem for which efficient algorithms are known. The lens calibration is done from image correspondences only, without any calibration objects or any assumption about the scene. We demonstrate our method in real and simulated experiments with high quality, but cheap and widely available, Nikon FC-E8 fish-eye converter for COOLPIX digital camera. In practical situations, the proposed method allows to estimate the new model from 9 correspondences and can be thus used in a RANSAC based estimation technique.

Omidirectional cameras provide a large field of view, typically larger than 180°, what is appropriate for applications like surveillance, tracking, structure from motion, and navigation. This work is motivated by using omnidirectional cameras for structure from motion, 3D reconstruction, and creating 360x360 omnidirectional camera. The omnidirectional camera can be achieved i) by combination of a standard directional camera with a curved mirror in order to obtain a large field of view [2] or ii) by using a special converter like fish-eye lens which is mounted directly to the standard camera. Recently, a number of high quality, but cheap and widely available, e.g. Nikon FC-E8 fish-eye converter for COOLPIX digital camera, appeared.

Using such a camera calls for finding a camera model, which maps image points to corresponding 3D vectors. The methods for estimating of camera model with lens distortion divides into two basic groups. The first one includes methods which use some knowledge about scene. There are methods using calibration patterns [3], plumb line methods, and a method based on the fact that a lens non-linearity introduces specific higher-order correlation in the frequency domain. The second group covers methods which do not use knowledge about scene. There are calibration method from pure rotation and calibration for rotation and translation. These methods calibrate cameras from point correspondences only. Fitzgibbon [4] deals with the problem of nonlinear lens distortion in the context of camera self-calibration and structure from motion. He introduces a one parametric model for the radial distortion and suggests an algorithm for simultaneous estimation of multiple view geometry and lens distortion from point correspondences. This model, however, cannot be directly used for omnidirectional camera with angle of view larger than 180° because it represents images by points in which rays of a camera intersect an image plane. Our goal was to generalize this method for omnidirectional cameras to derive an appropriate model, to incorporate non-linearity of the lens, and to find an algorithm for estimation of the model from epipolar geometry. We assume that only point correspondences, information about the field of view of the lens, and its corresponding view angle are available.

For cameras with angle of view larger than 180°, images of all scene points cannot be represented by intersections of camera rays with one image plane as it is for standard cameras. Every line passing through an optical center intersects the image plane in one point. But on one such line two scene points can lie and they can be seen in the image at the same time. For that reason we will represent rays of the image as a set of unit vectors in $R^3$ such that one vector corresponds just to one image of a scene point. Scene points are projected into a sensor plane. An image on a sensor plane in a metric coordinate system is digitized to a digital image related be an affine transformation, which can be estimated by transforming an ellipse to a circle up to a rotation around the center of the circle and scalar factor. From this pre-calibrated image, 3D vectors are computed by applying non-linear function. Using stereo-pair of omnidirectional cameras, points correspondences corresponding to the same scene points in these two acquired images, and epipolar constraint, parameters of non-linear function can be estimated [1]. This calibration allows us to create 360x360° omnidirectional camera.

In [1] the division model capturing the relation between image points and 3D vectors emanating from the optical center to a scene point is suggested. The division model with two parameters leads to solving a Quadratic Eigenvalue Problem for which efficient algorithms are available. The number of the parameters can be reduced to one by taking into account that i) fields of view is circular on the sensor plane and ii) the angle of view is known. It allows to use robust method RANSAC with 9 point kernel for essential matrix and parameter of the omnidirectional model estimation.

Our work extended the non-linear lens model estimation from epipolar geometry for omnidirectional cameras with angle of view larger than 180°. It formulated all steps of an omnidirectional camera calibration which lead to the full calibration. This research suggested the model of the omnidirectional camera, the way how to decrease the number of parameters and algorithm for estimation of the parameters from epipolar constraint. The algorithm was tested on synthetic and on real data. Real experiments suggest that our method is useful for estimating parameters of a camera model and structure from motion with sufficient accuracy, to be used as a start point for s bundle adjustment. The important conclusion is that the suggested method allows us to incorporate our omnidirectional camera model into a 9 point algorithm using RANSAC for outliers detection and essential matrix computation.

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# Convergence of the Expectation Minimization Algorithm for the Conditionally Independent Model to the Global Maximum

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This contribution extends knowledge related to the Expectation Maximization (EM) algorithm which is a basic tool for treating incomplete data in statistics and for unsupervised learning in pattern recognition. The EM algorithm is an iterative method for maximum likelihood estimate for problems regarded in statistics as incomplete data problems. The name EM algorithm was given to it by A.P. Dempster, N.M. Laird and D.B. Rubin. They read a lecture on the topic before the Royal Statistical Society in Britain in 1976 and published it in the celebrated paper [1] in 1977. The EM algorithm has become a standard piece in the toolbox of a statistician.

Let us assume that we are given a conditional probability $p(x \mid k, \theta_k)$ where $x \in X$ is an observed variable, $k \in K$ is a hidden state, and $\Theta = (\theta_1, \ldots, \theta_{|K|})$ is a vector of unknown parameters of the distribution (e.g., if $p(x \mid k, \theta_k)$ has the Gaussian distribution then the parameter $\theta_k$ denotes a mean vector $\mu_k$ and a covariance matrix $\sigma_k$). The unknown probability of the hidden state $p(k)$ and the parameters $\Theta = (\theta_1, \ldots, \theta_{|K|})$ describe a statistical model $m = (p(k), k \in K, \Theta)$. Furthermore, we have an independently drawn set of observations $(x_1, \ldots, x_n)$ generated according to a finite distribution mixture

$$p(x \mid m) = \sum_{k \in K} p(k) \cdot p(x \mid k, \theta_k),$$

which is not known, since the model $m$ is unknown. As the set $(x_1, \ldots, x_n)$ does not contain hidden states, it is called incomplete data. The logarithm of the probability $p(x_1, \ldots, x_n \mid m)$ is called the log-likelihood function $L(m)$ of the model $m$ with respect to the set $(x_1, \ldots, x_n)$. Due to the assumption of independence of the sample $(x_1, \ldots, x_n)$, the log-likelihood function can be factorized as

$$L(m) = \sum_{i=1}^{n} \log\left( \sum_{k \in K} p(k) \cdot p(x \mid k, \theta_k) \right).$$

The task of maximum likelihood estimation is to find such a model $m$ that maximizes the log-likelihood $L(m)$, i.e., we have to solve

$$m^* = \arg\max_m L(m).$$

Unfortunately the problem of maximum likelihood estimation of the finite distribution mixture is usually highly non-linear and does not have an analytic solution. To solve this problem one can employ standard optimization techniques. An alternative way to solve the maximum likelihood estimation problem is to use the iterative EM algorithm [1][2]. The EM algorithm consists of two steps: (E)-step estimates the hidden variables, (M)-step finds the model which maximizes expectation of log-likelihood function for complete data. The EM algorithm

converges to a fixed point which corresponds to a local minimum of the log-likelihood function in general.

M.I. Schlesinger [3] discovered that in a special case of a statistical model the EM algorithm converges to a global extreme. This special model is the conditionally independent model with two hidden states. In the conditionally independent model the components of observed variable $x = [x^1, \ldots, x^d]$, $x \in X$ are conditionally independed when the hidden state $k \in K$ is fixed, i.e.

$$p([x^1, x^2, \ldots, x^d] \mid k) = p(x^1 \mid k) \cdot p(x^2 \mid k) \cdots (x^d \mid k),$$

and the set of possible observations $X$ is assumed to be finite. The proof is done for further restricted case when the number of hidden states is two, i.e. the set $K$ has two elements only. The Schlesinger's important result was published in a technical report in Russian in 1997 and remained almost unnoticed by the research community.

This contribution builds on M.I. Schlesinger's results. Under the same assumptions we shortened and simplified the proof of global convergence. We also smoothed away two minor imprecisions in the original proof and learned that they do not affect validity. We hope that the shortened proof helps us to achieve more enterprising aim which is to generalize the proof for more than two hidden states. More details can be found in [4].

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# Formal Parallel Translation

# Directed by Parallel LLP(q,k) Parser

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Parsing and translation algorithms of context-free languages belong to the fundamental algorithms of the formal languages theory. The formal translation directed by sequential *LL* or *LR* parsers [1] is the mathematical background for compiler and interpreter construction, for automated text processing systems etc. The mentioned translation algorithms are sequential ones thus do not exploit the power of parallelism. There exist parallel versions of the translation algorithms that are applicable under specific conditions (such as postfix translation grammars [2] combined with parallel *LRP(q,k)* parser).

Our research is focused on the development of an optimal parallel translation algorithm directed by parallel *LLP(q,k)* parsing algorithm. The idea of our parallel *LLP* parsing algorithm is described in [2,4]. Since the parallel translation phase requires access to the pushdown store contents generated during the parsing, we assume the *LLP* parser with gluing based on the parallel parentheses matching [3,4].

The translation algorithm can be divided into two main tasks. The first task is the parallel *LLP(q,k)* parsing itself. The parsing consists of two phases parsing and gluing. During the parsing phase each parsing processor evaluates the contents of its pushdown store contents as seen by sequential *LL* parser on its position in the input string. Our solution is based on a precalculated table named *PSLS*. The table has similar function as the parsing table in the traditional sequential *LL* parsing - it informs the processor which pushdown store contents to use (and thus what to do) when certain lookahead and lookback string is seen. The *PSLS* table is evaluated from the input context-free grammar, we have developed algorithms that evaluate *PSLS* table contents for arbitrary finite lengths of lookahead and lookback strings. The algorithms are described in [2,4]. Since the parsing is done by indexing the *PSLS* table, it has time complexity of *O(1)*.

The gluing phase is based on the parallel parentheses matching algorithm [3]. The input triplets provided by the parsing phase are passed through homomorphism, one for the initial pushdown store contents and one for the final pushdown store contents. The homomorphism encodes the pushdown store contents as a string of parentheses of /*N*/+/*T*/ different types. Opening parentheses correspond to the symbols in the final pushdown store contents whereas closing parentheses correspond to the symbols in the initial pushdown store contents. The processing is based on the fact the gluing is finished with success if and only if the order-preserving concatenation of the homomorphic transformation of the parsing phase results forms balanced parentheses structure. At the end of the gluing phase, the parser knows whether the input string belongs to the input language (thus is accepted) or not. The gluing has time complexity *O(1)*.

The second task is to evaluate the output string in the case the input string was accepted. The task can be again divided into two steps. The first phase performs the local translation and evaluates the kinds of output symbols that will appear in the output string. The second phase then evaluates the position of each output symbol in the output string. The idea of the parallel translation is somewhat similar to the parsing phase. The translation examines

precalculated table *TPLLT* which again contains the contents of the pushdown store before and after an input symbol has been processed. In contrast to the *PSLS* table, the *TPLLT* table contains output symbols besides nonterminal and input symbols. The only problem is the placement of the output symbols in the initial pushdown store contents, there is not any way to evaluate their positions without extensive communication with other processors. To avoid this time-expensive technique, we place meta-output symbols on any position in the initial pushdown store where such a output symbol may occur. The meta-output symbol substitutes zero to infinite real output symbols.

The second translation phase takes the initial and the final pushdown store contents and encodes them using the same homomorphism the gluing uses. The serialized homomorphism contains parentheses of */N/+/T/+/D/+1* different kinds, however, the parentheses string not is not balanced as the meta-output symbols are matched with an unlimited number of opening parentheses. To finish the translation task, the corresponding meta-output symbols must be found for all opening parentheses that represent output symbols. Since the string is not balanced, the parentheses matching algorithm cannot be used. Instead, we propose rather complicated 12-step algorithm that consists of parallel prefix sum, string packing and sorting steps. The result of is the desired output string that corresponds to the input string in the considered translation.

The translation task is again time optimal. It takes *O(1)* time to access the *TPLLT* table and then it performs a fixed number of operations with time complexity *O(log(n))* each, thus the time complexity of the entire task is *O(log(n))* if *n* processors is used. Even better, the algorithm is scalable and can also be cost optimal if *n/log(n)* processors is used. On the other hand, the hidden multiplicative constant is high here, making the parallel translation ineffective for short input strings.

The important property of our parallel translation algorithm is that it does not restrict the translation grammar in any way. The output symbols may be placed on any position in the translation grammar rules, the only requirement is that the input grammar is *LLP(q,k)*. This is significant advantage compared to the existing parallel translators. In the future, we will try to introduce attributes and to develop parallel translation algorithm for attribute translation grammars.

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# Dynamic Generation of Test Sequences for Reactive Systems

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The mission of the software quality assurance is to develop software testing tools and methods to improve quality, correctness, and conformance to standards. Hard requirements on the precise specification and substantial testing have to be fulfilled mainly during the development of safety-critical systems. These systems are usually engaged in applications with high reliability and safety requirements.

Safety-critical systems are often modeled by reactive systems. Reactive systems react to an environment that cannot wait (e.g. control systems of physical processes). They are generally intended to be deterministic both in the term of input/output behavior and time response. Their description involves concurrency. Data in reactive systems are usually simple signals and they have a distinct control part often modeled using the formal framework of finite state machines. Thus, several approaches to specification, design, verification, and testing a hardware and software can be combined [2]. Moreover, simple formal models like finite state machines allow for efficient reasoning about the models using model-checking. Symbolic model-checking is based on clever state space exploration and offers completely automatic proof of the required properties. Model-checking algorithms have recently been used in several practical tasks. Efficient planners are designed on the basis of counterexample generation algorithm. The task of test sequence generation can be viewed as a planning problem. Moreover, conformant planners [4] with nondeterminism in an initial state and actions allow for generation of test sequences for distributed systems, which are often loaded by nondeterminism that cannot be controlled. In particular, counterexamples from model checkers are potentially useful test cases. Efficient model-checking algorithms can be utilized for specific tasks of the test generation process.

The research within the grant project is focused on testing of synchronous systems where inputs are periodically sampled. The states of an automaton are the valuations of the memory, and each reaction corresponds to a transition of the automaton. The system is synchronous if such a transition is considered atomic (i.e. input changes are only taken into account between two reactions) and such a reaction takes no time. An atomic reaction is called an instant (logical time), and all the events occurring during such a reaction are considered simultaneous. When introducing concurrency, the advantage of synchronous systems lies in their modular composition. When automata are composed in parallel, a transition of their product is made of simultaneous transitions of all of them. When participating in such a compound transition, each automaton considers the outputs of others as being part of its own inputs.

Our work is motivated by the previous experience in methods for improving software quality, particularly in verification using theorem proving and design of a test driver for a railway interlocking system [1]. Our intent is to develop a conformance testing method with formal background that would be applicable in industry. The method exercises the prescribed functionality of the software code by executing a series of tests. Usually this is done as black-box testing which is common in procurement, when a purchaser or third-party must verify that proprietary software satisfies its specification.

In this research, we are mainly interested in testing of control-dominated systems (as the railway interlocking system described in [1]). Thus, we confine to synchronous finite state machines. Several testing methods perform exhaustive testing of finite state machines, e.g. Transition Tour, W-Method, Unique Input Output Sequence, etc. However, they can be used only for finite state machines with limited size, e.g. hundreds of states. Exhaustive testing is almost impossible for testing of large reactive systems. In general, full confidence cannot be achieved in practical tasks. Thus, we explore partial testing methods.

We use the formal model of the system as an oracle for the generation of test sequences. The formal model consists of an initial state of the system and a deterministic transition relation. The system is symbolically represented by BDDs. The test sequence generation can be automated using planners [3]. Our prototype of the testing tool generates the path from an initial state to a target state by the breadth-first search known from symbolic model-checking [1]. Currently, we define the fault coverage measure in terms of visited states and transitions. The most difficult task in testing is to select appropriate set of test cases in order to increase its fault detection capability while minimizing its size. Some partial testing strategies have been designed. According to the selected testing strategy, new test sequences increasing the test set coverage are automatically generated. In order to decide whether a test passed or failed, inputs and outputs of the system implementation are compared to the response of the oracle. Thanks to the synchronous nature of the system under test, a flat finite state machine is constructed from distributed parts of the system as a synchronous product. The designed algorithm takes the actual inputs of the system into account and can reach a target state even if there is nondeterminism.

Experiments on benchmark systems and on the safety-critical railway control system developed by the AZD Prague, Ltd. have been performed. We are developing a prototype implementation of the testing tool in the Scheme language Guile that allows us effective experimentation with a BDD package. We have also identified some topics for further research, e.g. support the measure of conformance by a statistics and further improvements of testing strategies.

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# Non-central Cameras for 3D Reconstruction

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This paper is devoted to 3D reconstruction from non-central cameras. By non-central camera we denote a camera, which does not have a single center of projection in which all light rays forming an image intersect, as opposite to central cameras. 3D reconstruction from central cameras is a well-known and understood topic. In recent years, non-central cameras gained much attention and geometry of some classes of these cameras was investigated. It was shown that for a certain class of non-central cameras a relation equivalent to epipolar geometry for two central cameras can be found.

How does a non-central camera look like? It can be realized by some special optics, by an ordinary camera observing some reflective surface, or by moving a camera on a specific path and composing novel images from parts of images acquired during the movement of the camera. We focus on the case, when a camera is moved on a circular path. From a captured image sequence, we select parts of the images, for example one image column from each image, and compose a mosaic image. The mosaic image is then an image captured by a camera, which does not have to be central. It is clear, that the number of images determines the camera's resolution in the direction of movement, usually corresponding to horizontal image axis. The resolution in the vertical axis is then given by the resolution of the camera, which was rotated. If the motion of the camera was on a closed path, in this case a circle, the mosaic image has a horizontal field of view of 360°. The vertical field of view is again determined by the camera, which was rotated.

We focus on a practical realization of one particular non-central camera, the 360 x 360 mosaic. This camera is capable to observe full 360° in both the horizontal and the vertical direction. It is in fact created by rotating an omnidirectional camera (a camera with a 360° field on view in one direction) on a circular path. The main advantage of this camera is that it can observe everything in a scene except the cylinder created by raising the rotational circle. For example, if this camera is placed in a room, it captures the whole room including the floor and the ceiling. Moreover, the camera creates two images, which compose a stereo pair, and therefore dense stereo reconstruction algorithms can be applied directly. Also, the geometrical model of the camera is very simple, having only one parameter, the radius of the rotational circle, allowing a similarity reconstruction if the radius is not known.

The research supported by the internal grant of the Czech Technical University in Prague was aimed mainly on a creation of the 360 x 360 camera using an omnidirectional camera employing a special lens instead of a mirror. Usually, omnidirectional cameras are created by either perspective or orthographic camera observing a mirror. The shape of the mirror as well as the relative position of the mirror with respect to the camera is of great importance. Composition and calibration of the resulting omnidirectional sensor is a complicated task. We propose to use a special lens, namely the Nikon FC-E8 fisheye adapter, which can provide omnidirectional image, instead of the mirror. The lens we use has a field of view in one direction 360° and in the other direction 183°. It is also very cheap, because it is mass manufactured as an accessory to Nikon Coolpix digital cameras.

In order to use the lens for capturing the 360 x 360 mosaic images, the lens has to be calibrated. This means that a mapping between the light rays and pixels has to be recovered

using a known calibration object. We accept a common assumption, that the function describing the mapping is radially symmetrical with respect to some distortion center. The center of distortion is an intersection of the optical axis with the image plane. The mapping function is determined by the design of the lens. Some very expensive lenses are made to follow a certain mapping function. The lens we use is a mass-produced lens without any documentation provided by the manufacturer, therefore we had to find the underlying function empirically.

In general, every function can be approximated, up to a certain order, by a Taylor sequence of polynomials. This fact is used in estimation of radial distortion of lenses by a polynomial of some specified order, usually degree three. The coefficients of the polynomial have to be found by fitting the model to measured data using some nonlinear optimization method. We found out in our experiments that even though the polynomial can approximate measured data well, the convergence of the minimization is bad. We therefore derived a function based on the projection models, which has the same number of coefficients as the polynomial of degree three. Minimization of the reprojection error converges more reliably and faster when using this function than in case of the polynomial. We verified our model and calibration procedure using experiments on real data employing several different camera and calibration objects.

The main result of the work supported by the grant was the model describing the Nikon FC-E8 fisheye lens. This was demonstrated by employing the lens in realization of the 360 x 360 mosaic camera. In an outgoing research project we also use the fisheye lens for mosaic acquisition and the lens was then, together with the calibration procedure, employed in several other projects in our laboratory.

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# Wavelet-Based Rate Scalable Image Coding

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Compression is a process intended to yield a compact representation of a signal. In the case where the signal is defined as an image, a video stream, or an audio signal, the generic problem of compression is to minimize the bit rate of their digital representation. There are many applications benefit when, image, video, and audio signals are available in compressed form. Without compression, most of these applications would not be feasible. Some of these applications are: video conference, broadcast video, audio conference, and high definition television (HDTV).

A specific coding strategy known as embedded rate scalable coding is well suited for continuous rate scalable applications. In embedded coding, all the compressed data is embedded in a single bit stream and can be decoded at different data rates. In image compression, this is very similar to the progressive transmission. The decompression algorithm receives the compressed data from the beginning of the bit stream up to a point where a chosen data rate requirement is achieved. A decompressed image at that data rate can then be reconstructed and the visual quality corresponding to this data rate can be achieved. Thus, to achieve the best performance the bits that convey the most important information need to be embedded at the beginning of the compressed bit stream [1, 2].

Wavelet transform coefficients are defined by both a magnitude and sign. A major objective in a progressive transmission scheme is to select the most important information (i.e. coefficients) which yields the largest distortion reduction to be transmitted first. This means that the coefficients with largest magnitude should be transmitted first because they have a large content of information. The coefficient's sign and its position should be also transmitted.

Several techniques have been proposed to achieve rate scalability in still image compression. Two of the most important techniques are Shapiro's Embedded Zerotree Wavelet (EZW) [1], and Said and Pearlman's Set Partitioning in Hierarchical Trees (SPIHT) [2]. Both make use of "spatial orientation trees" (SOT). Spatial orientation trees are structures that use quad-tree representations of sets of wavelet coefficients that belong to different subbands, but have the same spatial location. This structure, which can be efficiently represented by one symbol, have been used extensively in rate scalable image and video compression

In [3], a wavelet-based image compression scheme is presented. This iterative algorithm seeks to minimize a distortion measure (MSE) by successively pruning a tree for a given target rate. The survivor node in the tree are quantized and sent in the data stream along with significance map information. To further compress the stream, this map is predicted based on statistical information. Results show about a 0.5 dB gain in PSNR versus SPIHT for grayscale images.

In [4], the texture representation scheme adopted for MPEG-4 synthetic/natural hybrid coding (SNHC) of texture maps and images is described. The scheme is based on the concept of multiscale zerotree wavelet entropy (MZTE) coding technique. MZTE was rated as one of the top five schemes in terms of compression efficiency in the JPEG2000 November 1997,

among 27 submitted proposals. This scheme provides many levels of scalability layers in terms of either spatial resolutions or picture quality.

In [5], the image compression scheme adopted for JPEG2000 is described. The scheme offers rate and spatial scalability with excellent compression performance. In the Embedded Block Coding with Optimized Truncation (EBCOT), each subband is partitioned into relatively small blocks of samples, referred to as “code-blocks," and generates a scalable and embedded bit stream for each code block. Code-blocks are of 32x32 or 64x64 samples each, and provide random access to the image. The layered bit stream may be truncated at any point during decoding. EBCOT uses the Daubechies (9,7) wavelet filter (5-level decomposition), although JPEG2000 can use other filters. Results shown performance gains of about 0.5 dB against SPIHT at various data rates.

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# Wavelet-Based Rate Scalable Video Coding

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Many applications require that digital video be delivered over computer networks. The available bandwidth of most computer networks almost poses a problem when video is delivered. A user may request a video sequence with a specific quality. However, the variety of requests and the diversity of the traffic on the network may make it difficult for a video server to predict, at the time the video is encoded and stored on the server, the video quality and data rate it will be able to provide to a particular user at a given time. One solution to this problem is to compress and store a video sequence at different data rates. The server will then deliver the requested video at the proper rate given network loading and the specific user request. This approach requires more resources to be used on the server in terms of disk space and management overhead. Therefore scalability, the capability of decoding a compressed sequence at different data rates, has become a very important issue in video coding. Scalable video coding has applications in digital libraries, video database system, video streaming, video telephony and multicast of television including high definition television (HDTV) [1].

A specific coding strategy known as embedded rate scalable coding is well suited for continuous rate scalable applications [2, 3]. In embedded coding, all the compressed data is embedded in a single bit stream and can be decoded at different data rates. In image compression, this is very similar to the progressive transmission. For video compression, the situation can be more complicated since a video sequence contains multiple images. Instead of sending the initial portion of the bit stream to the decoder, the sender needs to selectively provide the decoder with portions of the bit stream corresponding to different frames or sections of frames of the video sequence. These selected portions of the compressed data achieve the data rate requirement and can then be decoded by the decoder. This approach can be used if the position of the bits corresponding to each frame or each section of frames can be identified.

In [4], an application of the SPIHT (set partitioning in hierarchical trees) [3] algorithm to video sequences, using three-dimensional (3D) wavelet decompositions and 3D spatio-temporal dependence trees is presented. A fully 3D-SPIHT encoder/decoder is implemented and is compared against MPEG-2 in parallel simulation. Although there is no motion estimation or compensation in 3D SPIHT, it performs measurably and visually better than MPEG-2, which employs complicated means of motion estimation and compensation.

In [5], a hybrid coding scheme is presented. Motion estimation and compensation is used to reduce the temporal redundancy in the sequence. For the intraframe (I) and predictive error frames (PEF), a scheme known as partitioning, aggregation, and conditional coding (PACC) is used on the coefficients resulting from their discrete wavelet transform (DWT) decomposition. PACC refers to a partitioning of the quantized wavelet coefficients into two groups: zero and non-zero coefficients. The zero coefficients are encoded using a Zerotree structure as in Shapiro [2]. A Zerotree symbol is used only for coefficients in the lowest subband of the decomposition. Non-zero coefficients are represented using two maps: a magnitude map, that contains the absolute value of the coefficients, and a sign map. All three maps are encoded using Conditional Coding, which exploits the spatial redundancy within the

maps. Motion compensation is performed at half-pixel accuracy. The motion vectors and symbols generated by PACC are coded using a binary arithmetic coder.

In [6], a high performance hybrid wavelet video coding termed video significance-linked connected component analysis (VSLCCA) is presented. This algorithm is developed for very low bit rate applications. Fine-tuned block-based motion estimation following of H.263 Recommendation is used to reduce temporal redundancy. Zero, one, or four motion vectors per macroblock are determined by using full search block matching algorithm with half pixel refinement. Then, exhaustive overlapped block motion (OBMC) compensation is used to reduce the artificial blocking effect caused by block-based motion estimation. Each predicted block in the current frames formed as a weighted sum of as many as nine blocks from the previous reconstructed frame which are determined by translating the current block using motion vectors associated with the current block and its eight neighboring blocks. Wavelet transform is applied to compact the motion-compensated error frame energy into few significant coefficients. All the wavelet coefficients are scalarly quantized. In the video SLCCA algorithm, the clustering property of the wavelet coefficients is exploited in this algorithm, by organizing them in “connected components" using morphological operations. VSLCCA codec exceeds H.263 and ZTE in PSNR by as much as 2.07 dB and 1.38 dB at 28 kbits, respectively for intraframe coding. For entire sequence coding, VSLCCA is superior to H.263 and ZTE by 0.35 dB and 0.71 dB on average, respectively.

In [7] A coding scheme based on the hybrid coding structure with motion estimation and compensation performed in the transform domain (in-band) using the overcomplete DWT is presented. The coding process resembles the classical hybrid coding structure. Experimental results demonstrate that a simple realization of the proposed coding scheme can decode to a variety of bit-rates and resolutions achieving at the same time competitive performance compared to state-of-the-art scalable coding standards.

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# Influence of Network QoS Characteristics on MPEG Video Transmission

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One of the prospective applications expected to be used frequently in National Research and Educational Networks (NRENs) is high-quality video transmission. Applications of this type use mostly MPEG encoding for video and audio data (MPEG1, MPEG2 or MPEG4). Required bandwidth, ranging approximately from 2 Mb/s to 10 Mb/s, is relatively small when compared to the backbone capacity of current NRENs. However, these video transmissions are supposed to be available also in points farther away from the backbone. A typical example is broadcasting a conference session from a lecture hall connected using a wireless link with the capacity in the order of 10 Mb/s to 100 Mb/s having less than optimal network QoS characteristics. The objective of this research was to verify influence of primary QoS characteristics (loss rate, delay and jitter) on the quality of video and audio signal.

Following simulation network was used for tests. The sending PC was equipped with Optibase MPEG MovieMaker 200 encoding card and the receiving PC was equipped with Optibase Videoplex Xpress decoding card. Both cards support MPEG1 and MPEG2 encodings in SIF, QSIF, Full-D1 and Half-D1 formats. The Moviemaker 200 card can transmit data encoded online from the S-video input or it can read data stored in a file. We used this particular hardware because it was just what we managed to get for testing purposes. The sending and the receiving computer communicated over a router based on a Linux machine running NIST Net emulation package. NIST Net allows to configure network QoS characteristics experienced by traffic passing the router. These characteristics include adjustable throughput, loss rate, duplications and delay (including standard deviation and linear correlation). The user can supply his own distribution function for delay emulation, if required.

We found the following observations to apply almost equally to different stream types (MPEG1 SIF, MPEG1 QSIF and MPEG2 Half D1) and rates ranging from 4 Mb/s to 10 Mb/s. As expected, packet loss rate was a critical parameter. MPEG without FEC proved to be completely intolerable to packet losses bigger then 0.02%. With 10 Mb/s stream in 1500-byte packets, loss rate of 0.02% represents one lost packets in 6 seconds. These single packet losses were observable as image pixelization when looking carefully at the video sequence. We used a rather dynamic demonstrational clip from Optibase. It is likely that less dynamic sequences, such as broadcasting from a conference would suffer less from lost data. The loss rate of 0.02% caused some extensive pixelizations already. This faults were interspersed with period of acceptable quality.

On the other hand, the video transmission proved to be highly resilient to delay and jitter. We tried various combinations of mean delay and standard deviation and the system was able to adapt to the mean delay of up to 10 seconds which is well beyond conditions in real-

world networks. A particularly interesting point is the value of standard deviation which was still acceptable. For example, the mean delay of 100 ms with standard deviation of 10 ms means approximately 47% of reordered packets. As we found that packet losses are not acceptable, the reordered packets have to be put in order in the buffer on the receiving machine. The video transmission was also tolerable to high packet duplications (tested up to 10%), which could be expected and is well beyond conditions in real-world networks.

In addition to emulation, we tried transmission over a real network between two buildings in the university campus. There were three routers interconnected with Fast and Gigabit Ethernet links along the path. The image was free of interruptions or visible pixelization, but with slight constant uttering. We did not have an opportunity to try transmission over a wirelless link, but loss rate measurement that we performed on one of our wirelless links suggest that it may be difficult to transmit MPEG video without FEC over a wirelless link. The packet loss rate measurement on the Microcom wirelless 10 Mb/s link from Prague to Podebrady over a period of 5 days was performed. There was an almost constant loss rate of about 1.7% although the link was only very lightly loaded. Such loss rate would probably render MPEG video transmission impossible. We currently do not know whether this is a standard operation condition of the wireless technology used or if there is some technical problem.

We found that MPEG video transmission without FEC is highly susceptible to packet losses. Maximum acceptable packet loss rate for awless image was approximately 0.01%. Such packet loss rate is probably diffcult to achieve on wireless links which means that MPEG video transmission without FEC is probably not possible over wireless links. Tests on real wireless links would have to be conducted to find out the actual behaviour of this class of application on wirelless links. We also suppose that the observable image quality can depend on the decoder implementation. If the decoder could render duplicate frames instead of damaged frames, it would be probably considered much less disturbing by users.

# System of Autonomous Cooperating Agents for Disaster Reconstruction

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Disaster reconstruction is very discussed problem in the modern world. Mobile robots play important role in the stage of exploration of inaccessible or dangerous places for the human rescuer. The robots are able to operate in the disaster area right after disaster faded down or directly during the disaster course. However, nowadays technology provides only direct control by human operator (wireless or hard-wired). This technology is very advanced, but dependence on human is very restrictive. So the autonomous independent robots development is quite important. The RoboCupRescue project as the software simulation is very close to this domain and the results of this project can be used for human rescue squads support and lately for real robot rescue teams control. This project main goal is to develop new algorithms and technologies for software agents' behaviors, which will simulate rescue robots in RoboCupRescue Simulation domain.

The RoboCupRescue system simulates disasters in highly populated areas. The goal is to minimize losses caused by the disasters. Several teams of autonomous agents operate in this area and attempt to maximize efficiency of the disaster reconstruction with effective inter-agent cooperation. The rescue agents are restricted by limited visual information and limited communication abilities. We recognize three main types of rescue agents: Ambulance Team (AT), Fire Brigade (FB) and Police Force (PF).

This project is aimed to next main problems in rescue team simulation:

**Identical agents cooperation:** Standalone agent is not able to manage disaster consequence. Efficient cooperation of all the agents of one type must be taken into account from the global view. For example low number of FB agents might not be able to extinguish a conflagration, and too many FB agents are able to extinguish a fire quickly but another fire can expand to non-manageable size at the same time. The coalition formation and team planning play important role in this problem.

**Non-identical agents cooperation:** Abilities of the various types of the agents are complementary. It is important to guarantee efficient cooperation for rescue problem solving. For example AT agent is not able to save civilians from the building that is on fire until the fire is extinguished and FB agent is not able to get to fire until the road is cleared by the PF agent. The heterogeneous team planning and coalition formation is extension of the previous case and represents more general and complex solution of the problem.

**Limited communication cooperation:** Rescue agents communicate together to guarantee effective cooperation. Number of messages to send and receive in time interval is limited. It is important to ensure robust negotiation system based on limited number of messages. Newly extended Tri-base social model is very efficient in this domain.

**World model creation and maintenance:** Disaster simulation is the real-time application. Environment state is being changed permanently. Information stored in the world model is non-accurate, incomplete and getting old. Thus the agent needs model as accurate as possible. This model is actualized by received information and by predicated world modification.

**Shortest path finding:** It is difficult to find the shortest path in incomplete world model (graph). In general, the agent is unable to find optimal path. The agent is forced to make the decision (move) quickly, but it must minimize the risk of wrong decision. The time wasted by long decision-making or choosing of wrong way can cause loss of human lives. Effective working with the world model helps to solve this problem.

**Goal management:** Goal management is related to efficient cooperation of the agents. Negotiation between identical and non-identical agents is important in this process. The goal election can be made on the local level, when the agent minimizes the losses locally, or on the global level, when all the agents effectively cooperate on the overall losses.

**Replanning and reconfiguration:** The world state can be dramatically changed during the simulation. These changes can cause impossibility of using current solution and can change the goals evaluation and priority. In the first case, alternative plan has to be made and actions of all participating agents have to be replanned. In the second case, agents have to be reconfigured and assigned to particular tasks (goals). Each agent makes new plans with respect to the new situation.

Each agent maintains social model in different way (to meet different requirements), but every model contains the same basis. Our goal was to make i) robust common base of the model and ii) specific extension for each type of the agents. Tri-base model serves as a common base and it is extended by new modules. Newly developed model operates with dynamic non-accurate world model, prepared plans for specific type of the agents and team, and standalone agent's goal managing and negotiation. This model helps the agents to make decision effectively with respect to global goal and cooperation with the other agents (both identical and non-identical). Well maintained cooperator base allows effective cooperation under the conditions of limited communication. Dynamic social model helps agents to response to external changes in real-time with efficient goal replanning and team reconfiguration.

There are situations, when complex decision making causes waste of the time. Agents have implemented fast algorithms for spontaneous reactions (e.g. the AT agent meets injured civilians). These fast algorithms guarantee good decision-making in the case of poor world model (e.g. lack of data at the beginning of simulation) especially for the path finding in the unknown world.

All the algorithms and techniques are designed for use in RoboCup Rescue Simulation system. The agents are developed in JAVA to guarantee maximal portability and reusability of the code. Use of original Tri-base technology, developed by Gerstner Laboratory, helps to enhance the quality of the decision-making and lower the time consumed by this process. New extension of the model together with designed algorithms allows efficient team planning and coalition formation for effective cooperation on goals achieving.

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# Peer-to-Peer Search Engine

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## Introduction

The number of computers connected to the Internet is growing all the time along with its information content. In such a big amount of information is impossible to be oriented without search engines (for example Google, AltaVista, etc.). The major part of search engine is so called *robot* (or *spider*) – a simple program that is constantly downloading the content of web pages into special databases – so called *indexes* – for further processing. Based on such databases is possible to build an inverted index which makes possible fast and easily search for pages (e.g. containing the words user searches for). But it's impossible to download all available information (web pages) on the web into such indexes and keep them valid (in realtime), as networks are too slow. Naturally are indexed only static web pages or dynamic pages which do not need special state information such as cookies to be indexable (downloadable). Direct search of for example on-line databases is impossible in this way. Statistics done over the Internet [1] shows that on-line databases (Deep Web) contain approximately 500 times more information than web pages (Surface Web) can offer. Moreover, it has been proved that the relevance of information stored in databases is higher.

## Client/Server Model versus Peer-to-Peer Model

The another problem is that it's impossible to search in files of different formats in disk space of particular computer connected to Internet. This disadvantage follows from the client/server model, which is the Internet-dominating model – only server can offer information to clients but the clients cannot be searched. Possible solution of this disaccord is to use the Peer-to-Peer model, mostly used in local networks. In this model, each computer can be both client and server. Peer-to-Peer model is not used over the whole Internet, because is very bandwidth-consuming and there's still no way how to provide the same quality of services provided by client/server model when using Peer-to-Peer. But for the search purpose and using appropriate communication organization is possible to use the advantages of Peer-to-Peer model. This idea has been the starting point of our approach to research.

## An Uniform Interface to Web Data Retrieving

During the time, computers offer more and more types of information, for example WWW pages, files, database data, etc. We can look at on all types of information sources and work with them in an uniform way. For this purpose, we establish a special layer which removes the

notion 'information type' (WWW page, file, row of a database table, etc.). Then, to find any information, it is only important to know the computer's address and the port to which listens a special server implementing the layer mentioned above. This server registers all information sources (WWW server, FTP server, DB server, etc.) and offer uniform operations to work with all non-homogenous types of information. As a response from the server will be established a set of URLs pointing at founded information (for WWW page will be returned its URL, for a row of a db table will be returned an URL to any dynamically generated page representing the row data, etc.). For all the information offered by a particular computer will be generated a special local inverted index to speed up the searching process. Keeping the index valid will be easy due to relatively small amount of data located on the computer.

If we want to apply this system on the whole Internet, we have to choose some applicable organization of computer communication. The headstones of the Internet are subnets. So we look at each subnet as a set of searchable computers. From this set one computer as 'central server' will be choosen which will direct queries to computers in subnet. Each central server will know the addresses of some neighboring central servers of other subnets Let's pretend that in this solution, computer A makes a query. Then sends this query to the central server which forwards the query first to all computers in the local network and then to the neighboring central servers. If the wanted information is founded on some computer, this computer will send the result directly to the computer A. To prevent flooding, each query will have limited number central servers to pass through. In the case of central server's failure, each computer in central server's network will be able to replace it – all key information about the subnet and neighboring central servers must be distributed over the whole subnet. After establishing, the new central server lets the neighboring central servers know about the change.

**Future Work**

The problem of finding appropriate communication organization is the key problem of our research. The main objective is to reach a state when by minimal network load the system will find relevant information. The main criterion for evaluating the system will be relevance of the results and speed of their acquisition.

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# Can Video Data Stream Improve the Audio Signal?

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At this time the amount of data stored in electronic format is quickly increasing because of popularity of working with computer. The large data are usually saved in data warehouses or huge databases. These stored data are almost quite damage and non-complete. Therefore it is necessary to extract only beneficial data which are usage for next processing. The group of these problems based on processing of data is called "data mining". These data problems are solved by many approaches (statistical approach, approaches utilize artificial intelligence and similar approaches). One part of data problems, which is only concentrated on signal processing, is called Blind Signal Separation (BSS). These problems are always solved by traditional mathematical techniques or also untraditional techniques by using neural networks. One mathematical (especially statistical) method is well known as Independent Component Analysis (ICA), which can be implemented by neural networks too. The main idea of the BSS problem is separated damaged signals (e.g. medical signals like EEG with artifacts, economic signals like price stock in time or audio signals with noise). Our research has only concentrated on the audio signals. This problem, which specializes on the audio signals, is also known as "cocktail party problem" [3]. For this report it is not important if we use mathematical [4] or neural solution [5]. Now we only concentrate on improvement of a system based on the ICA method. For this purpose we use outside information about a speaking person with using a camera.

The main idea of this improvement of the ICA method is based on comparison between the estimated signal *s'* (it is obtained from a system of the ICA method) and the video data stream *v* (from the camera). The estimated signal s' is audio signal which is obtained from the damaged audio signals. The video data stream *v* is created by using a camera. A system utilizes the camera searches the position of the mouth and after that observes it. If the system detects that the mouth is changing (open & close) - it means that a person is probably speaking, the system saves these video data stream in electronic format.

*Important remark: The video data stream means the movement of the mouth in time. We can imagine the video data stream which is in fact very similar as the audio signal. It is the main idea of our improvement.*

After that we have the estimated audio signal *s'* and the video data stream *v*. The estimated audio signal is not quite perfect therefore it must be improved by outside information from the camera. Firstly we have to recognize if the video data stream is identical with audio signal (for example: the system can separate other audio signal we want to obtain). Than we evaluate comparison between the estimated audio signal *s'* and the video data stream *v*. We have used several techniques, namely: a system based on mutual information or a system utilizes fuzzy logic.

Now we make up experiments which only detect a speaking person and our system evaluates if the audio signals is identical with the video data stream. The results are very dependent on a tested environment. Because we work with the camera, therefore it very depends on used light in environment. We can describe these conclusions:

- For artificial light is better the system based on fuzzy logic, because these system detects a speaking person "vague", on that account it is not necessary bright face.
- The system utilizes mutual information is easer therefore it is better for daily light in used environment. This system recognizes only speaking or not speaking.

These experiments have been prepared on a PC with the Intel 900 MHz processor, with 256 MB operation memory. The operation system was Linux Debian 3.0 and we a PHILIPS webcam.

At this time we are completing our system which is consist of two parts. First part is a system based on the ICA method (mathematical or neural, it is not important). The second part utilizes the system which detects a speaking person and compares the estimated audio signal *s'* with the video data stream *v*.

In conclusion we would like to note that one part of our system is very available for next processing and this solution is very promising for work with the system utilizes the ICA method. This system will be used for cocktail party problem and similar audio-processing problems. This final system will be introduced on POSTER 2003.

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# Aldebaran

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Aldebaran is a fully functional server devoted to propagation of physics and astrophysics. During the past years we have realized teaching texts and applets and physical databases which can be helpful for both lecturers and students. On the server you can find study texts for these lectures:

- Physics II - 02F2
- Astrophysics – 02ASF
- Theoretical Physics 1 (Theoretical Mechanics) - P02TF1
- Theoretical Physics 2 (Quantum Mechanics) - P02TF2
- Theoretical Physics 3 (Statistical Physics) - P02SF
- Theoretical Physics 4 (Waves and Instabilities in Plasma) - P02VNP

In past year we had start up new examinational system for Astrophysics. It is sophisticated system used for the exam of the students of Astrophysics – 02ASF. This system generates each student's exam questions and the student have time limit to answer. It allows to exam permanently growing number of student, last semester about 250 students.

Furthermore in 2002 was completed list of the Nobel Price Winners in Physics. This is a very useful and interesting part of the Web section "Famous People" in which you can find the bibliography of famous mathematicians and Physicists. Nowadays it covers 335 biographies.

In 2002 pages devoted to plasma physics had been added to the server. We intend to offer a database of our department papers as well as information about plasma labs in CTU and outside. These pages will include many photos of interesting phenomena, teaching texts, applets, lectures, etc.

Also tables of mathematical and physical constants can be found on the server, many special lectures, and basic information about lectures. The study materials are supplemented with interactive applets written in Java language. Students can understand the phenomena via various simulated experiments. These applets are created under cooperation with the lecture PJW (Programming Languages for the Web) and with other departments of the CTU (Department of Physical Electronics of the Faculty of Nuclear Sciences and Physical Engineering and with the Institute of Physics of the Faculty of Mechanical Engineering). We intend to increase their number significantly in future. During 2002 three new applets had been added to ALDEBARAN:

- Electromagnetic Simulator
- Charged Particles in Magnetic Dipole
- Charged Particles near Conductor

A very huge section is devoted to Astronomy; you can find here information on solar system, stars, nebulas, plasma universe, sky orientation, telescopes, gravitation, interactions and cosmology, supplemented with a lot of pictures, animations, sounds, etc.

This server is constructed on the INTEL implementation with processor Celeron 800, memory 256 MB and with software RAID-5 field. Operation system on this server is Linux. The server contains 12085 files, 9046 figures, 32056 internal hypertext links and 500 external hypertext links.

The server originated on January 1, 2001. During two years it became well known not only for CTU students but as well in all Czech astronomical observatories. The number of accesses (in period 2001-2002, only first access to main page is calculated) was about 90 000. In 2003 we would like to start electronic conference on physics and make the server more dynamical. From January news in Physics will be regularly (every 14 days) published on the server. As the webmaster of the server ALDEBARAN I wish a great success to the contributors.

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# Methods of the Image Quality Assessment

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This text deals with methods of the image quality evaluation that are necessary in digital communication, data transfer and storage. The main reason for image quality assessment is always increasing use of the image data compression. These compressions distort original images.

Three are trhee main ways how to assess image quality: subjective, objective and human visual models [1, 2].

Subjective quality testing is based on many observers that evaluate image quality [1]. These tests have a very strict definition of the observational conditions.

Objective image quality evaluation is easier, faster and cheaper than the subjective one because we don't need observers. Objective quality testing is given by mathematical approaches, most often by Signal to Noise Ratio or Mean Square Error.

The third way how to assess the image quality is usage of a human vision model. Human vision model combines and uses both objective and subjective methods with respecting human perception properties. Therefore it can show better correspondence with the human perception than the objective one. These vision models can model only some parts of the human vision that we need (spatial resolution, temporal motion, colour fidelity, colour resolution...) [2, 4]. Majority of these models requires a tested image and its corresponding matching reference in order to determine the perceptual difference between them. Human vision models can be divided into two groups. The first group comprises one-channel models [2] that feature computing with the whole entire image. In the second group there are multi-channel models [2, 3, 4] based on neuron response of brain cortex that is known as it's selectivity to spatial frequencies and orientation. These models decompose image into many spatial frequency bands and/or orientations. Then, separate thresholds are set for each channel. At the end of the processing the channels are weighted and summarised in order to get a number that represents the overall image quality.

For testing of the image quality we prepare image tests with various compression methods and compression ratios. The used image compressions are: JPEG, JPEG2000, DCT, fractals and wavelet. These images were tested by all the methods described above.

For subjective testing we used DSCQS (Double Stimulus Continuous Quality Scale) test with respecting ITU 500.3 recommendation for image quality testing.

For objective testing we used MSE and MAE.

For human visual system testing we used two models with structure analogous to the already published models [2, 3, 4]. The first one has 5 levels of computing in L, a, b channels, 10 levels in each L, a, b contrast channels and 5 levels in each L, a, b oriented channels. Together there are 60 channels. To get one value that describes the overall image quality we use weighting of selected channel distances [2]. The second model consists of 31 frequency-oriented channels that are weighted by JND difference metrics [3].

Results of the testing are represented by comparison of used methods. Subjective testing performed by observation is very time demanding but the results correspond to the human perception. Objective testing conducted by mathematical evaluation using computer is easier and faster. Testing by human visual model is easier and time demandig due to the computing alghorithms. Results of testing by the human visual systems have better correspondence with the human perception (i.e. subjective testing) than the objective one.

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# Development of Study Materials for On-line Distance Learning

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Recent development of information technologies enables the creation of new formats and derived applications for sharing of multimedia information within Internet. New tools improve the functionality of information network and also open new opportunities for its use. These facts are clearly reflected in the possibilities for data presentation on Internet. A special part of this field is represented by an educational process in a distant form with the use of computer network. Current level of available technologies enables to produce well prepared study materials accessible for different users in various time and location. This was the topic of the project.

The main concrete aim of the project was to create a complete system of hypertext pages from important and mutually related topics of the following subjects: cadastre of real estates, mapping and mathematical cartography. Program modules for management of partial activities connected to the teaching process - as knowledge tests and their evaluation, support of practical training (particular tasks and instructions for their solution, check of results), etc. - can be understood as supplementary parts of the complete system.

The proposed system makes the study of the above mentioned scientific topics easier and it represents a useful supplement to classical study materials. The text can be easily updated, widely accessed and used and moreover presented by new technological tools. The study system was created also for the students of other study programmes involving the introduction to geodesy and cartography, and also for wider public users as a tool for solving practical tasks. In future it may be used as a fundamental source of study materials for distant on-line learning in the study branch of geodesy and cartography.

Real estate cadastre topic and connected problems of large scale maps creation (mapping, mathematical cartography) is one of the most important parts of our specialisation and a large part of the graduates are active in the jobs of this field. The proposed set of study materials can be very well used together with existing printed study texts which might soon be out of date (especially the parts of real estate cadastre).

Goals of the project can be specified as follows:

- creation of study materials in the form of web pages
- development of supportive programme modules.

Methods used for the solution of the first task were usual activities in this field of work:

- proposal of content structure of study texts
- collection and study of available background materials
- graphic design of web pages (cascade styles)
- formulation of text and its transcription into web pages.

The second goal was reached by the following activities:

- evaluation of possibilities of WebCT system utilisation

- getting knowledge on tools (accessible via Internet) for support of distant learning
- proposal of the programme for testing students' knowledge in the web browser
- development of main functions of this programme.

Concrete aims reached within the project solution:

- The authors learned about the WebCT system licensed at the CTU and used it in the practical courses taught by the project leader. The gained knowledge was used in further tasks of the project.
- Identified topics of the above mentioned study subjects were worked out and made available for students in the form of web pages. It was not possible to create a complex system of all the topics from the subjects as such a process would need much more time. We involved also some students of voluntary subject Programming IV into the project tasks solution. By using the prepared template they worked out the background texts for several topics. We plan to finalise the main set of topics during the second half of the year 2003.
- The authors concentrated on the development of programme modules for automated check of results of particular tasks (in mapping and mathematical cartography). The students themselves can check up the results in the form of digits of characters on a corresponding web page. The solution is based on PHP system. Proper results are either stored in a database (the check is done according to the task number) or they are directly calculated from given initial data.
- Within the project the development of programme system for testing students' knowledge has been started. The solution is based on XML format and PHP system.
- The first version of system for interim evaluation of students has been created. It enables to maintain lists of students and their evaluation within particular subjects. System administration and results presentation is done via WWW Internet service. The solution is based on PHP and MySQL systems.

Besides the project team, several students were involved into the project work. They worked out several topics into the form of web pages and two of them participated also at programme modules development. They will use the experience within the diploma work.

The developed system of study materials is on-line presented on Internet. It is available not only for students of geodesy and cartography but also for students of other civil engineering branches and to all those who are interested in the mentioned fields.

It can be concluded that such a large system should be continuously updated and developed. Thus, the reached project solutions will be improved and made more complete (especially in working out all parts of the topics).

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# Multi-Agent Systems in Virtual Organizations

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In the age of fast changing market situations as well as growing specialization in individual market segments, new ways of economic thinking are demanded. In order to survive in the global market, especially small and medium enterprises (SME's), need to cooperate sometimes even with their major competitors. These co-operations enable enterprises to share resources, skills, and costs and at the same time decrease the risk of investments.
In many respects, there are similarities between the virtual enterprises and multi-agent systems that predetermined agents to be used and exploited in this area.

ExPlanTech is a fully functional multi-agent system for production planning that is deployed in the real manufacturing environment. The system basically consists of two agent classes: operator agent and group of workshops agents where one workshop is single planning unit which represents a resource in the factory (it is usually workshop, machine, store etc.). However, the system is able to operate only on the local factory data (local resources) so it does not take into account for example delivery dates of raw material, components, tools or subparts. In case that necessary components and material are not stored in the local store, the data about material, delivery dates and quantities is ensured in form of rough estimations based on typical delivery dates of a particular supplier.

Our aim was to design, model, implement and test the possible exploitation of the multi-agent systems for industrial application in terms of virtual organizations.
The first step towards virtual organization is the definition of the entity that can represent the enterprise to the outer business world.
We have designed the concept of enterprise-to-enterprise (E2E) agents representing the factory to the surrounding world. There are at least two basic aspects of enterprise-to-enterprise agents: i) customer related where E2E is an interface for customers who can easily track their orders, check fulfillment of the project deadlines; and ii) supply chain management point of view where E2E is an interface presenting the factory as a service or group of services. A service is a general word for accessible resources like machinery, human resources, material, activities etc. Each service has some capacity measured in its particular units (manpower, time, pieces etc.). This kind of interface on one hand makes inner data accessible for related companies (cooperators, customers, suppliers).

This approach, when we turn back to the example with material provision, can extremely speed up the process of negotiation, booking and final delivery of required material. By connecting of a factory store through the E2E agent to the supplier sites we can reach the state when the store is automatically updated according to the current material needs. The agent taking care about the store is responsible for searching of a suitable supplier, can negotiate price, amount and delivery date or can order the material in advance.

During the design phase we have focused our effort to the modularity of the solution. We have intended to develop independent modules that must be coupled with particular agent to allow communication with the ExPlanTech multi-agent planning tool. The well-defined interfaces ensure modules to communicate with the environment (explantech system, extra-enterprise agents).

We have designed following interfaces: PassiveEEInterface and ActiveEEInterface.
PassiveEEInterface allows aquiring data from the explantech system and works in query-answer manner. It is called passive in terms of having no possibility to evoke changes in the planning system.
ActiveEEInterface supports ability to plan, re-plan and cancel particular order, allows to change capacity of resources (workshops) and to send queries to the system. User can be informed using the active interface about changes in plans of subscribed orders that were planned through this interface.
Each interface was implemented as one module. PassiveLocalInterfaceModule implements PassiveEEInterface that periodicaly checks Operator agent and stores its data structure. Data from workshop agents are obtained upon individual query. ActiveLocalInterfaceModule implements ActiveEEInterface, inherits properties of passive module and moreover, implements permanent and concurrent planning.

**E2E and extra-enterprise agents implementation**
E2E agent gives access to the local agent community for remote extra-enterprise agents (EEA) and implements realization of orders in different communities (enterprises). E2E communicates over HTTP protocol with remote partners ("agents involved in communication" EEA vs E2E, E2E vs E2E). So the extra-enterprise agent needs to know URL and name of the E2E agent in order to be able to get data. Every sent message is answered by acknowledgement. Partners watch data that are sent and then send each other only updates. Partners have a choice to pick one of three levels of information complexity. EEA may ask information at once or in updates as soon as some changes in the plan occurs.
Extra-enterprise agents can be classified according to the implemented interface to passive extra-enterprise agents and active extra-enterprise agents. EEA are designed to allow user to approach the ExPlanTech community for example from the web interface, mobile devices (PDAs, phones) or remote gui interface.

E2E and EEA agents are designed and implemented with respect to already existing multi-agent planning tool ExPlanTech. It implies used agent platform which is FIPA compliant agent framework called JADE. All agents in the ExPlanTech community are written in JAVA.

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# Modeling of Agents' Rational Reasoning on TAC (Trading Agent Competition)

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## Introduction

This project aims to develop methods of distributed artificial intelligence that can be used in competitive environment of virtual electronic market. Agents trading on electronic market can be faster and can work with larger knowledge bases than human traders. Advantages of human trader are experience and ability of smart respond to changing state of the market. Using multi-agent systems (part of distributed artificial intelligence) as a test-bed allows us to study new methods and algorithms for automatic trading on electronic markets. Of course at this time nobody trusts computers to deal without human control but computer's suggestions are accepted gladly.

## Trading Agent Competition

Beginning of this project is based on use existing virtual market platform. This platform is called Trading Agent Competition (TAC) and is being developed and run by Center for eBusiness@MIT at Massachusetts Institute of Technology (MIT) in USA. Researchers can develop their own agents, which connect to the server (provided by MIT), and act in virtual trading game. The task of agent is to satisfy demands of imaginary customers ordering the excursions. The set of one excursion consists of transport to the place of trip and back, accommodation in one of two possible hotels, and at least one of three amusements. Plane tickets, accommodation and tickets to amusements are traded on different types of auction. The agent that best satisfies its customers and reaches the maximum profit is winner of the game.

In the first part of project the new agent for the TAC was developed. One of the most suitable programming language for artificial intelligence is LISP and it is used for developing at our Department of Cybernetics so this one was chosen for programming the agent for TAC. Accessible libraries for communication with the TAC server are for languages C++, Mathematica and JAVA. By reason of nonexistence of libraries in LISP first task of project was developing this library. The library and simple agent that uses it proved the ability to design and develop new virtual market by Department of Cybernetics.

TAC is a test-bed with well-defined task for agents. This task (to provide a trip) is done and is not changed. This test-bed serves to researchers that want to prove their algorithms without developing the agent environment. Advantages of TAC change to a handicap when one experiments with strongly distributed community of coequal agents. Handicap of TAC is in one central server run by MIT. Centralization of some functions to the one unit of community causes dependence of whole community on the one central unit. The server, where all exchanges are provided, does not allow particular agents to communicate to each other and form coalitions to reach goals easily. It is why it was decided to develop new virtual market.

## Agent Exchange

Agent Exchange (AX) is the new virtual electronic market environment. It is being developed at Department of Cybernetics in cooperation with Agentcities.NET. The aim of AX

project is to develop publicly available test-bed for electronic trading. There is no central unit in the design of agent community acting in AX. The AX community consists of agents of five different roles. The minimal number of agents acting any role is one and maximum is number is unlimited for any agent role. The agent roles are: Trading-agent, User-agent, Bank-agent, Exchange-agent and Scenario-agent. The AX project has been divided into parts solved by several researchers. The part being solved within Modeling of agents' retional reasoning on TAC project includes design of communication protocols and ontology, design and development of Exchange-agent using one type of continuous double auction (CDA), and design and developing simple Scenario-agent.

**Trading-agent** exploits its resources and rationality in order to make profit on transforming different types of resources by indirect interaction with the other trading-agents. The Trading-agents can buy or sell resources via the Exchange-agent. Trading-agent is controlled by User-agent that is leader of Trading-agents team.

**User-agent** is an interface between a human user and the Trading-agents. This agent manages the team of Trading-agents that a human user owns. Each team has its own team-leader.

**Bank-agent** organizes payments for the inter-agent trading. The Bank-agent administers the money and commodities accounts for the subscribed agents.

**Exchange-agent** is responsible for organizing the trades among the trading agents. This agent is envisaged as an open environment for implementing various auctioning strategies. In used variant of CDA orders to buy and orders to sell remain in the auction until they are accomplished, canceled by their owner or by appointed deadline. The remaining of the orders in the auction does not depend on accomplishing another orders not matching this one.

**Scenario-agent** influences the trading environment by shipping and delivering specific good into/from the market.

The developed protocols and ontology allow start of community and Trading-agents to control the accounts and get information from exchanges, put the bid to sell/buy to the exchange. Exchanges are allowed to check traders' solvency and realize a commodity transaction. The protocols and ontology are being tested on the basic AX community.

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# Data Acquisition and Pre-processing for Vehicle Gearbox Diagnostics

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Day-production of the manual shift transmission in car industry is about thousand pieces. This quantity needs knowledge of new efficient and reliable diagnostic methods of gearbox, which provides the complete local faults test. Some mechanical and electrical solution of these test systems is offered by many worldwide producers in the machinery industry. The various drive conditions such as forward and reverse gear, uphill and downhill, as well as curve driving can be simulated on transmission test stand. The vibration of gearbox housing is usually measured during the test. Vibrodiagnostic signals are converted into a digital form, and the envelope spectrum analysis is used. . If the envelope spectrum was found in the demarcate area, the transmission was checked as OK. In another case this transmission was checked as KO. But the reproducibility of those test results is not satisfying and that is the first reason for investigation in this area.

After a new car has been completed, its functionality is checked by a test drive. The test driver simultaneous evaluates the inner vehicle noise during the test drive. He can lay off the vehicle because of the excessive gearbox noise and that is the second reason for investigation. Although the manual shift transmission was during the test on test stands declared as OK, the manual shift transmission can be declared as KO after test drive. Functional manual shift transmission test, which can be divided into several parts, is a very extensive problem in the industrial surroundings. This paper is focused on the first part, that is intended on data acquisition and pre-processing, especially on testing manual shift transmission on test stands.
One of the most important quality features of the transmission is noise. The level of the noise can be direct measured by acoustic pressure or it can also be derived from the vibration of the gearbox housing. Both methods have some positive and some negative features.

By using microphone we obtain the real level of the noise, which the customer can hear also and this is just the main advantage of this measurement. It is also touch-less and that is the second advantage. But such method makes big demands for environment of measurement place. It is necessary to make the level of the background noise lower then those low-level components of transmission noise. It is very complicated to realize this condition on a transmission production line, because we need a place (chamber), in which the noise reduction is lower by 40 dB in comparison with the industrial surroundings. Another requirement is an anechoic surroundings. If we don't respect this restriction, the standing wave can be caused in this way.

When we measure vibration of the gearbox housing, we don't need the anechoic chamber, but the problem consists in the choice of optimal transducer placement. It can happen, that one transducer doesn't acquire all fault signals from all transmission parts. And also the optimal number of transducers and transducers placement have to be chosen. We directly don't know the noise level, but we can easily select the type of gearbox fault.

There were the transmission noise and the vibration of gearbox housing measured in this project. The main reason for measurement both of these signals (vibrations and acoustic pressure) was the possibility to compare both signals and also the possibility to decide whether these signals can detect all gearbox faults.

The manual shift transmission test stand (situated in chamber) and B&K portable signal analyzer were for measurement at disposal. This equipment was lent by Auto Škoda a.s. Mladá Boleslav .

For gears fault detection seven transducers placement were chosen on gears housing. The placements were chosen by vibration sources positions and by the geometrical parameters of gearbox housing. The first two places are located on vibration source. One of them is situated near the shaft bearing – point A and the second one next to the differential – point B. The other three placements are located on largest surface on the gearbox housing. The last placement is situated at the same place, where the transducer in test stand is normally located at the production line.

The frequency range of vibration was expected to be lower then 5 kHz. As the method of mounting the accelerometer to the measuring point glue was used. This method of mounting guarantees the mounted resonant frequency above 10 kHz at least. During the test the vibration at point A and B were measured simultaneously. The number of the simultaneously measured points was limited by signal analyzer, which can measure up four canals in the same time and also by the number of accelerometers, which were at disposal at time of measurement (just two accelerometers). All vibrations were measured at constant speed and at up-hill and downhill simulation too. The speed range was selected from 1000 rpm to 2000 –3000 rpm (it depends on selected speeds). All fault gearbox frequencies in this speed range have their mirrors in measured frequency range. Each measurement takes about 60 s. This time length allows various data processing and signal averaging.

The transmission noise was measured by a microphone simultaneously. The microphone was mounted about 50 cm above the middle point of the gearbox housing. For the acoustic pressure transducer no restrictions were set (only sufficient frequency range). The speed was measured by the optical tacho-transducer.

Pre-processing software was developed. This software tool enables opening of saved signal history file and transferring all sampled signals or transferring interesting parts of signals into Matlab matrices. All information about measured signals, which has the signal analyzer stored, are represented and also the signals in time domain are shown. The maximum, rms, average value and the frequency domain are there represented.

At the time of writing this abstract three complete transmissions have been measured and about 3 GB data have been stored on PC hard disk. At the end of the project about ten manual shift transmissions will have been measured.

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# Discrete Approximation of Linear Models with Delays in States and Inputs

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The rapid development of the digital technology came out in modelling, simulation, identification and control of so-called hereditary systems i.e. systems where time delays and latencies are essential feature of process dynamics.

Time delay systems can be described by state equations; however, since time delays are a kind of dynamics that is qualitatively different from point accumulation and these state equations have not been originally intended to represent them, no finite dimensional model of this form is able to describe systems with delays adequately. This is an evident drawback. It is impossible to work with an infinite dimensional state vector and the states are necessarily only mathematical abstractions with no real physical meaning. That is why, more appropriate mathematical models are necessary for a reasonable description of time delays systems. In the last decade anisochronic models (as opposed to isochronic models) are more often used for description of these systems [4]. These models separate accumulations and delays as different kinds of dynamics and represent each of them in its own appropriate way.

The transfer function of the linear anisochronic model can be computed in a formally identical way as for isochronic systems. However, the resulting transfer function is not rational. It is a meromorphic function that contains transcendental exponential terms both in numerator and denominator and it has an infinite number of zeros and poles in general case.

The anisochronic state models are suitable for description of both SISO and MIMO time delay systems with considering time delays not only in inputs but also in state variables. Transport processes and all systems, in which measurement, decision and action are separated by some interval, belong to the most typical time delay systems. The model may also be used to represent higher-order delay-free systems, which can be approximated by lower-order difference-differential equations (usually by a serial combination of a first or second order delay-free system and single transportation delay). It is possible to find more information on these anisochronic models in [3].

The linear anisochronic model is frequently used for description of hereditary systems. This model is described by matrix differential equation. If anisochronic model is to be used for digital modelling, simulation, identification or control, it is necessary to find a discrete approximation of this model. However, the discretization is considerably more difficult for systems with state delays than for systems without state delays which can be discretized fairly easily. The basic difference consists in the fact that the characteristic equation of the system with state delays is not algebraic but transcendental and therefore it has an infinite number of roots. All the roots have an influence on the system dynamics but all of them cannot be found. The very fact that the continuous system to be discretized is infinite dimensional while the discrete system is finite dimensional indicates that the discretization can be only approximate in principle.

Up to now most of presented methods of discretization are associated with searching dominant roots [2] or with approximation derivation by difference.

To avoid the problem of searching roots of the characteristic transcendental equation of the anisochronic model the original approach was applied to discretization of linear model with delays in states and inputs using Taylor series [1]. The mentioned approach allows determining the structure and the order of the discrete model with respect to the required accuracy of the approximation about the operating point. The mentioned approach was further elaborated for the continuous-time linear anisochronic models of the second order, which are now often used because of its universality for practical applications where delays and latencies play a significant role. The suggested methodology was tested on non-oscillatory process, critically damped process and oscillatory one.

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# Tuning and Evaluating TCP End-to-End Performance in LFN Networks

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The characteristic of traffic in typical today's network bone, as shown in [1], consists about 90% of Transmission Control Protocol, known as TCP. It's possible, therefore, to consider the TCP as the main protocol, responsible for the generic data throughput performance. Because TCP is a bi-directional protocol, we are examining primarily it's end-to-end particular performance. The resulting throughput depends, except other parameters, on the network path properties, dataflow in both directions and the TCP implementation. Therefore, the objective is to analyze selected unidirectional end-to-end TCP flow in today's network environment, so that the path parameters and their impact on throughput can be closely studied.

The behavior of TCP is determined above all by the size of sending window, which represents the amount of unacknowledged data. Since original specification, given in [2], many extensions have been added [4]. The resulting window is obtained as an intersection of congestion window and receiver window nowadays. Further, both windows can be modified by additional windows, which is the trend towards all modern implementations. For efficient utilization of all available bandwidth, the resulting window must be larger than bandwidth * roundtrip delay product, called pipe. When this product is a big number, such network is called Long and Fat Pipe Network, shortly LFN. Absolute majority of all modern wide-area networks can be treated as LFNs, especially for the original TCP stack implementation.

Except for a packet loss in underlying layer, there can be two main reasons of low TCP performance. The first reason is an insufficient window representation, which is directly violating the performance condition. Original 64kB size limit can be then increased using either Big Window Extension or Window Scale Extension. The second choice, specified in [3], is fully implemented on all today's commodity systems. Unfortunately, all parameters are set conservatively by default, to met at most the original TCP specification, with all former limitations. So, for fully functional window scaling, some related kernel parameters must be always added or changed. Detailed guide about enabling Window Scale Extension in commodity systems, including undocumented features and known bugs, is a subpart of this research.

Second reason are the former mechanisms [4], added to avoid congestion in network. In LFN environment, especially when TCP utilizes all the available bandwidth, congestion mechanism can be easily started. It leads to long term window shortage, with direct impact on throughput performance. The result is, that there exist some optimal size of window, when the throughput is determined only by the window itself. Bigger windows are overfilling the available pipe, and subsequent packet losses periodically force the congestion mechanisms to decrease the window. Further, when the window size overcomes some crucial limit, packet losses can appear in time distributed bursts. When the duration of burst is longer than the retransmission timeout, congestion mechanism may perform multiple window decrease. Such process can lead to extremely small windows, with the same linear increasing trend, as congestion avoidance performs for 64kB windows. Insufficient speed of congestion window

recovery will then fix the low performance for a long time period. Detailed revision of present congestion avoidance mechanism and possible burst drop protection are the objectives of further research.

Measurement of TCP end-to-end performance in LFN environment must met four conditions. Basically, the sender must be able to generate a steady flow, bigger than available bottleneck bandwidth of the path. It implies that we must use a fast network interface, and ensure, that the sending queue is sufficient to keep the flow for at least one context switch time period. In advance, the receiver must be able to keep its buffer empty, so that the advertised window will be always greater than the size of available pipe. It means, that the same overhead is necessary here too, to screen out unwanted context switching gaps. Separated receive window, used in some modern TCP implementations, can solve this requirement transparently. Third condition claims that the window must be allowed to grow at least till the pipe size is met. It implies that the window extensions must be manually activated, using TCP stack variables setting or socket system calls. Fourth condition claims invariant network parameters, so that the measured results can be mutually comparable. Because real networks cannot be always considered as invariant environments, network emulation should be used instead.

The emulation can be performed using NISTNet or similar program. Because at least half of the pipe must be kept in the emulating queue, and examined in very fine time resolution, the requirements for the host system are high. Otherwise, unexpected packet drops or additional delays can occur, and the accuracy of the measurement may be significantly decreased.

In terms of this end-to-end performance project, TCP performance of many systems (Windows95, 98, 98SE, 2000, XP, Linux kernels 2.0.x, 2.2.x, 2.4.x) was examined. Due to the unexpected dispersion in results, we were forced to revise, debug and map their TCP stacks. The TCP behavior was verified directly against the link layer, using packet analysis. Captured packets were examined manually, processed by own scripts, or analyzed with helpful utilities, like TCPTrace or TCPSlice. Known bugs, undocumented features and oddities in TCP stacks of mentioned systems were summarized in a performance tuning guide. This guide can be helpful for performing further measurements in practice and to avoid many systematic errors.

With regards to our results, we cannot recommend the usage of NetPerf, popular Iperf or similar utilities, for measuring purposes. Our method used a direct packet watching on the sender side instead, while the mentioned utilities were used only as flow generators. The flow bulk was verified using RUDE/CRUDE packet emitter, and the performance was analyzed later from stored packets. Because the TCP handshake is cumulative, this method can cope with large dropouts in captured data, without significant impact on the measurement accuracy.

All experiments were performed also in real network, using two PIII/850 MHz hosts and a gigabit link between CESNet and Uninett in Norway. The path contained OC-192, OC-48 and Gigabit Ethernet links, with full pipe capacity about 5.6 MB for full Gigabit Ethernet speed. Subsequent measurements, detailed model of packet drop bursts and revision or redesign of present congestion avoidance mechanisms are the aims of further research.

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# The Lossless Data Compression

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The data compression has big practical importance for information technology. It is used mainly in two areas: data transmission and data storage. While the importance of compression for data transmission is widely accepted, it is often noted, that capacities of storage devices are steadily increasing and thus data compression in this area is becoming less important. Less often noted, however, is the fact that our ambition to store information is similarly growing quickly. That is why the data compression is believed to have a big importance even in future.
Compression algorithms can be divided in two groups: lossy and lossless. The lossy algorithms are widely used for storing images, audio and video data. The lossless algorithms are used for data transmission and storing of a general data. This article deals only with the lossless algorithms and their possible applications.
Recent development in area of lossless data compression has divided most of algorithms into two separate parts: problem of coding and problem of modeling. The first one has been solved with invent of the arithmetic coding. When this method is used, the number of resulting bits is almost the same as the entropy of source message is. The inefficiencies results from rounding errors, the end of file problem or approximations taken for sake of speed and are usually negligible in practice. The method has been further developed by Witten, Neal, Cleary [1] and Moffat [2] so that complexity of encoding is linear with number of produced bits. The method was further improved with idea of range coder, which makes it possible to read and write whole bytes. In spite of all arithmetic coding improvements, the static Huffman coding still works faster than static arithmetic coding. Unfortunately Huffman coding is sub optimal in terms of compression ratio. In practice the difference between lengths of messages encoded with the Huffman coding and the arithmetic coding are not too big. That is why Huffman coding is still used in many practical implementations of compression algorithms, like ZIP.
The most challenging part of data compression is problem of modeling. Several models suitable for general input data have been proposed. Method that currently achieves best results in terms of compression ratio is called PPM*. The serious disadvantage of this method is its big demand of computational resources (in both time and space). The BWT algorithm [3] is another well-known model. It achieves results only slightly worse than the PPM* does, but uses much less computational resources. This algorithm is used in popular compression programs like bzip2. The big disadvantage of this method is its static nature. This makes this algorithm useless for applications like online data compression on a communication channel. Another modeling scheme is called DMC. Method is based on dynamic construction of Markov chain, which generates encoded messages. Author believes, that this method can achieve results similar to PPM* with much less usage of computational resources.
One particular class of yet not well-examined models are models based on syntactical analysis of input message. Such model should be able to profit from the following observations. For a syntactically correct message it can predict next input symbol more accurately than general models without any deeper knowledge of source language structure does. More accurate predictions result in shorter output of an arithmetic encoder. Another fact the model should be able to profit from is possibility to reduce number of symbols, which has to be encoded. Model

can for example maintain symbol tables and use them to encode variable or function names as a single symbol.

Although theory of both LL and LR parsing is well developed, this particular application cannot use them without modifications. If we want the compression to be lossless, syntactic analyzer has to deal with information like indentation, white spaces or comments, which are usually discarded by lexical analyzer and are not processed at all. The algorithm should be able to compress even syntactically incorrect input (of course with worse compression ratio). To achieve this, the syntactic analyzer has to be able to recover from errors effectively. The main disadvantage of this approach is its restriction to sources, which can be described by LR grammars.

The data compression algorithms can be used not only as specialized programs but can be also incorporated into the kernel of operating system and work as part of file system. This solution is much more convenient for user than usage of specialized programs. Unfortunately it also implies several problems, which have to be solved. The environment of OS kernel usually puts severe constraints both on used memory and computational complexity of compression and decompression algorithms. The methods based on LZ77 [4] seem to be the best choice in this case. Another problem is possible fragmentation of randomly accessed compressed file. The problem can be solved in several ways. The simple solution is compression of several file system blocks at once and storing the result in integral number of file system blocks, leaving possibly unused space in the last one. This approach does not fully solve the problem and moreover it reduces overall compression ratio.

Alternative approach is based on idea not to compress data immediately, but defer it to some later time, when there will be free resources to process pending requests. This approach make possible to process time-consuming operations like file defragmentation in background without remarkable slowdown experienced by user. Such approach also makes possible to use algorithms with big computational complexity of compression (decompression should be as fast as possible though). It also implies the necessity to implement new structure in file system holding all requests, which are to be processed in background in future. This schema of file system work has to be tested under different types of workloads. It is expected to suit well the needs of typical home or office user, but it probably will not be suitable for heavily stressed file servers.

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# Formal Description of Design in Visual Prolog

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The basic problem of an engineering design in CAD systems [1] is how to describe not only the specific design process in a convenient way but also to specify parameters, requirements and limitations posed on a designed object in a definite way. This object does not have to be only a mechanical engineering product. The same problems also rise with the descriptions of products in branches of civil engineering, VLSI design, software engineering and so on.

The subjects of our research is the finding and testing of a suitable formal means for the description of design process. Thereby it is understood not only the description of a product structure but also the description of semantics of specific data entering the design, i.e. indefinite information, expert knowledge [2], rules and results given by standards, binding limits posed on the product, functionality requirements, etc. – so the description of relationships among data-parameters. The goal of our research is to describe and design the world whose implementation would be a contribution in automation of design process – i.e. to design, implement, verify and test in factual example convenient formal means for the description of design process.

The Visual Prolog [3] has been chosen as a suitable implementation environment. The designed product in research is an accommodation unit (flat) which consists of the defined number of rooms. Each room has a window and a doors interconnect the rooms. One of the rooms has an additional door out of the flat. Another requirement is that each wall in a room has either a window or a door or it can be the wall without any window and door. The windows must not direct to opposite sides and must not look to the north. The solution of program logic is the matching of windows and doors to individual walls-directions and orientation of the walls to the cardinal points.

The program consists of a few modules. The main module is an algorithm that solves the whole problem by means of available worlds of modal logic:

$$w_0 = \{flat(in\_room, room1, \ldots)\}$$

where the world $w_0$ represents the main specification of a flat which consists of a room with entering door and other rooms (minimum 1+1). By fulfilling this specification the solution of the whole task is determined. Further it is necessary to go over the factual implementation of individual rooms which will be represented by other worlds:

$$w_1 = \{room1(door, window)\}$$
$$w_2 = \{in\_room(in\_door, door, window)\}$$

By gradual refining – supplying other necessary conditions – we will form other worlds by successive enlarging previous worlds.

*The example of the world* $w_2$ *:*

$$w_2 = w1 \wedge (Door \neq Window) \wedge (Window \neq \text{"North"})$$

*and implementation* $w_2$ *in Visual Prolog:*

```
world(2) = direct(D), direct(W), D <> W, W <> "North".
```

The final worlds will realize factual variations of solution where new clauses will be represented now by the modality of possibility.

Other modules will enable binding limits entry given by the user and to realize the visual side of the program.

At present the specific algorithm is created and programmed and it is necessary to finish the user interface and the visualization of available solved examples.

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# The Scientific Image Data Optical Processing

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New technical parameters of CCD or CMOS image sensors bring not only high accuracy of optical measurements, but also a huge amount of data. Because of the limited capacity of transmission channels and archive media, it is important to find fast compression algorithms appropriate for supposed image data processing. Loss-less compression algorithms are often used in scientific applications but their efficiency is limited. Maximal achieved compression ratio depends first of all on the data type and amount of image signal entropy. Typical compression rates of loss-less algorithms are from *1:1.5* to *1:3* [1] for Huffman and arithmetic coding. Other possibility is usage of more efficient lossy compression techniques characterized by decorrelation parameters. Typical examples of this possibility are JPEG or JPEG2000 standards. It is necessary to consider whether the algorithms optimized for multimedia applications and human vision are suitable for scientific image data compression. JPEG standard is recognized as a not suitable one because its quantization tables are defined for color image signal with maximal depth 12 bits per each color channel, while the typical scientific (for example astronomical from BOOTES project [2]) images are gray scale with higher (*14 – 16* bits) bit depth. Application of special compression algorithms based on wavelet [3], fractal or Karhunen – Loeve [4] expansions seems to be a better solution.

Let $\ddot{X}$ is an input gray scale image matrix and *R* is an decomposition operator conducting fragmentation of $\ddot{X}$ into sets of *M* image submatrixes $\left\{ \left[ x_j^i \right]^\alpha \right\}_{i,j=1,\alpha=1}^{N_1,N_2,M}$ with dimension $N_1 \times N_2$.

The derived sbmatrixes can be assumed as $N_1 \times N_2$ realizations of random process in Hilbert vector space [4] over the complex numbers. Then an equation for KLE base vectors $\{ | \Phi_s^r ] \}_{s,r=1}^{N_1,N_2}$ evaluation can be derived

$$\sum_{n=1}^{N_1} \sum_{m=1}^{N_2} \Xi_{nj}^{im} \, | \Phi_{is}^{jr} ] = \alpha_s^r \, | \Phi_{ns}^{mr} ] \qquad \begin{matrix} n,s = 1,...,N_1 \\ m,r = 1,...,N_2 \end{matrix},$$

where *m, n* are indexes within the entire base matrix and *r, s* describes entire base matrix. The symbol $\Xi_{nj}^{im}$ has been used for elements of covariance matrix

$$\Xi_{in}^{jm} = E\left\{ \left[ x_j^i \right]^\rho - E\left\{ \left[ x_j^i \right]^\alpha \right\}_{\alpha=1}^{M} \right\} \left\{ \left[ x_n^m \right]^\rho - E\left\{ \left[ x_n^m \right]^\alpha \right\}_{\alpha=1}^{M} \right\}_{\rho=1}^{M},$$

where $E\left\{ \left[ x_j^i \right]^\alpha \right\}_{\alpha=1}^{M}$ represents the mean value operator calculated over *M* image submatrixes. Calculation of these equations and other scientific data processing brings a high computation effort. Our novel approach is to replace selected parts of numerical calculation for optical computation methods and data process using light. The most important case is an optical realization of non-uniform sensitivity sensors and optics correction. Correction is obtained by dividing the acquired image (after subtracting dark map) by another image made on a bright uniform optical signal background. This image is often called as a flat field. 2D parallel multiplication can be realized as a direct implication of native properties of optical systems. Let the input image intensity distribution is $I_1(x, y)$. Then flat fielding can be done by pointwise multiplication by the transparency *T(x,y)*. When the distribution of slide transparency is equal to

$$T(x,y) = \frac{K}{F(x,y)},$$

where $F(x,y)$ is a flat field image and $K$ is their average value, then corrected image is obtained after image walking through transparency.

Optical low pass filtration method has been used to determination of sky background map on the image. Value of signal in sky background is important for object searching, calculation of their brightness and correction of non – uniformity of sensitivity of detection system ($K$ value estimation) also. Low – pass filtration in Fourier domain can be performed by mechanical putting an iris in the transform plane. This iris will permit all light corresponding to frequencies below a specific value (with larger distance from spectrum centre) and block the light corresponding to frequencies above this radius. High-pass filtration in Fourier domain can be realized using small aperture with arbitrary shape.

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# Mobile Multimedia Collaboration and Annotation within the EU Project MUMMY

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Fast progress in the mobile technology has enabled us to run a lot of application that could be found on the desktop computers and on the mobile (PDA) devices as well. The mobile environment however differs in specific aspects that make it difficult to perform the same task as on the desktop computers.

With respect to upcoming wireless technologies the European Community launched within 8th and last call of the 5th Framework Programme the cross-programme action "Mobile applications and services". Along with partners [1] CTU succeeded with the R&D the proposal "MUMMY – Mobile Knowledge Management". The MUMMY project IST 2001-37365 started on October 1st and will run for 3 years.

The vision of MUMMY is to enable mobile, personalized knowledge management based on the usage of rich multimedia to improve the efficiency of mobile business processes. MUMMY project will provide:

- New multimedia and hypermedia technology for a seamless integration of pocket-sized computers into the knowledge management control loop, addressing the topics of knowledge development and usage.
- Substantiation of the expedience of the developed components through rudimentary portal establishment and trials for the construction industry.

CTU is involved as a research partner and leader of the work package "Provision & Access of Content and Collaboration with Mobile Computers".

In the framework of this package CTU will research the following topics:

- Content Adaptation
- Annotating of Vector Graphics and Images
- Collaboration and Live Sharing of Annotations
- Media Integration

Our goal is to enable a mobile multimedia collaboration and annotation in conjunction with data preprocessing and offering relevant data. The whole system is designed with respect to the mobile environment specifics. We have several scenarios for using the system.

The most important one is a support for a construction manager inspecting a construction site. In this scenario the user can request 2D blueprints stored in a SVG (Scalable Vector Graphics), XML based format. He can browse them using a PDA (Personal Digital Assistant) device and compare the design with the reality. If the reality does not match he can make changes in the blueprints or make (e.g. type, draw or record) an annotation. Furthermore he might request a consultation with another expert. They can share the data, communicate on-line and the system will propagate all the actions made by one user to all other collaborating users. After the consultation is done, the changes are stored in an extra SVG file.

This scenario relates to all shown research areas:

The goal of the Content Adaptation task is to modify the data to be transferred to the user's mobile device according to the current situation. The situation is analyzed and the data modified based on actual context. The context is a set of parameters describing the device the user is using, actual location, environment properties like noise level or light conditions, time and other values. After the adaptation the data will be presentable on the limited mobile device (screen, memory, performance, installed software) and additional support to the user will be provided. For example a part of the data format may be extracted or simplified before sending to the user. To process the adaptation correctly we are, in addition to the context information, using additional information, e.g. metadata describing the adapted data.

The task Annotating of Vector Graphics and Images deals with the problematic of design of an efficient SVG editor for a PDA device. Along with the editing of SVG data the metadata are modified/created. The focus lies on the editing of previously adapted data. Concept of projection of changes to the original data, adaptation awareness and suitable user interface will be developed.

Collaboration and Live Sharing of Annotations solves the problem of sharing the data with other users. In the mobile environment the connection reliability is very problematic. The system must combine on-line and off-line approaches of data synchronization. This is achieved by data and event buffering both on the server and client side. On the server side data naming and locking mechanisms will be developed suitable for the mobile usage. Furthermore in conjunction with the adaptation techniques the objects of collaboration must have the same representation by each of the collaborating users. Another functionality that has to be solved is the user communication management. The user will be able to watch the on-line/off-line status of other users, manage user groups, invite to collaboration and admit or refuse calls for collaboration. Finally user interface must be solved that would fulfill the requirements of mobile environment.

Media Integration task is focused to the problem of integration of various data formats used for communication and data exchange usable in the mobile environment to achieve added value in knowledge communication.

There are many requirements to the used data format. It must be a container of other data formats as well as for metadata used. Also it should support streaming technologies and incremental data update and should comply with international standards. As a suitable candidate we have chosen the MPEG-4 format.

The research activities within the MUMMY project are coordinated with respect to later practical use. The partner spectrum comprises besides R&D institutes as well large industrial companies in the areas of mobile technology and network provision, civil engineering and facility management. The prototyped results will be fed into field-trials ant the end of the project.

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# Data Mining – Automatic Data Preprocessing

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Data preprocessing is crucial part of data mining – it provides a clean and well explored data; in ideal case, of course. Unfortunately, this goal is very hard to achieve.

There is currently no common standard and universal method. There are several methods discovering some characteristics of the data, some classification of available processes (filtering, calculation of new values, splitting data), but these methods stay implemented as separate programs and small applications [1].

Practically, each data miner has its own way how to handle data; he or she usually loads the data into some spreadsheet application (for example into Excel) to see the values, rarely he makes a graph. Often is the data directly processed by a data mining tool. This is the worst case for reasonable results, because the is no data understanding (no idea what is being processed), dirty data are inspected (data mining algorithms are confused by exceptional cases). Data mining then provides poor results. That is not about poor quality of algorithms or data mining methods, but about bad or missing data preprocessing.

The only simple, existing, and a user-friendly way is a big commercial system (like Clementine), which is both extremely expensive and complex; usually it is concentrated on other tasks (data mining). This solution is unacceptable for data preprocessing purposes only. Preprocessing is usually a part of databases, but there is only simple set of available modules regarding capabilities of the database, they don't add any additional value.

For all these reasons we have decided to design and implement our original universal data preprocessing system, SumatraTT. This system has been developed within GOAL and Sol-Eu-Net European Union projects and has been tested in several real applications. Within the grant project the research is focused on fast data understanding and methods for automatic module suggestion. The system proved its advances and potential for further development. The most important feature of SumatraTT for data miner is RAD – Rapid Application Development.

SumatraTT is graphically oriented system for data processing in general. It consist of a basic application together with a set of modules sorted in hierarchy. All capabilities of SumatraTT is determined by a size of the module set.

SumatraTT basic modules cover most of the preprocessing tasks like filtering, input and output from/into various data formats, various field handling, adding attributes, value calculations, history handling (adding historical values into a record).

One of most important features of the system is an implementation in Java. It simplifies easy new module creation – based on clearly and well-documented basic support-module classes.

First task in data mining is data exploration and understanding.

Data exploration consist of identification of available sources and recognition of its format (database with JDBC/ODBC/specific interface, comma separated values, DBF, or any specific binary format like Excel table). The format determines module to be used and specific format capabilities (for example NULL processing). This part can be sometimes difficult when data comes from completely different sources. In extreme case the format is so individual, that it is necessary to write a special program for pre-preprocessing. SumatraTT can help in case of acquiring data from text reports – it contains regular expression module.

Data understanding is much demanding and is in fact the most important part of the whole data mining [1]. Data miner cannot present any reasonable results until he or she deeply understands what data are on the input, which relations exist in the data, what restriction apply.

SumatraTT supports (first) quick data understanding by its module for fast reporting. This module investigates the structure of a given source of data and generates exhaustive and graphical report on the data. It supplies several statistical values (minimum, maximum, average values and others) and both graph of values and histogram. It generates HTML page with such information, so it is possible quickly describe the data and publish it for wider audience for collaboration in data miners group. The report contains thumbnails of the graphs with interactive links to full-size graphs.

There are several others modules dedicated to data exploration, which is closely related to visualization. A rich set of graphs can be generated and automatically saved in pictures into files. These graphs are very flexible in types and graphical attributes. The system supports all common types of graphs (line, point, symbol, XY, pie-chart and others). A configuration of graphs allows to specify titles, fonts, colors, and symbols to be used. A histogram module offers several methods for making a histogram (basic, with fixed range, classes with equal number of cases). The most interesting feature of this module is its interactivity – it can compare two classes and visualizes positions of the classes in the data stream. It can explore time-dependent dependencies.

While data miner completely understand the data, it is necessary to design a transformation of the original data into more desired form. This transformation should correct errors in the data (when the errors are not a matter in the mining). All the data should have the same format. Very often it is necessary to carry out complicated calculations – classification, splitting data into several sources using several different methods, recalculations of the source data, depending on the data miner's goal.

The data processing is in SumatraTT supported by automatic suggestion of available modules based on data format (only suitable modules are offered).

Finally, the whole processing is automatically documented in HTML page with detailed description – all available on one mouse click.

The whole system is successfully used in cooperating universities for data preprocessing.

The future development is concentrated on a deeper and faster data understanding and a further support for automatic transformation design based on acquired information.

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# Detection and Tracking of Moving Objects in Jittered Images

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It is a critical technique in automatic target recognition and navigation to detect and track dynamic object in complex environments. The situation is more complex when the object of interest is moving and moreover, the camera is shaky. In such a case jittered images are acquired. The task is to detect and consequently track the object of interest. First, it is necessary to manage the image jittering. Practical examples of detection and tracking of objects are for example a detection of driving cars from autonomous vehicles, detection of walking persons on the road, and so forth. Generally, we can recognize the following three categories.

The first one is based on static sensors, which extracts dynamic objects from fixed background scene, and is usually implemented by image difference operations. A living example of this technique is an urban traffic supervision system. The difference between this technique and our method, is the using of a non-stationary camera. In our case the target is detected on the basis of an apriori information that target is in the central part of the image.

The second approach employs moving sensors. However, the background scene is assumed to be very far, which is therefore having a constant global motion factor. This topic has been widely studied as detecting a flying airplane hidden in the cloudy sky. In our case the global motion factor is not constant.

The third problem is that the sensor has an unknown motion, as well as the background motions are unequal because of the comparatively short distance between the camera and the target. This technique is applicable for obstacle avoidance in autonomous road following, and is also crux for intelligent guided bombs.

In our task we solve a general problem of moving object tracking in the sequence of images acquired from a non-stationary camera. The target can be a moving object or a part of the object. The target shape has not an influence on the tracking algorithm. This algorithm has been developed for proper target detection and tracking of moving objects like persons walking on corridors that have been sensed by a camera mounted on a robot chassis. The aim of the process of image acquisition is to keep the moving object in the central area of the image. In this way we manually prompt the evaluation system to find and consequently tract the object concerned. The algorithm detects the position of the target and the center of the image. If the positions of the target and the center of the image are the same, the algorithm reports its detection. The proposed method is based on both a fast stabilization of a shaky image sequence and on a sophisticated algorithm that allows detection and consecutive tracking of the object without a previous stabilization.

Let us emphasize that we do not know what is the real object we want to track. We do not know how big is the object, or if we track only a small part of a large and shape complicated object. The only information about the demanded real object (or its part) available for the program is an effort of the camera system to keep the center of the camera frame over

the real object and the fact that the object must contrast with its background in some way. In fact, we do not find any exactly bordered object but only one point. This point is for us a representative of the target. A natural representative is a gravity center of the found object contour. Of course the point is related to the background picture and to the real object.

The main idea of the target detection follows these steps:

1. Stabilize the image sequence (calculate the shift between two consecutive images)
2. Calculate average position of the image center over the stabilized image
3. Detect static and dynamic targets with respect to the image background
4. Overlay indication of the image center and the target point

The stabilization is based on an observation that the camera can only moves and not orbit and zoom. The algorithm of stabilization calculates profiles of intensities in both vertical and horizontal direction along the previous and current image. Then a correlation of the intensities is performed. A size of differences is the groped shift.

The average position of the image center is calculated to obtain an estimation of the object position. In fact it is a position filtration.

The object of interest is detected on the basis of an intensity contrast with the background and if it is dynamic, then moreover on the basis of its movement during consecutive images. The boundary points of the object representing the object contour are obtained as places of steepest gradients of intensities on lines (rays) casted from the estimated object center from the previous image.

The indication of current and estimated object position overlay is indicated on the basis of distance measure between these two positions.

Several methods that sufficiently successfully track the moving object in the central area of the acquired sequence of images have been introduced. Consequently new methods adapted to the new and original problem have been introduced. The methods are very resistant to blur, noise and shaky movement of the camera. The target tracking is not dependent on the object shape and size. The algorithm is also color independent.

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# Face Detection from Discriminative Regions

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An algorithm for detecting instances of isolated objects against cluttered backgrounds based on still images is presented. The algorithm is applied to detection and localization faces from frontal views.

The ability of detecting and interpreting faces by machine is challenging task with impact to many real applications (e.g. security, database searching and indexing, interfaces for human-computer interaction etc). Without any additional constraints, the face detection is very difficult problem of computer vision. Given a single image or a sequence of images, the goal of face detection is to identify and locate human faces regardless of their position, scale, orientation and pose. Complications arise from huge variability of face appearance caused by high degree of variability in size, shape and texture, diverse lighting, complex backgrounds, facial expressions and presence or absence of extra facial features (e.g. glasses). The complexity of face detection is similar to complexity of face recognition, as the detection can be treated as recognition among different object classes, while the recognition implies distinguishing between specific objects within one object class. In this terminology, the objects detection is understood as natural generalization of object recognition.

Many contemporary methods for object detection share the same framework: The whole image is scanned by window and every candidate is classified as face or nonface. The classification is based on features extracted from image information within window. The main disadvantage of such an approach is its computational complexity. In general case, the number of possible feature extractions is huge, since all admissible transformations (e.g. translation, rotation, scaling, non-linear deformation etc.) of window have to be considered. It implies that in order to achieve reasonable processing time, the feature extraction and feature classification have to be as simple and fast as possible.

In the proposed method a face is described as composition of small regions with well-defined local orientation. The problem of face detection is reduced to the problem of identifying a set of discriminative image patches with given property and decision about face presence is based on spatial arrangement of the local parts. Both the discriminative image patches and their spatial arrangement are learned from training database containing 600 face and around 5000 nonface examples.

The used method filters the image by a two-dimensional quadrature filters and the local orientation is estimated as combination of the filter responses [2]. We use 2-D Gabor filter proposed by Daugman [4]. In particular, we selected four circular Gabor filter with orientation uniformly distributed over the space and with bandwidth fixed around 1.52 octaves. To cope with scale we use eight filter sets with frequencies covering three octaves. The Gabor filter concept forms a basis for minimizing the sensitivity to phase in the signal and provide the best trade-off between spatial and frequency resolution. In order to decrease time needed for computing filter response we approximated Gabor filters by second (real part) and third (imaginary part) order derivatives of Gaussian.

For selection of discriminative feature set and training classifier we use boosting technique proposed by Viola and Jones [1]. Boosting is a general method, which attempts to improve the accuracy of any given learning algorithm. The AdaBoost learning algorithm, introduced by Freud and Schapire [3], is used to boost the classification performance of a simple learning algorithm (called weak learner) by combining a collection of simple classification functions to form a stronger classifier. The learner is called weak because its performance can be relatively low and error rate less than 50% is enough for boosting. In order to boost weak learner, it is called to solve a sequence of learning problems. After each round of learning, the distribution of training examples is re-weighted in order to emphasize those, which were incorrectly classified by the previous weak classifier. The final strong classifier takes the form of a linear combination of weak classifiers.

The conventional AdaBoost procedure can be easily interpreted as a greedy feature selection process [1]. The main idea behind this algorithm is to associate a large weight with each good classifiers and a smaller weight with poor classifiers. Inherently, it is an aggressive mechanism for selecting a small set of good classification functions, which nevertheless have significant variety. Drawing an analogy between weak classifiers and features, AdaBoost is an effective procedure for searching out a small number of features, which have significant variety. By restricting the weak learner to the set of classification functions each of which depends on a single feature (orientation of local image patch in our case) the AdaBoost algorithm can be designed to select single feature which best separates the positive and negative examples from training database.

Main contribution of proposed method is its insensitivity to in-plane face rotation, since this rotation can be normalized by exploiting information about mutual orientation of local image patches. Next, as the orientation estimation is relatively insensitive to local image brightness and contrast, the proposed method is robust to illumination conditions as well.

In future we plan to test and validate several possible improvements of proposed method, like extension to detecting also faces rotated in-depth and testing of different method for local orientation estimation.

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# Usage of the Optimal Normal Basis in the Elliptic Curve Cryptosystems

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Elliptic Curve Cryptosystems (ECC) belongs to the public-key cryptosystems. Security of the ECC depends on the complexity of solving problem named Elliptic Curve Discrete Logarithm Problem (ECDLP).

For cryptographic purposes are used the elliptic curves over the finite fields of type $F_p$, where *p* is prime, or fields of the type $F_{2^m}$. In this paper we will discus only fields of type $F_{2^m}$. Such field has $2^m$ element and the elements of the field are polynomials of degree less then *m* with binary coefficients in the $F_2$. Indeed not all of expressions of this field are equally suitable for hardware realization and that why we're trying choosing such representation where basic operations (addition and multiplication) can be implemented in the most effective way. Normal basis representations have the computational advantage that squaring an element can be done very efficiently. There are various types of the GNB. Type of the base *T* is an integer representing rate of complexity of multiplication with respect to the given base. Less size of the *T* means, that multiplication (using selected base) is more effective. The Gaussian normal bases of types 1 and 2 have the most efficient multiplication rules of all normal bases. For this reason, they are called *optimal* normal bases. For given *m* and *T* field $F_{2^m}$ has at most one GNB of the type *T*. Optimal Normal Basis (ONB) gives us possibility of an alternative definition of the multiplication on the elements of a field $F_{2^m}$ .. Type of the ONB for each value of *m* is determined in IEEE P1363 Annex A.8. While optimal normal basis multiplication is less insightful than polynomial multiplication, it is in practice much more efficient. Multiplication by the ONB has two phases. First we have to do a setup for multiplication and than to perform own multiplication.

**Setup for multiplication**

1. If $F_{2^m}$ has a *Type I* ONB, then irreducible polynomial *f(x)* have to be: $f(x) = x^m + x^{m-1} + ... + x^2 + x + 1$. Otherwise, if $F_{2^m}$ has a *Type II* ONB, than irreducible polynomial *f(x)* will be computed as $f(x) = f_m(x)$ while using following recursive formula:

$$f_0(x) = 1$$
$$f_1(x) = x + 1 f_1(x)$$
$$f_{i+1}(x) = x f_i(x) + f_{i-1}(x), \quad i = 1,...m$$

At each stage, the coefficients of the polynomials $f_i(x)$ are reduced modulo 2; hence *f(x)* is a polynomial of degree *m* with coefficients in $F_2$. The set of the polynomials $\{x, x^{2^1}, x^{2^1}, ..., x^{2^{m-1}}\}$ makes a base of the field $F_{2^m}$ over $F_2$ called normal basis.

2. Construct the matrix *A* of size $m \times m$.

Rows and columns of the matrix are indexed form *0* to *m-1*. Its $i^{th}$ row makes a string

corresponding to the polynomial $x^{2^i} \bmod f(x)$. The elements of the matrix e $A$ are elements of the $F_2$ .

3. Determine the inverse matrix $A^{-1}$ of $A$ over $F_2$ .
4. Construct the matrix T' of size $m \times m$, whose $i^{th}$ row will correspond to the polynomial $x \cdot x^{2^i} \bmod f(x)$. Than compute the matrix T = T'A$^{-1}$ over $F_2$ .
5. Determine the product terms $L_{ij}$, for *i, j = 0 ... m - 1*, $L_{ij}$ = T(j-i,-i). Element *T(g,h)* denotes (g,h) entry of the matrix *T* with indexes divided modulo 2. Each product $L_{ij}$ is an element of the $F_2$ . It should also be the case that $L_{0j}$= *1* for exactly one *j*, $0 \le j \le m-1$, than for each *i* $0 \le i \le m-1$ exists $L_{ij}$=*1* for exactly two *distinct j,* $0 \le j \le m-1$ .

The matrix is precisely determined by the type *T* and dimension *m*. Multiple matrix $m \times m$ is made by the elements of the field $Z_2$ and it's very „sporadic". Only 2m-1 of the m$^2$ entries of the matrix T are 1, the rest being 0. Hence ones are not distributed randomly, but in the first column is only one 1 and in the other columns there are exactly two 1's. This scarcity of 1's is the reason that the normal basis is called an optimal normal basis.

**Multiplying by ONB**

Lets have a multiplying matrix *L* for field $F_{2^m}$, elements of the field $a = (a_0 a_1 \dots a_{m-1})$ and $b = (b_0 b_1 \dots b_{m-1})$.

For *k=0,…m-1* lets maker following steps:

1. $c_k = a \cdot L \cdot b^{tr}$, $b^{tr}$- transposed vector of the *b.*
2. rotate vector *a* to the left as follows $(a_0 a_1 \dots a_{m-1}) \to (a_1 \dots a_{m-1}, a_0)$
3. rotate vector *b* to the left as follows $(b_0 b_1 \dots b_{m-1}) \to (b_1 \dots b_{m-1}, b_0)$
4. increment *k* by 1
5. go back to the step 1

The result of the multiplication is a vector $c = (c_0 c_1 \dots c_{m-1}) = (a_0 a_1 \dots a_{m-1}) \cdot (b_0 b_1 \dots b_{m-1})$

Thus $(a_0 a_1 \dots a_{m-2} a_{m-1})^2 = (a_0 a_1 \dots a_{m-2} a_{m-1}) \cdot (a_0 a_1 \dots a_{m-2} a_{m-1}) = (a_{m-1} a_0 a_1 \dots a_{m-2})$ can be calculated with a simple rotation of ($a_0$ $a_1$ $a_2$ $a_3$… $a_{m-1}$).

Squaring is a very efficient operation when optimal normal basis representation is used. Since exponentiation typically involves many squaring operations, exponentiation is performed far more efficiently using optimal normal basis representation than using polynomial representation.

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# Pattern Matching in Compressed Text

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The pattern matching in compressed text problem is defined as finding (all or the first) occurence(s) of a given pattern P in a text T, using only compressed form of P or T or both (as defined in [1, 3]).

Pattern matching is one of the most important problems in computer science, with many applications in computer practice and other scientific fields. Without pattern matching, fulltext internet searchers would be impossible. But the applications of pattern matching does not contain only internet searchers, but also many applications in biology (work with DNA), and so on. But, the size of stored data grows faster than the storage media. The solution for this is the data compression, which is approach of reducing redundancy in the data leading into smaller space occupied by the data. There are two main approaches to data compression: lossless and lossy. The data compressed by a lossless data compression can be decompressed in their original form. The data compressed by a lossy data compression and decompressed are a bit difierent (a bit here means so much it is not a problem). In this paper we will consider only lossless compression.

There are many pattern matching problems: there is a 6D classification given by Melichar and Holub (see [2]). The result of pattern matching can also be various: all positions of the pattern occurrences in the text, simple does contain/does not contain pattern (and others, see [2]). There are also many compression methods. There are at least ten very important compression methods, and many others (see [4]). Each algorithm solving pattern matching in compressed text can be partially described by specifying pattern matching problem it solves and compression method it uses. But, to classify algorithm more precisely, these two dimensions (pattern matching and compression method) are not sufficient. There is another dimension describing solved problem: which one of P and T is compressed on the input? We recognise four types of problems here: plain text-plain pattern, compressed text-plain pattern [1], plain text-compressed pattern, compressed text-compressed pattern [3] (let denote them plain-plain, compressed-plain, plain-compressed, compressed-compressed, respectively).

The first (plain-plain) problem is well known common pattern matching problem. The second (compressed-plain) and fourth (compressed-compressed, also known as fully compressed pattern matching) problems are currently intesively being researched. The third (plain-compressed) problem was neither defined nor researched yet.

In total, we get three dimensions defining the problem (pattern matching problem, compression method and compressed pattern matching type). As can be seen, the size of the problem is huge. It is obvious that trying to find a special algorithm for each particular problem would produce huge number of algorithms. Therefore a kind of unification scheme would simplify the problem.

There, in fact, exists a simplification scheme for pattern matching problem: all pattern matching problems can be solved using finite automata. The problem with a general finite automaton is that to find a compressed pattern matching algorithm simulating a finite automaton can be very hard problem, and the maximal time and space complexity could simply be impractical in many cases. Therefore, it seems to be reasonable to define the pattern matching dimension as

matching for "one pattern", "multiple patterns", matching for a pattern with errors and general pattern matching.

For the compression dimension, there also exists a simplification, named "collage systems". Collage systems unifies several compression methods, such as LZ78, LZ77 and RLE. Any algorithm for collage systems can be used for any of these compressions.

Another interesting questions is evocated by compressed-compressed pattern matching: as defined in [3], the compression method used to compress the text is the same as the compression method used to compress the pattern. The problem could be simpler if the compression methods would differ. This approach would also have a practical advantage: the text stored in permanent storage could be compressed by a good compression ration and slow compression method. The pattern, changing quite often, could be compressed by a faster but worse compression ratio method.

Another difficulty in the real world is that practical compression approaches work in layers. For example, the input text is passed into a compression algorithm producing stream of numbers. This stream is already compressed (smaller than the original), but as we show later, it still can be made smaller. Imagine there are long sequences of just a few numbers. Such sequences can be encoded much more efficiently than the original stream. Therefore a new compressing layer should be introduced taking care of this encoding. In this case, we would like to have a pattern matching algorithm whose input will be the result of all the layers of the compression, and that will produce a set of matches in the original text. Unfortunately, creation of the algorithm for two compression levels is usually more complicated task than creation of an algorithm for one compression level. One of the solutions would be to create the resulting algorithm step by step, layer by layer. There are no analyses of such an approach. Current algorithms for pattern matching in compressed text solves effectively only one compression layer, causing that in layer architecture it is necessary to decompress all lower layers and that perform matching in text compressed by only one layer.

There are two diffierent criteria for comparison of algorithms performance: time and space complexity. There are two diffierent limits for time complexity: either the algorithms operates faster than an algorithms decompressing the text and matching in the decompressed form. Or the algorithm is faster than algorithm matching right in the decompressed text. It is obvious that the second limit is harder to achieve.

In the future, we would like to investigate pattern matching in multi-layer compressed text. We also would like to find a new algorithms for currently unsolved problems.

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# Local Affine Frames for Object Recognition

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Establishing reliable correspondences in a pair of images taken from arbitrary viewpoints is a critical problem in many computer vision tasks. Applications include appearance-based object recognition, 3D scene reconstruction, motion recovery, image mosaicing, content-based image retrieval, mobile robot navigation and many more. The task is, given a pair of images of the same scene or object, to determine which parts of the images depict the same part of the scene. The problem gains complexity once the distance between the two views increases. The corresponding point may then lay anywhere in the other image, or even disappear, and its visual appearance may change dramatically due to geometric and photometric deformations. In situations when local image deformation cannot be realistically approximated by a translation or a translation with rotation, full affine model is required. Local correspondence cannot be therefore established by comparing regions of a fixed shape, like rectangles or circles, since their shape is not preserved under the group of transformations that occur between the images.

Although our work is mainly aimed at the object recognition task, we are also interested in wide baseline stereo and content based image retrieval problems. The object recognition problem is essentially this: given some knowledge of how certain objects may appear, and an image of a scene possibly containing some of the objects, to find out which objects are present in the scene and where. The challenge here is to build a system that is immune to the effects of variable background, noise, image clutter, object occlusions, and illumination and viewpoint variations.

Object recognition, being one of the oldest fields in computer vision, is still attracting attention of many researchers. As a consequence, a wide range of approaches have been proposed. In general, two main trends can be distinguished: model-based and appearance-based approaches. While model-based methods try to analytically model the relation between the object and its projection to the image, appearance-based methods recognise objects by visual similarity, without attempting high-level image analysis. Model-based approaches usually rely on extraction of 2D primitives, such as image edges, which are hard to obtain and interpret reliably. On the other hand, appearance-based approaches, that directly use the intensity function or its transformation (eigenimages, colour histograms), are prone to fail under viewpoint and illumination changes, once the appearance of the object changes substantially.

As an attempt to combine advantages of both approaches, methods based on matching of local features, ie. on solving the correspondence problem, have been proposed. Like in the appearance-based approaches, an object model is learnt from images thereof, however local features are extracted and used for the matching. The advantage here is that the deformations of object appearance caused by viewpoint changes, although being globally complex, can be approximated by simple transformations at local scale. Various methods in this category, including ours, differ in the choice of local image regions and in the features computed over these regions.

In our work, an assumption is made that image deformations can be reasonably well approximated by local affine transformations of both the geometry and the illumination. Such assumption holds for objects where locally planar surface regions can be found, and where the size of such regions is small relative to the camera distance, so that perspective distortions can

be neglected. The proposed approach is based on a robust, affine and illumination invariant detection of local affine frames (local coordinate systems). Local correspondences between individual images are established by a direct comparison of normalised colours in image patches represented canonically in normalised affine frames. The method achieves the discriminative power of template matching while maintaining the invariance to illumination and object pose changes. The main contribution of this work is the utilisation of several affine-covariant constructions of local affine frames for the determination of local image patches that are being put into correspondence. The robustness of the matching procedure is accomplished by assigning multiple frames to each detected image region, and not requiring all of the frames to match.

Local affine frames facilitate the normalisation of image patches into a canonical frame and enable direct comparison of photometrically normalised intensity values, eliminating the need for invariants. It might not be possible to construct local affine frames for every region. Indeed, no dominant direction is defined for elliptical regions, since they may be viewed as affine transformations of circles, which are completely isotropic. On the other hand, for some regions of a complex shape, multiple local frames can be affine-invariantly constructed in a stable and thus repeatable way. Robustness of our approach is thus achieved by selecting only stable frames and employing multiple processes for frame computation. Two main groups of affine-covariant constructions are proposed, based on region normalisation by the covariance matrix and the center of gravity, and on the detection of stable bi-tangents. Transformation by the square root of inverse of the covariance matrix normalises the shape up to an unknown rotation. To complete an affine frame, a direction is needed to resolve the rotation ambiguity. In frame constructions derived from the bi-tangents, the two tangent points are combined with a third point to complete an affine frame. As the third point, either 1. the center of gravity of the region, 2. the center of gravity of the concavity, 3. the point of the region most distant from the bi-tangent, or 4. the point of the concavity most distant from the bi-tangent is used.

Successfull experiments in object recognition, image retrieval and wide-baseline stereo domains demonstrated the generality and general applicability of the approach. The experiments are described in detail in [1,2,3,4]. Achieved results are superior to the state of the art.

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# Common Subsequence Automaton

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A subsequence of a string T is any string that can be obtained by deleting zero or more symbols from T. Given a set P of strings, a common subsequence of P is a string that is a subsequence of every string in P. The problems on subsequences arise in many areas, *e.g.* in molecular biology and coding theory. One of the problems with great practical impact is the longest common subsequence (LCS) problem. The problem is to find, given a set P of strings, a common subsequence of P that has maximal length among all common subsequences of P.

Algorithms for this problem are used in chemical and genetic applications and in problems concerning data and text processing. For example, in the study of the evolution, the LCS is used as a measure of the correlation between two molecules of DNA. In text processing, the LCS is used to find the differences between two files, or as a metrics for measuring the distance of two strings, which has application *e.g.* in spell checking. If the number of strings in P is not bounded, the problem is NP-complete, as was shown by Maier.

The problem is known for decades and a huge number of algorithms has been proposed as a solution. The algorithms for the LCS problem are usually divided into two groups in literature: the algorithms for the LCS problem of two strings, and the algorithms for the LCS problem of three or more strings. Although all the algorithms from the latter group can be used also for two strings, this separation is sensible, because many algorithms from the former group do not have any straightforward generalization for three of more strings. We will shortly mention several algorithms from both groups.

The first solution of the LCS problem of two strings was probably dynamic programming, which is based on recursive computation of the LCS matrix and was discovered independently by several scientists. The algorithm has quadratic (in the length of the input strings) time and space complexity. Hirschberg [2] showed how to compute the same matrix in the linear space using the "divide and conquer" strategy. Another improvement of the dynamic programming algorithm is from Hunt and Szymanski who computed only those entries of the LCS matrix that correspond to matches between symbols of the input strings. An algorithm with the best known worst-case time complexity was given by Masek and Paterson. They used the Four Russians' algorithm for computing transitive closure to speed up the computation of the LCS matrix.

Itoga extended the dynamic programming for the case of arbitrary number of strings. Hsu and Du introduced a common subsequence tree and described an algorithm that builds and traverses the tree in an efficient way. In the worst case the algorithm is the same as dynamic programming but when the number of matches is low, the algorithm requires much less time and space. Crochemore and Troníček [4] mentioned an automaton that accepts all common subsequences of the given strings and gave an off-line algorithm for its building.

Another problem on subsequences is to decide, for a string S and a set P of strings, whether S is a subsequence of P. Preprocessing strings in P allows us to solve the problem in time linear in the length of S. Baeza-Yates [1] described the automaton accepting all subsequences of given set of strings and a right-to-left algorithm for its building. The automaton is known as Directed Acyclic Subsequence Graph (DASG). Crochemore and Troníček [4] gave a left-to-right algorithm. An on-line algorithm is from Hoshino *et. al.* [3].

In this paper, we describe an on-line algorithm building the CSA. The language accepted by the CSA is a subset of the language accepted by the DASG for the same strings. This implies some similarity between the CSA and DASG. The on-line algorithm building the CSA described below is modification of the algorithm from Hoshino *et. al.* [3]. A possible application of the CSA is the LCS problem or the problem of separating two sets of strings. Given two sets P (positive) and N (negative) of strings, we say that a string S separates P and N if S is a subsequence of P and simultaneously S is not a subsequence of any string in N. The problem has application in discovery science and machine learning. We slightly reformulate the problem: given two sets P and N of strings and a string S, we ask if S separates P and N. We assume that the problem should be answered for several different strings S. Then it makes sense to preprocess strings in P and N. We will build the CSA for P and the DASG for N. With these automata we are able to answer the question in time linear in the length of S.

We will describe (informally) an on-line algorithm building the CSA for a set of strings $T_1$, $T_2$, …, $T_k$. In the first step, we build the DASG for $T_1$ (which is also the CSA for $T_1$), and then in each subsequent step we load the next string. That is, after loading i-th string, we have the CSA for $T_1$, $T_2$, …, $T_i$.

We will explain the idea of loading a string into the automaton. The states of the automaton are divided to active and non-active. At the beginning, before appending the first character of the string, only the initial state is active. Once a state becomes active, it remains active until the whole string is processed. We process each string character by character. When a character is being loaded, we examine transitions from all active states labeled with this character. Let q be a state where any (one or more) such transitions end. Two situations can occur: (1) all the transitions that lead to q start in active states – then no splitting of q is needed, or (2) at least one input transition of q starts in a non-active state – then q must be split to two states. In this case, we create a new state with the same output transitions, and redirect all transitions leading to q and starting in an active state to the copy. The new active states are found as targets of transitions that start in an active state and are labeled with actual character. When the whole string is loaded, all states that are not active will be removed.

In general case, the automaton built by the presented algorithm is not minimal and can be minimized using a standard approach. The time complexity of loading string depends on the number of states of the automaton. If the number of states of the CSA after loading string T is $O(v)$ and we implement the set operations in logarithmic time, loading a string T requires $O(v\sigma \log v)$ time, where $\sigma$ is the size of the alphabet.

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# A Simulation of Supervisory Human Operator Cognitive Processes

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From the viewpoint of the tremendous growth in the area of a control of large technological processes, the method enabling a real-time monitoring of a human supervisory operator's psychical stress level appears as a suitable approach promising control process fault minimization through the elimination of faults caused by the human factor. Particular attention should be given to the application of the stress/fatigue level estimation techniques, applied both to the supervisory operators training process and to the real supervising of plant and control processes.

During the recent years, a wide spectrum of simulations of human behaviour and cognition, covering the whole area from artificial intelligence and fuzzy logic to control theoretic techniques, appeared on the scene. However, there is still great deal the can be done in the area of a real-time monitoring of a human operator's psychical stress and/or fatigue levels and integration of such estimators in simulation systems. An experimental Yoshikawa and Takahashi's study focused on a research in the line of human's cognitive features, appears as a fundamental work in this field. A concept of the two-way adaptive human machine interface was presented. Basic concept was later integrated in Mutual Adaptive Interface.

We consider the ability of model to account for the cognitive functions and cognitive processes, that need to be included in a simulation process to describar human operator behaviour. These are: cognitive functions (perception, interpretation, planning and execution) and cognitive processes (memory/knowledge base and allocation of resources). In addition to these basic processes, we also consider types of connection that are active within the human model and combine cognitive functions and cognitive processes and mechanism that couple the human model with the machine and socio-technical context.

Our system of cognitive model consists of the following components: perception, interpretation, planning and execution, memory/knowledge base and allocation of resources model, emotionnal reaction modul and personality tzpe modul.

This cognitive model is connected to the intelligent system for the estimation of the human supervisory operator stress level from the real-time acquired physiological parameters, both under the normal and safety critical conditions, and the human supervisory operators training improvement through this system application. The system for the synchronised parallel physiological parameters acquisition and monitoring was presented in detail. This system consisted of the following components – measurement devices, client computers, server, and SQL server. Seven client modules were implemented, from which four ones are more sophisticated, namely the ECG client module, EOG client module, eye-movement module, and general signal pre-processing module. The other client modules were implemented as simple data-collection clients performing no more sophisticated signal analysis and parameterisation. The stress curves reconstruction is discussed. The pilot experiments focused on the stress level classification through the feed-forward neural network and fuzzy rule system were described.

Real-time measurement of the physiological parameters followed by the real-time stress level estimation can support the training process in two ways:

- To set a stress curve for each human supervisory operator for particular examples. This stress curve enables to discover more stressful parts of the trained example, to identify them and modify the training process to eliminate these weaknesses.
- To define a capturing of the trained example for each human supervisory operator and for each trained example. This capturing of the trained example consisted of three factors – correctness, time and stress level. Human supervisory operators have to find a correct solution of the trained example in some admitted time (usually seconds). The last factor characterizes a stress level set to the human supervisory operator, while he solves the trained example. If the stress level is high, the particular example must be trained again. The capturing of the trained example enables to find an optimal number of repetitions of the training process of each particular example for each particular human supervisory operator.

Simulation of human operator cognition are used in four different principal types of aplications: design, safety assesment, training and accident analysis. A safety assesmnet study can be perormed from two quite different approaches – design basis and probabilistic safety assesment.

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# Distributed Computer of Space Facility

# Software Architecture

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There are groups of industrial materials processed by melting with following crystallization or solidification. Quality of them is negatively influenced by the Earth gravitation. Basic material experiments have been carried out in orbital space stations in micro-gravity environment during several last years and next experiments are under development. Samples of selected materials are processed in equipment called crystallizer, which is mechatronic computerized facility consisted of multi-zone tubular furnace, electrical vibrationless drives for positioning of processed samples and manipulating of in-sample measurement facility, furnace heaters power converters, temperature measurement and control electronics, gravitation measurement unit, safety and overheating protection unit, Crew Interface Computer (CIC) and other auxiliary units.

The paper presents requirements and software architecture of TITUS MPP (Multipurpose Platform) distributed control computer. TITUS MPP is crystallizer developed to be used for scientific material experiments on-board of ISS (International Space Station) which is under construction now.

Software general design requirements listed below are applicable as on the whole distributed control computer as on its separate intelligent nodes. Selected important items are: * Crew safety, * Station safety, * Crew friendly (automatic processing, clear crew interface), *High quality parameters, * Reliability, * Communicability (crew interface, telemetry channel to the Earth), Traceability (easy to diagnose faults, support of nonstandard operation behavior analysis, support of error analysis), * Modifiability (future function modification, addition of fully new functions and options), * Serviceability (easy to repair in orbital station), * Easy to assemble/disassemble (easy to disconnect functional units to be stored in station stock, easy to connect units again and restore system operation).

MPP control computer is network based. Set of intelligent nodes is connected by two computer networks. Internal network connects master node (called central controller) with slave nodes which control equipment drives, heating, protection etc. Internal network is LonWorks technology based where network layer is CSMA/CA type. Central controller is connected to CIC computer by another network based on ProfiBus protocol which is of master/slave type. All nodes are designed with the same philosophy. Number of different node types has to be minimized. Each node has host processor and network communication processor. Where it is possible the same node type is used and node self-modified based on its network position. Network configuration tool is not applicable (suitable) on the orbital station, so each node (its host) is sensing its current position and host configures network communication part parameters. In addition to network connection each node has local service channel to make software development, debugging and software installation tasks easier. Each node runs from in-RAM code and has FLASH disk to store program and data. Communication

model is client/server type, each node has set of high-level commands. Commands are accessible from both connection points (network/local). On local service channel in addition to high level commands is set of low-level commands for development and test purposes only. It is supposed that new or upgraded software can be downloaded on the orbital station. Technological programs for experiments are prepared on the Earth by physicist and astronauts take them on the storage medium to the orbital station when mission starts. In the station programs are loaded to the CIC computer on the mass-storage medium (HDD). When certain experiments has to be started, its technological program is downloaded to the central controller unit (through network). This unit requires services from all other nodes based on master/slave model and controls experiment execution. Slave nodes communicate with master only, no slaves intercommunication is allowed. From user's point of view each network node has set of high-level commands. Command structure depends on node type. Example of command set (no details) for temperature nodes follows: * Set node mode (protection/control), * Change node state (reset, init, go, hold, stop...),* Set temperature control behavior for controlled channels (temperature gradient, target temperature, protection temperature), * Get temperature process data, * Set behavior of run-time diagnostic module, * Get gathered diagnostic data, * Set fault/error monitoring module (error stack model), * Get error stack contents and another commands. User service commands/responses on the network utilize message option of LonWorks. Network variables are seen too wasting channel capacity. Inner design of each node is affected by several factors, where some of them are: * Software reliability and function security (crew and station safety, extremely expensive repair of possible errors when found on orbital station), * Requirement faults/errors to be traceable (error analysis documentation), * Limited node resources (speed, storage space, operating memory size), * Limited development time and expenses, * Limited men resources. In this project software is partitioned such that system software (BIOS, low-end user services-communication API,..) are common for all node types and node application software is developed by one module type/one programmer method. So problems which arise where several programmers work in the same node are eliminated. As a result we did not use general full-featured real-time operating system. To satisfy nonstandard behavior traceability requirements it is used self-documented table driven process scheduler/dispatcher on background/command level. Processes consist of statically pre-planned threads. Processes are event driven (dynamically planned mainly by command processor output). Running thread of process can not be preempted by another process but in time between threads preemption is possible. Scheduler/dispatcher is able to utilize different synchronization clocks for different groups of processes. Time critical parts are interrupt driven outside the scheduler/dispatcher area. Architecture described above is valid for node host processors. Network communication is processed by network processors (not described here). Resulting architecture of host software may be seen as coroutines-background/interrupts model.

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# Teachers' Training for New Programming Courses in Structured Study

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The school year 2003/2004 will mark an important milestone with respect to teaching at the Czech Technical University due to the introduction of new study programs offered at all its faculties. The structuring of these programs, which makes them compliant with the Bologna Declaration, aims at responding to actual needs in higher education in the European context while providing the students a more homogeneous study environment across European universities.

When designing the new programs to be offered by the Faculty of Electrical Engineering, the Department of Computer Science and Engineering took this as a challenging opportunity to accompany the structural changes with corresponding course contents updates that would make them to better match the actual situation in the ICT industry. Most of these updates can be considered "local", since they concern the courses included exclusively in Computing Programs at BSc and MSc levels. Nevertheless, there is also one important change in the introductory computer programming courses that has a "global" effect as these courses are compulsory for all students of the Faculty.

Since almost 25 years ago, these courses have been built on the Pascal programming language background. Pascal is almost perfectly suited for pedagogical purposes due to its simplicity and clean orthogonal structure. On the other hand, its basic procedural programming paradigm has become rather insufficient since the time of Pascal introduction. Both modular and object oriented programming has been gradualy penetrating into practical Pascal implementations used to develop real industry applications. The need for rapid development of efficient software systems calls for usage of component programming methodology and, as a consequence, for object oriented programming representing the essence of this methodology.

This need was not the only reason that lead us to the decision to replace Pascal with some truly object oriented language, specifically with Java. Most software applications that are being developed now are in fact Web applications that permit an easy and flexible usage via a variety of Web browsers. The interrelation between Java and WWW stems not only from the Java language definition and inclusion of necessary tools in standard Java classes. Syntactically close to Java, the JavaScript scripting tool for creation of dynamic WWW pages represents another important joining link between Java and WWW.

The effect of change from Pascal to Java will be profound since it will influence to some degree almost all software oriented courses offered by the Dept. of CS & Eng. First of all, there is a complete change of contents in the introductory computer programming courses offered at the Faculty. This change is far from being just of a syntactic nature, as it was the case, for example, when passing from Algol 60 to Pascal. It is the change from procedural to object oriented thinking in programming and in algorithmic problem solving.

It is well known that a novice in programming is equally apt to adopt to either way of thinking, so that from the pedagogical point of view, a harder task implied by this change is to properly prepare all academic staff that is involved in teaching the introductory courses. What

makes this task so hard in our teaching environment is the fact that it involves teachers from other departments of the Faculty, not only from the Dept. of CS & Eng.

It was specifically this task that we considered it worth an internal grant support from the CTU. We organized to runs of the "teach-the-teachers" course aimed at making the related personnel acquainted with the object programming style and Java programming environment (JBuilder by Borland). During these courses, the participants were asked both to solve a basic set of problems and to prepare extended sets of problems that will be suitable for their own seminar and laboratory classes. The materials obtained this way are used now to prepare detailed teaching notes for instructors in a week-by-week style. We consider the existence of such teaching notes a necessary condition to keep the needed standards of teaching in an environment of some 1400 students divided into 5 parallels for lectures and into 70 teaching groups for seminars and laboratories.

Naturally, our preparation for the new courses does not stop at the end of year 2002. It will continue with at least one more run of introduction to Java directed specifically to the remaining teachers (and possibly other interested personnel) from other departments and, even more important, it will be gradually transformed into a critical evaluation and improvement of the course materials after we open it the first time for our students.

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# Planar Circuits for MW and MMW Technology

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To design, produce and correctly operate microwave and millimeter wave circuits using modern planar technologies, detailed knowledge of the parameters of lines and basic circuit discontinuities over a wide frequency band is necessary. The objective of the project was to create of a complete concept of leaky waves in open uniplanar transmission lines, mainly in the slot line and in the coplanar line. Higher order modes, higher surface leaky modes, modes leaking into the surrounding space, and dielectric substrate losses were included in the analysis. The originally designed measurement of the electromagnetic field by means of noise verified the theoretical calculations. One of the goals was to optimize the design of planar leaky wave antennas utilizing the leakage of power into the space above and below. The results have widened and deepened the basic understanding of the behaviour of slot-type transmission lines.

The main problem was to investigate slot- and coplanar-line characteristics over a wide frequency band, energy leakage in the form of surface and space leaky waves, and their dispersion characteristics. The next problem was to calculate the electromagnetic field distribution in the structure of the layered media. The method of moments applied in the spectral domain was used. The key point of the whole procedure was to integrate the Green function multiplied by the base functions in the complex plane of the spectral variable. The propagation constant of the individual modes was sought by solving a dispersion equation in the complex plane. Programs for calculating the dispersion characteristics and the field distribution in the transversal plane of the slotline, coplanar waveguide, conductor-backed slotline and inverted conductor-backed slotline were written. New components of the modal spectra of these transmission lines were revealed, namely the dominant modes on the conductor-backed slotline, which can propagate along the line from zero frequency. The behaviour of these modes is very interesting. The dominant wave on the slotline is the standard bound wave. The dominant waves on the conductor-backed slotline and on the inverted conductor-backed slotline are not bound, so these lines cannot be applied for a standard signal transmission. Leaky waves radiating power into the space above the conductor backed lines were studied with the aim to utilize them as antennas.

The slotline leaky wave antenna was designed, optimized and fabricated. The radiation pattern of this antenna is smooth, the directon of its main lobe moves with increasing frequency towards the endfire direction, as expected from the behaviour of space leaky waves on the slotline. On the other hand, measurement of this antenna verified the theoretically described characteristics of the leaky modes.

Theoretical work was accompanied by experimental checking. An enlarged model of the slotline and of the conductor-backed slotline was fabricated, which permitted good resolution in determining the field intensity distribution. The measurements performed on these models gave us direct evidence of the behaviour of the dominant waves and waves leaking power into the substrate. Beside the standard monofrequency measurement using a sliding coaxial probe, a non-traditional measuring method was selected which can evaluate the field intensity by a noise generator as source and a radiometer as detector. This method enables the field intensity to be inicated while reflections and interference effects are eliminated.

Models of the line discontinuities were created by cumbersome calculations of their scattering matrices for various frequencies and combinations of structure parameters. It is necessary to approximate the resulting data by simple functions in order to apply them effectively in circuit analysis. A new fast interactive method for the approximation was designed. The procedure superimposes functions that describe differences between original data and the approximation in order to obtain scattering parameters of the discontinuity in the form of closed form functions. This ensures results that are sufficiently exact for practical implementations. The program is quite versatile and usable also in numerous other fields of applications.

The results of the research performed on the basis of this project have been presented at 23 international and national scientific conferences and in the IEEE Transaction on Microwave Theory and Technique [3]. The acceptance of our papers for presentation at prestigeous international conferences worldwide indicates the high scientific quality of the work. Beside the scientific importance, the project has created good conditions for education of students. Three postgraduate and ten graduate students have participated in the programme. Two diploma thesises and 6 semestral projects have been written. A student from the University of Rome is working on his diploma thesis in the framework of a CTU scholarship. All students participating in the project have extended their professional qualifications and acquired scientific skills.

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# SIP, Firewall and NAT

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Rapid evolution of new networking technologies made VoIP (Voice over IP) technology reality not only in countries like U.S.A but in the Czech Republic too. Czech academic network is a pioneer in VoIP deployment. Big providers like Aliatel, Eurotel or Contactel are almost ready to sell this service. Some of enterprises are using it as well. But the real world deployment of VoIP brings several problems to be solved.

One of the problems consists in using of firewalls and NAT boxes (Network Address Translation) at boundary network nodes. Firewall is used to protect network from unwanted incoming traffic and restrict traffic outgoing, chiefly disallowing some of the internet services. Set of rules serves to test whether the packet should be passed or rejected. NAT boxes solve the lack of free public IP address. Private addresses in packets flowing out of the private network are translated to smaller amount of public addresses at the boundary node to enlarge number of connected users.

SIP (Session Initiation Protocol) [1] and H.323 are two most used signaling protocols in VoIP. H.323 is ITU-T standard and SIP is IETF standard. Problems are nearly the same for both protocols. I prefer SIP because of less complexity and internet nature. Signaling flow self is not a real problem for firewall even NAT, because it uses well known port number 5060. Transport of information about media receiving addresses and ports during initiation signaling sequence is the real problem. The addresses and ports have to be known to set firewall rules for passing of media streams and all occurrences of private addresses should be overwritten in case of NAT. Several possibilities of solving the problem have been proposed [2]:

- ALG (Application Level Gateway)
- MIDCOM protocol (Middlebox Communication)
- Media Proxy
- STUN (Simple traversal of UDP through NAT)

What are main pros and cons of listed proposals?

ALG is application-aware entity built in the firewall that examine and modify application protocol flows and only allows messages in conform to the security policies to pass through. It seems to be good idea but several issues should be considered. Adding ALG into firewall for every problematic protocol leads to decrease of performance and possible stability issues. ALG is not an application level trusted entity and inspection of secured session will therefore fail. Further, signaling protocols are on the technology edge and new versions are frequently released, the ALG need to be upgraded to support new versions. This solution moves unwanted additional load to firewall developers.

Midcom could be the right way of solving this problem. There is need of less complex cooperation from firewall developers. Special protocol is designed to tell firewall what rules should be added or removed and how translation in NAT should be done to let media flows traverse the network boundary. Application aware logic persists only in proxies. The only one protocol is used for all problematic applications. We have successfully implemented and tested minimal version of this scenario for firewall with FCP (Firewall Control Protocol).

Idea of proxy could be used for media flows too. Pool of addresses and ports is set for traffic to be passed through the firewall or statically translated in NAT. This pool is provided to

media proxy. Media do not flow directly between endpoints, they pass the media proxy, where are at least changed the addresses. Major drawback is a delay generated by proxy. On the other side there is no need to change or upgrade the boundary nodes.
STUN [3] provides solution only for NAT and even not for all types. Several types of NAT, varying in translation restriction, exist in today networks. STUN is special protocol which helps client to find out how will be the flow translated. Probing packets are sent from STUN client built in proxy or phone to STUN server behind the NAT. Responses contain translated source address of probe packet. Proxy or client modifies the messages in according to response. Major drawback is that STUN doesn't solve firewall and symmetric NAT used in enterprises. This solution is therefore oriented to SOHO. Advantage is protocol simplicity.
Perspective solutions are MIDCOM or media proxy for enterprises and STUN for SOHO. Further work will be oriented to implementation of fast media proxy, performance and quality of service measurement and comparison with FCP solution.

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# Genetic Algorithms with Limited Convergence

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Genetic algorithms (GAs) are probabilistic search and optimisation techniques, which operate on a population of chromosomes, representing potential solutions of the given problem. In a standard GA, binary strings of 1s and 0s represent the chromosomes. Each chromosome is assigned a fitness value expressing its quality reflecting the given objective function. Such a population is evolved by means of reproduction and recombination operators in order to breed the optimal solution's chromosome. The evolution is running until some termination-condition is fulfilled. The best chromosome encountered so far is then considered as the found solution. GAs are very often engaged in solving multimodal optimisation problems. This implies that the ability of the GA to keep just the "raw" diversity is not good enough. Instead the multimodal diversity covering many niches of the search space is required.

This paper introduces a novel approach to protect GAs from getting stuck in local optima and so extending the search power of GAs. To achieve this we have proposed a GA where only limited convergence of the population genotype can take place. The main goal of the proposed algorithm called a *genetic algorithm with limited convergence* (GALCO) is to maintain the fruitful diversity of the evolved population during the whole run and so to preserve a GA from getting stuck in local optima.

To achieve this, a concept of a limit imposed on the convergence at every position of the chromosome is adopted. First an initial population of chromosomes is generated. It is made sure that the distribution of 1s and 0s does not violate the convergence constraint at any position of the chromosome. In our case the evolution starts from maximally diverse population i.e. every column of the population consists of an equal number of *PopSize*/2 1s and 0s regardless of the chosen convergence range.

The algorithm uses a specific replacement strategy to keep the desired distribution of 0s and 1s on each position of the chromosome during the whole run. The pair of newly generated chromosomes replaces the parents if the best-fit chromosome out of those four ones is the child. Under such a replacement operation the population genotype stays invariant. To further boost up the exploration power of the algorithm a special replacement operator was introduced, which is used to insert as much of the offspring chromosomes into the population as possible. It works so that the currently worst fit chromosome of the population is merged with the new one. In fact this is just another recombination operation providing a means for better exploiting of genetic material of the poorly fit individuals.

The proposed algorithm was experimentally tested on a representative set of test problems. First two test problems were based on non-linear non-separable and highly multimodal functions of two variables. The next two test problems were representatives of deceptive problems, i.e. problems that are intentionally designed to make a GA converge towards some local deceptive optimum. We have also tested the algorithm on an representative of so-called *Royal Road* problem. The used problem is defined as a concatenation of ten 16-bit schemata of all 1s. Only the combination of all 1s on the bits pertinent to a given schema contributes to the fitness with the value 16, any other combination has value 0. So the optimal

solution is of fitness 160 in the string of all 1s. The last test function is the periodic function that was used to analyse the ability of the GALCO algorithm to maintain multiple optimal solutions in a population. The function is defined on the interval $\langle 0.0, 1.0 \rangle$ with 5 equally-spaced maxima.

The results revealed several interesting aspects of the algorithm's behaviour. First, the best performance of the algorithm was achieved with convergence rate close to 1 (the desired distribution of 0s and 1s is almost half-to-half in every column of the population). This is in agreement with the intuition that the more equal the distribution of 0s and 1s is used the less the algorithm is prone to prematurely converge so the better results can be achieved. The second observation is that the algorithm does not require very large populations needed to solve the problems. In fact rather small populations (150-250 for our test problems) can be used with GALCO to effectively search a complex solution space. This becomes evident when compared to the results obtained with standard GA. Whilst the standard GA needs a large population to evolve good solutions the GALCO profits from its inherent explorative power described above.

It was also shown that the algorithm is capable of maintaining multimodal diversity of the population. So representatives of various optima can co-exist in the population during the whole evolution.

An interesting aspect of the proposed algorithm is that it does not require any tuning of mutation and crossover probabilities. Apparently any probability of crossover less than 1.0 does not make any sense. Second, there is no explicit mutation operator used in the algorithm. The variability of the population genotype is maintained by preservation of the gene distribution combined with the high generative ability of the recombination operators.

The GALCO algorithm exhibits many nice features. However they were presented and confirmed only in an empirical way. Future research in this area should focus on theoretical analysis of the algorithm that would help us to better understand its behaviour and to estimate its convergence characteristics. The use of the algorithm for solving of the problems with low linkage should be studied as well. Those are the problems with building blocks spread across the chromosome making their propagation to successive populations harder.

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# FPGA Implementation of USB 1.1 Device Core

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**Abstract:**
For the purpose of digital signal processing, networking, or general System-on-Chip (SoC), the designer needs a simple means of communication with the host computer system (usually a PC). The Universal Serial Bus (USB) is one of such means, featuring fast data transfer, simple connection and disconnection, and simple application usage. Our paper describes the design of a USB 1.1 device core using the VHDL language and its implementation into a Field-Programmable Gate Array (FPGA).

**Introduction:**
Nowadays extensive usage of FPGAs implies the need for communication that is faster than a simple serial line. The designer has to transmit large volumes of data between his FPGA application and the PC. The USB interface is one of the solutions to this problem. The USB interface conforms to the requirements of simplicity and universal usage, which comes from its widespread presence in current PCs. In order to use the USB, one has to add a USB core and a USB transceiver to the application board.

From the designer's viewpoint, there have to be software tools available, which simplify the implementation of the USB communication. On the PC side, these tools include a USB driver implementing the basic transfer methods, and a simple application demonstrating the way of communication with the driver. The FPGA side consists of the USB transceiver and the USB core, which is designed on the register transfer level (RTL).

Several designs exist, which deal with various parts of the given problem. The majority of them are commercial solutions, which are not suitable for research. The reason is the absence of source code and thus the inability of modification.

The ultimate goal of our work is to gradually create universal software tools for simple usage of the USB communication. During the design it is not possible to concentrate solely on one part, it is necessary to create them at the same time. The reason is the ability to test and gather specific communication parameters, which determine the fitness for a particular application.

**Solution:**
The main attention of this work is devoted to creating the communication means on the FPGA side, that is the USB core. The whole design is based on the USB 1.1 specification and the USB core is developed in a way that enables simple modifications and enhancements. The design is divided to simple parts by their functionality.

Very important parts such as the input part or the USB transfer controller require special attention. For example the input part needs using special synchronization circuit to eliminate jitter that is generated on the transfer line. Another part of the USB core is the USB transfer control, which manages all transfers and generates the response to each request.

Because of the complicated protocol, a microprocessor must be used. The processor controls the initial communication and sets the transfer parameters. We used an external microcontroller for this purpose.

During the development of the USB core we used these tools: ModelSim to simulate the VHDL code, Synplify Pro and XST to synthesize the VHDL code to the netlist and ISE to generate the implementation data.

The basic functionality was tested using the XSV-800 prototyping board from XESS. The prototyping board contains the Xilinx Virtex XCV800 FPGA and a USB transceiver (PDIUSBP11A), which we used. For debug purposes we created auxiliary tools that helped us understanding the USB protocol. We modified the core to build a USB "sniffer", which was extremely helpful in the analysis of the USB traffic.

**Results:**

The main result of this work is the USB 1.1 VHDL core. The core implements a BULK data transfer between the XSV800 prototyping board and the PC.

This design contains only the USB core without a microcontroller. As an external microcontroller we used the AT90S8515 made by ATMEL. The PC side consists of a USB driver and an application. The driver source code is a part of the driver development kit software by Microsoft. A simple application is written only for testing purpose and gathering transfer parameters.

To achieve the maximum transfer speed it is necessary to adjust the size of the data transfer buffers in the driver. In addition the application must used an integer factor of the data transfer buffers. The maximum transfer rate achieved by the correct settings was 8Mb/s. The ineffective driver source code is the bottleneck of the communication, which prevents achieving the maximum transfer rate.

**Future work:**

In the future we want to embed the microprocessor into the FPGA. We expect to use the microprocessor developed at our department. We plan to finish the core in such a way that it can be easily integrated in other projects. We need to further optimize the usage of the FPGA internal memory.

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# Evolutionary Techniques in Physical Design for FPGAs

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The process of implementing a logic circuit in field-programmable gate arrays (FPGAs), usually called physical design for FPGAs, has two basic optimization objectives: to use as few resources in the target FPGA as possible, and to maximize the operating frequency of the implemented circuit. The process itself is very complex, because an input abstract boolean network has to undergo many transformations before it can be successfully downloaded to an FPGA chip. It is usually decomposed into several subsequent steps according to the nature of the transformations, the steps are called mapping, placement, global routing, and detailed routing.

The timing-driven approach has already been studied in the literature , but the majority of studies considers only a one-way processing of information (the integrated approach described in [4] is based on interleaved placement/global routing cycles). This makes it extremely difficult especially for the mapping task to correctly estimate signal delays, as these are determined mainly by the future placement and routing of the design. This research presents a new, adaptive approach that introduces a statistical processing of area and timing data that should increase the performance of the design algorithms.

Signal delay estimation is essential for timing-driven algorithms. There are three important delay models used in the design algorithms: a unit-delay model, a linear delay model, and an Elmore delay model. The unit-delay model is the simplest one and is suitable for signal delay estimation at the mapping level, because the detailed network topologies are not known. A linear delay model is an improvement of the unit-delay model, it usually considers several types of interconnection resources with different delay constants. As it is easy and fast to calculate, it is usually used for delay estimation in placement and routing algorithms. The Elmore delay model is the most accurate of the three, but it has linear computational complexity, which makes it useful only for final checks of delay constraints.

Although a timing-driven algorithm has to work with some delay estimation model, one cannot simply state that to achieve best results it is necessary to use the most accurate model, because each model requires different amount of input data that may not be available at a given processing stage. For example, it makes no sense to use the Elmore or linear model in a common mapping algorithm, since the model requires a detailed knowledge of signal net routing, which is not available at that moment. It seems that to obtain optimal results, not only signal delays must be accurate, but all algorithms in the flow must also be designed with the overall strategy in mind, so that sets of most critical signal paths predicted at each level are coherent.

The usual timing-driven approach works with fixed heuristic algorithms, usually with a one-way flow of information, and separate models of a target FPGA device. This has two drawbacks: first, the performance of the algorithms depends on a human factor involved in the design of the heuristics, second, the performance of the heuristics is usually tuned for some benchmark circuits and may not be optimal for a class of designs a user works with. The

influence of a human factor may be more limiting than one usually things, especially for new, more complex devices (FPGAs), because they may contain complicated global features not clearly evident at first sight.

The adaptive approach aims at reducing both drawbacks. The idea is to employ evolutionary techniques to eliminate the human factor, and to introduce a global feedback to the system in terms of the most critical signal delay of the placed and routed design that will cause the system to adapt its performance according to the properties of the algorithms in the design flow as well as of the processed designs.

There are two ways the approach can be used: the first, more complex is to build a completely new system based on an evolutionary algorithm, the second is to use an evolutionary techniques to modify and tune the parameters (the cost function) of the heuristics to obtain the best performance. As a case study, two experiments have been performed: evolutionary techniques have been used to optimize a delay estimation model of an FPGA chip [3] (as a precursor to using these techniques to optimize heuristic functions in an integrated placement algorithm) and an adaptive mapping algorithm has been implemented that overcomes the difficulty of signal delay estimation at the mapping level [2]. The mapping algorithm optimizes its mapping policy according to a feedback based on a post-layout timing information. The difference between this approach and Flowmap-d is that the adaptive mapper builds a complete mapping strategy according to the feedback, whereas the Flowmap-d algorithm is fixed and works only with constant delay estimates.

The adaptive mapper is a demostration of a pure classifier-system approach, where the classifier system learns and carries out the whole task, the tuning of parameters of a delay model is an example of using an evolutionary algorithm to perform a multi-objective optimization without a human factor. The adaptive placement algorithm, sketched in [1], is an example of supplementing an existing algorithm with a classifier system to increase its performance. The advantage of the first approach is the possibility to evolve a complex strategy that solves the task, but on the other hand the evolution takes much longer than in the second approach. The second approach demonstrates possibilities of using a classifier system as a data-mining tool to tune parameters of a pre-programmed heuristic function without human interaction. Achieved results indicate the adaptive approach as a whole is viable.

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# Overload Protecting Methods for SCP Equipment in Intelligent Network and Their Simulation

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Present-day telecommunication networks are mostly equipped with Intelligent network platform that supports an offering of various interesting services. Reader can found a structure of these networks in literature noted in references, for example [1]. A key component of Intelligent network is the SCP. Its congestion or overload of an SCP can result in a great reduction in the Quality of Service (QoS) provided by the IN. For purposes of traffic and congestion analysis and explanation of load control methods several models of SCP are used. The first one is similar of traffic model of a normal switching system. Although this model is a big oversimplification of real systems, it is very useful for mathematical analysis. The second type of used model is more complied; it consists from two or more queues representing SSPs and which produce traffic for SCP. In this case the SCP is represented by queue also. A mathematic analysis using this second model is no longer simple and therefore this model is primarily used in simulations. Models can be found in [2], [3] or [4].

An input stream is usually assumed a Poisson type. The processing of request those consider a lookup to a database or communication between user and IP, are represented as a feedback delay of some constant value. The throttle is placed at the input to the system, so that only new requests may be rejected. It's not directly specified whether it is integrated into the SCP or it is located elsewhere in the network.

**Overload detections method**

For the SCP protecting from overload several methods for coming overload recognition is used. There are three min methods:

- **Queue Length Control (QLC) –** this method monitors an input queue length continuously and compares it with a predefined maximum value. When the predefined maximum value of the input length is detected it is classified as an overload.
- **Load Measure Control (LMC)** – this method continuously evaluates a load of central processor of SCP. This Load is compared with a maximum permissible value when it is exceeded, an overload is considered to occur.
- **Call Count Control (CCC) –** this method consists in that a number of new arrivals to the system are counted and, if it is grater than a specific maximum, it alerts of an overload condition.
- **Response Time Control (RTC) –** it consists in measurement of completion of the call request, the timer is starts at the call arrival and stops when the service is completed (final message is sent to the SSP).

**Throttles**

The throttles are used for reducing of the incoming traffic during overload. They are usually based on the following basic principles.

- Arrival buffering – all incoming calls are placed in a finite queue. If the queue is full, the last placed call is rejected
- Call gapping - there is an interval (a so called "gap") between each call arrival. A timer is set when call is accepted. If the next call arrives before the timer is timed out, this call is rejected.
- Percent throttling – a part of the arriving calls is accepted when a call arrives it is accepted with a certain probability.
- Window flow control – there can only be a limited number of calls in progress. When a call arrives it is accepted if the number of calls is less than a certain value (the so called window).

**Control strategies for IN**

In principle two basic control strategies have been investigated. These are:

- **A responsive system** - it consists of a detection algorithm at the SCP working in conjunction with an Automatic Code Gapping (ACG) throttle located in the SSP. The throttle is inactive when no overload exists. It is initiated and controlled through messages received from overload detection routine at the SCP that defines the severity of the overload and instructs the SSP to activate a suitably severe throttle.
- **A preventive system - window –** window is a preventive system with an inherent throttle. It is always active at the SSP and SCP never communicates with SSP to inform about overload severity etc. at any stage. Windows monitors a response time of the SCP to requests from the SSP by maintaining a value of requests sent out called the 'window'. There is a maximum size of window defined and when it is reached, all new calls are killed until an outstanding request acknowledgment (final message form SCP informing the SSP how to complete a call) is received from the SCP. If the response delays are too long, the maximum window is reduced, resulting in fewer call requests being sent to the SCP.

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# Intelligent Computer Support Methods for Conceptual Design of Systems

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Though the problems discussed in the field of Conceptual Design nowadays there are far from theoretical background and they are concentrated on many practical problems issues connected with the synthesis of concepts and operations with concepts (understood from nowadays points of view) they may be dated from times of Bolzano, 1837. Investigations resulted in allocation of emergence phenomena in the area between conceptual constructions, operations with intentions and semiosis phenomenon there is possible to find in [2].

Note: Intentions and operations with them (as they have been introduced by Tichý, e.g., in [1]) differs from concepts in a few points. (E.g.: Intentions are mappings from possible worlds into a space of values and they have no internal structure in general. Concepts (according to Bolzano) may be deeply structured.)

Nice studies of emergence in design have been done by Australian school (Gero and his people) though they have not spoken about semiotics. A very attractive trace in research of Emergence phenomena in the synthesis of natural systems and artificial human products has been done in [3].

In [4] there was introduced a simple image of evolution of a Conceptual Space and a Calculus (in our case a calculus for modelling and supporting emergence phenomena). Working hypothesis and a paradigm for emergence phenomenon in the conceptual design (which was in [4] supported by an illustrative figure) consists in the following essence: "Mental image which is acquired from the external world is not necessarily principal category in this paradigm. Its main task is a navigation of human solver attention during structuralisation of Conceptual Space. Principal importance there have Semiotic activities which operates in an initial stage with intentions and induce formation of concepts. Conceptual Space works as a melting pot for concepts and also as an interface between "the intentional" and "the extensional". (Transfers between "the intentional" and "the extensional" are known from miracle configurations of kaleidoscopes, from writing and reading poetry or from explanations of abstract paintings, as examples of "a spontaneous emergence".) However – the *emergence phenomena are not available from this side*. (It is possible to mediate them from this side but not to grasp them.) They are available from opposite side (in case of an appropriate calculus discovery). The chance for the construction of a general calculus for such a purpose is very small."

Note. Experience with various formal means showed that though exist some general relations between Conceptual Space and Calculus there are strong limitations in development methodologies which are necessary to avoid by *additional domain knowledge*.

A proto-formal representation of a Conceptual Space have to be equipped by *a very weak structure*. In our case there has been used Matroid structure which is a set equipped by an universal relation of *Independence*. By means of this relation there has been extracted a Basis of Matroid (as a maximal set of independent elements). Construction or discovery of a

*novel element of Basis* represents (in the level of mentioned proto-model of Conceptual Space) an *emergence phenomenon*. Matroid structure has no internal means for a novel element emergence and therefore there has been constructed a Calculus with "Degree of Emergence" (DE), [4].
In the proposed method of conceptual design the Emergence phenomenon there is included in a solution *redesign* process. ("There are known some candidates of the solution and there are searched for some other novel ones (better)".)
The process of a *solution formation* is executed in the structure of a ***problem context*** (*CNX*) (considered as a set of structured knowledge). In *CNX* there is constructed Matroid (*M*).

$$\boldsymbol{M} = \langle CNX, C_1, \ldots, C_m \rangle, \tag{1}$$

where $C_1, \ldots, C_m$ - are independent sets (candidates of the solution).
The Co-Evolutionary Design Method presented in [4] underlines the *distortion of the Basis* as a principal operation which initiates the emergence phenomenon. For measurement of the distance from "ordinary solutions" there was introduced "Degree of Emergence":

$$\mathrm{DE} = \rho(\mathrm{f}(\aleph_1), \mathrm{f}(\aleph_2)), \tag{2}$$

where $\rho(,)$ is a special metric function and $\mathrm{f}(\aleph_1)$, $\mathrm{f}(\aleph_2)$ are values of an objective function for the "old" and the novel Basis.

The method proposed in this research represents an approach "the design in words with the support of numbers". Concept and application of linguistic variable Degree of Emergence (DEF), is very natural: If the distance DE is *Small*, the emerged solution is usually discovered as a "dependent" knowledge element. If the distance is *Large* or *Extreme*, there is impossible to understand the emerged solution and to interpret it.) However – though the co-evolutionary design method, matroid conceptualisation and rule "how to work with formula for DE" are clear, the development of *a support for the emergence phenomena* is not simple. There was verified that number of "degrees of freedom" how to construct scales for quantification of design reasoning and discoveries is rather small.

The presented research line results in a software tool for the support of the emergence phenomenon (in the co-evolutionary design method).

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# A Flexible Minimization and Partitioning Method

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Logic design is always connected with many constraints, mostly following from the properties of the available physical elements. Whether we compose a circuit of simple logic gates, PGAs or LUTs in FPGAs, the number of inputs and outputs of one element is limited. Further limitations to be met are, e.g., the maximum load of the circuit inputs or maximum number of logic levels. All these requirements can be met by proper circuit decomposition [1]. The common two-level minimization algorithms (ESPRESSO) do not support any decomposition features and the decomposition is done independently on the minimization, as a sort of post-processing. The decomposition is then more difficult to do and the results are usually less satisfactory. Our minimization algorithm takes into account pre-defined requirements for the resulting circuit, since it combines the minimization and decomposition phases to produce better results.

The problem that we solve here is a *single-level decomposition* of a combinational Boolean function, thus the resulting circuit has as many logic levels, as there are in each block. In order to generate the required values of the output functions, mostly only a subset of all input variables has to be used for each of the blocks, especially when the number of inputs is large. This observation gives us some freedom when accomplishing the logic design, so that we can partially select which input variables will be used to synthesize a particular block.

The problem solution consists of two steps: first, all the outputs of the designed circuit have to be assigned to the individual functional blocks, then the minimization is performed, while the number of inputs entering the individual blocks is kept minimal (and/or another criteria are applied). If all the resulting functions meet the given constrains, the synthesis process is completed. If not, the minimization must be repeated with other parameters set and, if necessary, the outputs have to be reassigned. One of the next most frequent problems we encounter in logic design is the limited maximum fan-out of the logical elements. Especially nowadays, when the low-power design is often desired, the fan-outs of the gates are low, and thus the load minimization is strongly required. We have also combined the logic minimization and partitioning process with the load minimization.

The suggested partitioning algorithm is based on the BOOM minimization tool [2]. This tool proved to be very efficient for the two-level minimization of large functions (functions with a large number of input variables) with many don't care states. The minimization algorithm consists of two major phases: *generation of implicants* by the Coverage-Directed Search (CD-Search) and the subsequent solution of the *covering problem* (CP). In order to perform the minimization together with the decomposition, these two major phases have to be slightly modified.

The CD-Search is based on the search for the most suitable literals that should be added to some previously constructed term. This search is directed towards finding an implicant that covers as many 1-terms as possible. To do this, we start implicant generation by selecting the most frequent input literal from the given on-set. The selected literal describes an *n-1* dimensional hypercube, which may be an implicant, if it does not intersect with any 0-term. If there are some 0-minterms covered, we add another literal and verify whether the new term already corresponds to an implicant by comparing it with 0-terms. After every literal removal

we temporarily remove the on-terms that cannot be covered by any term containing the selected literal. We continue adding literals until an implicant is generated, then we record it, remove the covered 1-terms, and start searching for other implicants. In this way we generate new implicants, until the whole on-set is covered. The output of this algorithm is a set of product terms covering all 1-terms and not intersecting any 0-term. This procedure is done independently for all output variables.

Originally, the most frequent literals are preferred in the selection. Then the algorithm produces the best results in terms of minimality of the solution. However, this rule can be modified in order to produce a set of terms containing a minimum of input variables.

As the assignment of the output variables to the blocks was made before, we know in every CD-Search pass which block is currently being processed. When some input variable is selected during the CD-Search, it must be necessarily included in the processed block (if the term including this input variable is not removed during the CP solution phase). Thus we can record all input variables entering the blocks. The idea of adapting the CD-Search for partitioning consists in penalizing the selection of a variable that has not yet been selected into the currently processed block by some factor. Particularly, in the literal selection function the frequency of the literal that is already included in the processed block is multiplied by the CD-Search partitioning force *PF*, and is thus preferred to other literals. The higher this force is, the less input variables will be entering the blocks, however, on the other hand, the complexity of the result will be higher. Similarly, this function can be modified in order to minimize the load of the inputs. If an input variable entering other blocks than the processed one was selected, the load of this input would be increased by one. To minimize the load, the selection of such a variable must be penalized. Again, the higher this factor, the lower the load of the inputs, however it increases the complexity of the blocks.

The CP sloution phase can be modified in the same way. Some incremental heuristic must be used as a CP solution algorithm, while the weights of the terms are modified similarly as it was done in the CD-Search. We have found that both the CD-Search and CP solution phases have to be modified in order to reach satisfactory results.

The algorithm was tested on numerous benchmark problems. Mostly the number of inputs into a block were reduced twice when a decomposition was used, as well as the load of the inputs was significantly reduced. The details of the algorithm were published at [3, 4].

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# Formalization of Ontologies by Means of OMT and UML

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**Ontologies** belong into the field of Semantical Modelling of Knowledge [2]. Whilst the attention of knowledge technologies in the recent time has been focused especially on the formal representation of knowledge, ontologies are destined for modelling of the semantical content of knowledge. The main practical purpose of ontologies in science and in engineering is the facilitation of the interchange, the acquisition and the collection of informations.

The term "ontology" is not a novel one and there are usually used the following interpretations (quoted in [3]): • an ontology is a philosophical discipline, • an ontology is an informal conceptual system, • an ontology is a formal semantic account, • an ontology is a specification of a conceptualisation, • an ontology is a representation of a conceptual system via a logical theory, • an ontology is a vocabulary used by a logical theory, • an ontology is a (meta-level) specification of a logical theory. In works related to science and engineering is the most frequent the fourth interpretation.

Ontologies in the fields of engineering define a vocabulary of concepts and relations by which we may describe a problem domain. For the first sight they may be considered as a domain thesaurus, but they contain many other relationships that connect the different concepts to each other (generalisation and inheritance, aggregation, institution, owns, causes and constraints). From the point of view of formal representation of the ontologies – they have a form of *semantic networks*.

Because of the amount and the heterogeneity of concepts and data which have to be managed, the process of the ontology design is very complex and is associated with many criteria. The design process usually contains the following stages: • identification of the purposes, • construction of ontology, • evaluation, • documentation. In this proposed paper there are discussed the stages of construction and documentation of an ontology by means of OMT (Object Modelling Technique), [1] and UML (Unified Modelling Language).

**OMT** represents a collection of tools for the systematic analysis and design of systems. The base of the methodology is a structuralised formulation of the problem and its translation into Object (Class) Model. There is utilised the similarity between constructions of sentences in natural language and the object conceptualisation of world description. OMT is a result of interaction between a few methodologies (during recent 10 years). The essential influence on the OMT development had the View Analysis Methodology. OMT works with three main conceptualisation levels (the views) within the frameworks of which the systems are described by – Object (Class) Model, Dynamic Model and Functional Model.

**UML** is a visual graph-symbolical language. It respects the most of rules established in OMT. Whilst in OMT there are emphasised the features of the methodology (there is determined the time networking of knowledge based activities which are necessary to do in the system analysis and design), by UML are established rules of the notation. UML allows to use 8 levels of possible system description.

The effectivity of OMT and UML in the development of application is reinforced by special software tools which usually belongs to category of CASE systems. These tools reinforce not only the stage of Knowledge Acquisition (which is typical for the initial analysis

and a preliminary design) but also the stage of Software Engineering (in which the system models developed by OMT and formalised in UML are implemented and compiled in the code of a programming language.)

Comparing with special means which have been developed for formalisation of Ontologies (e.g., ONTOLINGUA) there was investigated (within presented research) if the means of OMT/UML are convenient for this purpose. The preliminary answer was "Yes" influenced by the fact that the environment OMT/UML is able to represent Semantic Networks. (This conclusion was also confirmed by OMG related studies.) In more detailed view there was possible to discover a few important factors: a) the position of interface between the natural and the artificial intelligence, b) the type of activities (operations, procedures, methods, algorithms, ...) the semantic content of which is necessary to model, c) the type and quality of software environment in which the ontologies will be implemented (Java, Delphi, C++, ORACLE, …). Factor a) turns our attention to essential purpose for ontologies development: "ontologies for enterprise integration", "collaboration design enterprise", "common understanding to special information interchanged between experts from different branches", etc. Does contain OMT/UML tools for the explanation, of, e.g., the function of "water flow oscillator" to an architect ? Could the computer deduce additional properties of such an oscillator described in OMT/UML represented ontologies ? The answer is "conditionally Yes" for both the questions. Reasoning about factor b) we feel the distance between semantic modelling of concepts of the type "control error" or "density of liquid" and the semantic modelling of activities of the type "the clamping", "the drilling" "the covering". (The first type of concepts is better representable in OMT/UML than the second type.) Within the framework of factor c) there are emphasised "embedded" abilities of programming environments for representation of ontologies. In Delphi, e.g., the substantives extracted by OMT from natural language problem formulation may be represented as the Unites, and this is not appropriate style for many real problems. Another situation is in Java environment.

The research is oriented in the development of ontologies for collaborative analysis and design of large-scale systems.

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# Optimizing of Neural Networks Using a Genetic Algorithm

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Solving different technical or scientific tasks typically leads to problems described by a system of partial differential equations. Through the last few decades, hand in hand with the growth of computer performance, the so-called artificial intelligence or soft-computing methods were developed as alternatives to traditional solutions of problems which are difficult to be defined, described or resolved using traditional ones. Our research deals particularly with neural networks [3, 4] which can be simply described as methods that are able to take experience-based data into account, such as observations or a coherence of measurements.

The output of a neural network is determined by a preceding training process which consists of finding so-called synaptic weights. The training of neural networks is actually an optimization process, because it can be seen as a minimization problem for an error function applied on all training examples . The synaptic weights of a neural network act as variables of the error function. The number of these unknown values often exceeds one thousand, which can cause serious difficulties.

For our class of problems, a layered neural network is the most suitable solution. It is usually combined with popular backpropagation algorithm for training. This method proved itself to perform relatively well for traditional tasks where neural networks are usually used, for example in technological processes controlling. However, it seems to be unsatisfactory for solving more complicated technical tasks, mainly for its tendency to fall into local extremes.

Genetic algorithms [2] are modern optimization methods which are based on an analogy with the evolution processes of living creatures during ages. The main emphasis during our previous work on optimization algorithms was put on the ability to solve multidimensional tasks and identification of local extremes. The algorithm called SADE [2] is the result of this development. It is based on the traditional genetic algorithm scheme using the operations of mutation, crossover and selection, and it is extended by the so-called local mutation. The synaptic weights are the real values, therefore the desired algorithm should be able to operate on real domains. Hence the crossover operator of traditional genetic algorithms was replaced by the so called differential operator.

The effectivity of training of a three-layered neural network was tested on various problems using both the backpropagation method and SADE algorithms. One of these problems is to estimate the function value of the third point from the values of the preceding two equidistant points. The complexity of this problem depends on the form of unknown function. The considered test example was a rapidly oscillating periodic function with an increasing amplitude. The obtained results indicate that the strategy based on genetic algorithms is faster and more accurate compared to the backpropagation method. The SADE method yields significantly lower error (by three orders) after approximately the same number of iterations [3,4].

Then the SADE training along with a neural network was tested for solving a much more complicated Civil Engineering problem. The main goal was to find a set of parameters of a constitutive model for concrete called the microplane model [1]. It is a fully three-

dimensional model, which includes tension and compressive softening, damage of the material, different combinations of loading, unloading and cyclic loading and incorporates the development of anisotropy within the material as well. The principal idea of this model is the projection of a macroscopic tensor onto a set of spatial orientations. Constitutive relations are applied for these orientations and acompanying microstrains. The macroscopic stress tensor is obtained from microstresses using principle of virtual work. The numerical work connected with this model is manifold in comparison with classical approaches.

For the microplane model, a particular type of concrete is described using 8 parameters: Young's modulus, Poisson ratio and other six phenomenological parameters, which even do not have a simple physical interpretation, so it is difficult to determine their values from an experiment. A usual scenario is that an experimentator is trying to fit stress-strain diagrams varying the model parameters by the trial and error method. As one of the more up-to-date approaches to estimate material parameters the neural network simulation could be employed. The preliminary results of our computations show that the neural network trained by the SADE algorithm has the ability to predict the microplane model parameters with a satisfying precision.

The overall results have shown that the SADE training is a fully capable method of training a neural network. The number of iterations needed to achieve the same output error is significantly lower compared to the traditional backpropagation algorithm. Also the minimal output error is by about three orders lower, which could be explained by the genetic optimizaton's higher resistance to fall into local extremes. Results of this grant project show that, in the engineering practice, a neural network could save a huge amount of an experimentator's time needed for searching parameters of the microplane, or even more sophisticated, model by the trial and error method.

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# Exploration of Design Space in ECDSA

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## Introduction

Elliptic Curve Digital Signature Algorithm (ECDSA) with point coordinates in $GF(2^m)$ proved attractive for hardware implementations. Moreover, much shorter keys suffice for the same cryptographic strength as provided by the classic RSA.

Although ECDSA has been standardized [2], there is still considerable degree of freedom in options such as key length, concrete elliptic curve used, or the field basis (polynomial or normal), collectively called domain parameters. Even for a fixed set of domain parameters, multiple algorithms exist for operations required by ECDSA, offering different trade-offs between cost and performance.

This paper deals with comparison of polynomial basis and normal basis representation of elliptic curve point coordinates. Addition, multiplication, division and squaring over chosen basis must be implemented. Since addition and squaring are simple operations in both bases, we should mention implementation of multiplication and division only.

In normal bases, multiplication is more efficient than in polynomial bases. On the other hand, division in polynomial bases can be performed by the extended Euclidean algorithm (GCD), which takes less cycles than the Itoh-Teechai-Tsujii (ITT) algorithm [3], applicable to any basis. We are interested in the interaction of these choices in a realistic context, that is, in an elliptic curve processor implemented in an FPGA.

## Design of the processor

The tested elliptic curve coprocessor implements scalar multiplication (by the add-and-double algorithm), addition and doubling of points on an elliptic curve over $GF(2^m)$. The points are represented by their affine coordinates. Field operations are performed in an arithmetic unit, which comes in two variants: one for normal basis and the other for polynomial basis representation. The processor works with fixed key length and basis. Configurations for different lengths are obtained from custom generators.

The polynomial basis unit consists of a squarer and a combined multiplication/division subunit. Division is done by the extended Euclidean algorithm in a four-register structure. Three of the four registers also serve for an LSB-first multiplier.

Multiplication in normal bases is computed using pipelined digit-serial Massey-Omura multiplier with digit width fixed by configuration. Inversion is computed by the algorithm of Itoh, Teechai and Tsujii [3]. The multiplier is built around three shift registers, with small number of data paths added to pass intermediate results during inversion, and three log $m$-bit counters in the local controller.

## Implementation and results

Xilinx Virtex XCV400E-8-PQ240 has been chosen for the implementation. Synthesis has been performed by Mentor Graphics Leonardo Spectrum 2001 and physical design by Xilinx ISE 4.1. The implementation results are presented in table. Polynomial basis version (PB) with GCD inversion is compared to optimal normal basis version (ONB) with Itoh-Teechai-Tsujii

inversion (ITT). The clock frequency has been obtained from static timing analysis of placed and routed designs. Bit-serial ONB implementation has 63 % area complexity of the polynomial one, while time complexity is 370 %. Digit-serial ONB implementation for digit width $D = 6$ has the same (94 %) speed as polynomial one, but it is smaller (77 %).

It is apparent that scaling the normal basis multiplier can compensate the gain in cycle count obtained from GCD inversion. The Itoh-Teechai-Tsujii inversion is expressed in terms of addition and multiplication [3]. Therefore, it scales whenever the multiplier does.

| Basis | Inversion algorithm | $m$ | $D$ | Clock [MHz] | $P+Q$ [µs] | $2*P$ [µs] | $k*P$ [µs] | Total #slices | Arith. #slices |
|---|---|---|---|---|---|---|---|---|---|
| PB | GCD | 162 | 1 | 74 | 6.6 | 4.4 | 1800 | 3343 | 1801 |
| PB | GCD | 180 | 1 | 81 | 8.2 | 4.5 | 2041 | 3660 | 1968 |
| PB | GCD | 210 | 1 | 88 | 8.8 | 6.1 | 2530 | 4267 | 2299 |
| ONB | ITT | 162 | 1 | 113 | 17.9 | 16.3 | 5543 | 2128 | 586 |
| ONB | ITT | 180 | 1 | 118 | 22.1 | 20.45 | 7662 | 2324 | 632 |
| ONB | ITT | 210 | 1 | 103 | 27.3 | 25.10 | 11002 | 2701 | 733 |
| ONB | ITT | 162 | 6 | 120 | 4.5 | 4.15 | 1404 | 2559 | 1017 |
| ONB | ITT | 180 | 6 | 119 | 5.5 | 5.2 | 1934 | 2832 | 1140 |
| ONB | ITT | 210 | 6 | 107 | 6.6 | 6.2 | 2691 | 3261 | 1293 |

**Conclusions**

The elliptic curve coprocessor has been implemented in FPGA. The processor has interchangeable arithmetic units, which enabled us to compare closely polynomial basis and normal basis arithmetic. In all cases, inversion algorithm considered optimal for the particular arithmetic has been used.

For $m$ where an optimal normal basis exists, the normal basis gives better results. To match the bit-serial polynomial basis multiplier in area, the digit width of $D = 6$ has to be used. This is also optimal for the multiplier itself with respect to the area/performance ratio.

The quantitative study is currently being extended to multiplication in sub-optimal normal bases and digit-serial polynomial basis multiplication.

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# Communication in Componentized Systems

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As the requirements on software grow more complex, so does the size of the software systems. The obvious way to compensate for the complexity is to divide the system into components. The structure of the system and the quality of interfaces between components determine certain properties of the system – its extensibility, robustness, customizability and others. Sometimes, these properties are more important than the actual functions of the available components. While the functionality of the components defines the short-term potency of the system, the structure is related to the long-term power. To build a competitive system, none of these aspects must be ignored.

The area of 3D graphics and multimedia forms a very complex system. A lot of effort has been invested into development of sophisticated components in the past. The structure and inter-component communications have earned more interest in the recent time. This paper summarizes the basic structure and ways of communication in componentized systems with 3D graphics and multimedia content.

Communication means can be classified according to two main criteria:

- Level of integration – at which level are the components communicating.
- Communication scenario – how are the data exchanged between components.

**Communication levels**

Communications in system can be classified according to level of integration into five main categories:

- **Native source code interface** is the least available and least general. Two components must be implemented using same programming language and they must be running on the same platform. On the other hand, the data transfer can be efficient because there are no additional rules.
- **Platform-dependent binary interface** is more general than the previous one. The components must still run on the same platform, but they can be implemented in different programming languages.
- In case of **platform-independent interface** (for example HTTP) the components may run on different platforms but they still may be integrated into one application.
- **Standardized file format** is the most spread kind of communication. This approach is very general and it is available in majority of current components (applications). The integration of components is not available - the components have no possibility to exchange additional data.
- This – **the manual data transfer** – is the most general approach that can be applied on every component pair. User must manually transfer every piece of data (for example copy color of each pixel – without clipboard).

**Communication scenarios**

The scenarios can be linear or non-linear, unidirectional or bidirectional. In case of linear scenario, each component has one input and one output point and they are connected in a line. In non-linear systems a component may have more connection points and can be connected in an arbitrary acyclic graph.

- The most spread communication scenario is an **unidirectional linear** system (also known under the name **the execution pipeline**). The data are acquired in the first component, enriched in the following components and finally presented to the user. Since the principle is very simple and since it can be applied using any of the described communication level, it is present in almost any software system.
- Using **unidirectional non-linear** communication scenario, a more flexible system can be build. Multiple components may work parallel because they are not depending on each other. For example, independent components for acquisition of audio, video and 3D graphics may work concurrently. The data produced in these components are the merged in some presentation application. Just like in the linear case, the cost of change is usually high, because all dependant components must be executed with the new data.
- In a **bidirectional non-linear** system, the format of the input data and the output data is the same. The components **share the same communication medium**. Each component is able to create new or enrich already existing data. Therefore the components must not destroy each other's data. Designing the interface (the shared medium) is the critical point of this scenario. Once the set of cooperation rules is defined, it becomes possible to merge and maintain data from multiple independently developed components with unrelated data models. This allows parallel development of the components and as a consequence lowers the development cost.

**Using XML as the shared communication medium**

If the XML standard is extended, it can be used as the shared communication medium. The document type definition files would have to contain the adapter definitions. An adapter is a simple script that is able to perform conversion from one type to another type. The XML-DOM parser will contain a new adaptation layer that can adapt the data in the file using the scripts. The components will ask the adaptation layer (which has the same interface as XML-DOM) to parse the data file and extract the required data. When updating the data in a file, the adaptation layer is used again to project the changes back to the file.

Since the interface of the adaptation layer is almost the same as the XML-DOM, the cost of change from classic component to a component, that is able to work cooperatively with other components, is very low. The shared communication medium scenario appears to have big potential, and will be the subject of future work.

# Simulation and Visualization of Combustion Processes in Pulverized Coal Boilers

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Our research focuses on the coal combustion processes inside boilers [1]. Nowadays, for both the ecological and economical reasons it is important to find optimal boiler configurations. It is very difficult to investigate the combustion processes of various kinds of combustibles directly in the boiler. Instead of that, typically Computational Fluid Dynamics methods (CFD) are used. The current CFD effort is based on solving complex differential equations (such as the Navier-Stokes equations) [2]. Currently, computation time needed for solving non-trivial tasks using these methods on current systems and software packages is still expensive, even on powerful computers. We develop a much faster methodology based on a completely different approach, than the computation of the differential equations. It even allows dynamic visualization of the combustion processes in the real-time.

Our methodology is just based on the particle system. Particle system is a common method for visualization of fuzzy objects (e.g. clouds, water, and fire) in computer graphics. It is used even for industrial technology. In our case, the application of particle system represents a real technological problem. The particle system allows us computation and visualization of mass elements in the boiler. The particles do not correspond to the coal or air particles in the boiler. Instead of that, they represent some corresponding mass of coal in the voxel under investigation. Various particle types represent proper amounts of air, gas, ash and other materials in the boiler space. Therefore, we call them virtual particles. Thus, one virtual coal particle carries many real coal particles. Currently, for simplicity and maximum computation speed, this part and all the other parts of our system are implemented only in the 2D space. The quality and speed of the simulation could be altered by increasing or decreasing the amount of these virtual particles.

The movement of the virtual particles is strongly determined by the flow array. Flow array are just pre-calculated vectors of motion which dramatically increases visualization and computation speed. The particles are moved only on the pre-calculated trajectories, so the computation is simple. These trajectories are computed only once at the beginning. They are saved in a floating point data structure. The Flow array divides the area of the boiler into mesh of squares. There are many ways how to obtain the flow array. The classical way is based on the differential algebra equations. Since we try to reach the maximum simulation speed, we do not use this approach. Instead of that, we use isotherm, loose flow which run from a circle jet [3]. The air stream flows through jets to the boiler. However, there may appear a situation, when a stream collides with the wall and/or there may occur a collision with some other air stream. In such a case, other virtual jets are added to handle this situation and to approach to the real situation.

Combustion process of the coal particles is in fact a quite complex problem [4]. Again we use some simplifications due to need for the fast computation. In each step we compute a temperature array. It contains weighted average of the particle temperatures for all the voxels. Depending on the current temperature, weight and proportion of the coal, the coal particles are being burned. For air particles, we just decrease their appropriate mass. For coal particles, we decrease the amount of the combustible part of the particle, and increase the amount of the

gas burnt. If the mass of the combustible part reaches some minimal value, we assume that the coal particle is burned out and we change it to the burnt gas particle.

To maintain the reliable and fast visualization, our system uses industry standard OpenGL platform. Thanks to this, nowadays, on a standard, even a cheap graphics accelerator could be used. There is no big lack of speed in particle visualization even when using 10 000 of particles. The selected local characteristics in the voxel, such as the total temperature, mass storage, the wattage, and heat flux state and/or changes can be real-time visualized. The particle tracks can be easily determined by the fast particle system animation. The current implementation enables real-time visualization of the combustion processes.

All the parts of our system have been implemented in the standard, ANSI C computer language. In the current implementation, we can use some interactive actions even during the simulation, in real-time, without restarting the whole simulation. Thus, we can move jets and disable/enable/delete/modify parameters of air or coal jets. Other features include tracking of the selected particles. It allows us to monitor its position and characteristics at any time until it leaves the boiler space. Visualization is based on the OpenGL graphics interface. A windowing interface is maintained by the GLUT library. This means that our system is easily and fully portable to other systems.

The current research brings promising results. We have simulated and visualized burning processes in a test boiler. We have discussed the obtained results with the experts from the Faculty of mechanical engineering of CTU. To compare our results with current CFD methodology, we used the FLUENT solver. The global parameters match good overall design and implementation of our ideas. Next we compared the images of the temperature and velocity maps, which summarize local characteristics. We found, they are visually similar, although at the closer look some differences still can be found. The behavior and results gained from our system were well comparable with a situation in the real boiler and FLUENT CFD system. Therefore, our system can be used for dynamic simulation or preview of dynamic processes of coal combustion in boilers. This may be used in the CFD process for the fast and efficient design for the boilers and could be used for the education purposes (namely at Faculty of Mechanical Engineering of CTU in Prague).

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# Colour Rough Texture Synthesis

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Photo realism in virtual or mixed reality scenes cannot be accomplished without nature-like colour textures covering visualized scene objects. One possible texture categorization is into either smooth or rough (also referred as the bidirectional texture function - BTF) texture subgroups. The rough textures which have surfaces with visible mesostructures (generating fine-scale shadows, occlusions, and specularities) do not obey Lambertian law and their reflectance is illumination and view angle dependent. Textures can be either digitized natural textures or textures synthesized from an appropriate mathematical model. The former simplistic option suffers among others with extreme memory requirements for storage of a large number of modeling cross-sectioned slices through different material samples. Sampling solution become unmanageble for rough textures because it requires to store thousands of different illumination and view angle sample images for every texture and even limited texture databases are of the tera bytes order.

Synthetic (model-based) textures are far more flexible, extremely compressed (few parameters have to be stored only), they may be evaluated directly in procedural form and can be designed to meet certain constrains or properties, so that they can be used to fill an infinite texture space without visible discontinuities. It is easy to synthesize any size of the required texture. Modeling multispectral images (textures) requires at least three dimensional models (rough textures generally need five dimensional models), however if we are willing to sacrifice some information a 3D/5D model can be approximated with a set of much simpler 2D models without compromising its visual realism. Among such possible models the Gaussian Markov random fields are appropriate for texture digitized not only because they do not suffer with some problems of alternative options (see [1],[2] for details) but they are also easy to synthesize and still flexible enough to imitate a large set of natural and artificial textures. While the random field based models quite successfully represent high frequencies present in natural textures low frequencies are for them more difficult. One possibility how to overcome this drawback is to use a multiscale random field model. Multiple resolution decomposition (MRD) such as Gaussian/Laplacian pyramids, wavelet pyramids or subband pyramids present efficient method for the spatial information compressing. The hierarchy of resolutions provides a transition between pixel-level features and region or global features and hence to model a large variety of possible textures. Unfortunately Markov random fields in general, and Gaussian Markov random fields in particular are not invariant to multiple resolution decomposition (MRD) even for simple MRD like subsampling and the lower-resolution images generally lose their Markovianity. Fortunately we can avoid computationally demanding approximations of a non-Markov multigrid random field by Markov random fields because there is no need to transfer information between single spatial factors hence it is sufficient to analyze and synthesize each resolution component independently.

We propose a novel algorithm for efficient rough texture digitized which combines an estimated range map with synthetic multi-scale Markov random field based generated smooth texture. The texture visual appearance during changes of viewing and illumination conditions is

simulated using the bump filter technique. The obvious advantage of this solution is the possibility to use hardware support of bump map techniques in contemporary visualization hardware.

There are several methods for determining range maps of object surfaces. The most precise range map can be acquired by direct measurement from observed surface. However these are complex methods which involve special hardware and measurement methodology. Alternatively the range maps can be estimated from surface images. It is possible to use stereo vision with two or more different camera positions or the photometric stereo approach which estimates surface range map from at least three images obtained for different position of illumination source while the camera position is fixed. Main disadvantage of this method is the necessity to obtain at least three images. Moreover the images in both approaches have to be mutually registered. Alternatively it is possible to estimate the range map using shape from shading techniques. These methods use the fact that image intensity $\boldsymbol{I}$ of each observed texture image pixel is given according to reflectance map $\boldsymbol{R}$:

$$\boldsymbol{I}(x,y) = \boldsymbol{R}(z_x, z_y, \boldsymbol{l}, \boldsymbol{c}, \rho)$$

where $z_x$ and $z_y$ are surface slopes in directions $x$ and $y$, $\boldsymbol{l}$ is the vector pointing from surface to illumination source, $\boldsymbol{c}$ is the vector from surface to the camera and $\rho$ is albedo of an observed material. The advantage of this approach is fast range map estimation from single surface image illuminated by single light source in known position. The range map estimation of texture images in this work was performed using the shape from shading algorithm published in [3]. In comparison with other methods from this group, this algorithm includes constrain which enforces integrability of surface slopes and hence a unique solution.

Our extensive testing results of the algorithm mostly on colour textures from the CUReT texture database [4] are encouraging. Some synthetic textures reproduce given digitized texture images so that both real and synthetic texture are visually indiscernible. The overwhelming amount of original colour tones were reproduced realistically in spite of restricted spectral digitized power of the model. The multi-scale approach is more robust and allows far better results than the single-scale one if the synthesis model is inadequate (lower order model, non stationary texture, etc.). The proposed method allows large compression ratio for transmission or storing texture information in comparison with alternative rough texture digitized approaches while it has still moderate computation complexity. The method does not need any time-consuming numerical optimization like for example some Markov chain Monte Carlo method.

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# The Longest Common Subsequence Problem

# A Finite Automata Approach

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The longest common subsequence problem is one of many unsolved problems in the computer science. This problem has application in many areas as computational biology, computer-assisted music analysis, data compression, text analysis, and others.

A *subsequence* of given string $S$ is any string created from $S$ by deleting zero or more symbols of it. For the set of strings $P$, the *common subsequence* of $P$ is such string that is a subsequence of every string $S \in P$. The *longest common subsequence* is a common subsequence having maximal length.

The problem of finding the longest common subsequence of pair of strings and multiple strings has been studied almost over the three decades. Most of published papers and reports are based on the dynamic programming, which leads to the quadratic time and space complexity (means a product of lengths of input strings). The improvement was leading to the linear space complexity while the time complexity remains quadratic.

Hébrard and Crochemore mentioned a finite automaton accepting all subsequences of a given string. Its right to left construction has been described by Baeza-Yates in [1] and left to right construction by Troníček and Melichar in [2]. This finite automaton is in some sources called *direct acyclic subsequence graph (DASG)*. We will refer it as *subsequence automaton (SA)*.

We present a new algorithm for longest common subsequence problem based on the well-known finite automata theory. Let us denote $Sub(S)$ the set of all subsequences of a string $S$. To find the longest common subsequence of a set of strings $P = \{S_1, S_2, \ldots, S_m\}$, $2 \le m$, the following three steps are used:

1. Construction of subsequence automaton $\mathrm{SA}(S_i) = (Q_i, A, q_0^i, \delta_i, F_i)$, $i = 1,2,\ldots,m$, accepting $Sub(S_i)$ for each string $S_i \in P$.
2. Construction of common subsequence automaton $\mathrm{CSA}(P) = (Q_c, A, q_0^c, \delta_c, F_c)$ accepting the intersection of above mentioned sets of subsequences $Sub(S_i)$: $CSub(P) = Sub(S_1) \cap Sub(S_2) \cap \ldots \cap Sub(S_m)$.
3. Finding set $\mathrm{LCS}(P)$ of the longest strings accepted by common subsequence automaton $\mathrm{CSA}(P)$. If the set $\mathrm{LCS}(P)$ is nonempty, then each element of it is the longest common subsequence of the set of strings $P$.

It is easy to see, that for all symbols $a$ longest common subsequence contains at most as much symbols $a$ as $\min\{|S_i|_a \mid i = 1,\ldots,m\}$, where $|S|_a$ is the number of occurrences of $a$ in $S$. Thus, the length of the longest common subsequence is at most

$$\sum_{a \in A} \min\{|S_i|_a \mid i = 1,\ldots,m\}.$$

Let $M = (Q, A, q_0, \delta, F)$ be a finite automaton. Let us define for arbitrary $a \in A$ the set $Q(a) \subseteq Q$ as follows: $Q(a) = \{q \mid q \in \delta(p,a), a \in A, p,q \in Q\}$. The finite automaton $M$ is called *homogenous finite automaton* if for all pairs of symbols $a,b \in A$, $a \neq b$, it holds $Q(a) \cap Q(b) = \varnothing$ (it means that transitions leading to a particular state are all labeled by the same symbol).

The left to right construction of subsequence automaton for string $S$ requires $O(|A| \cdot |S|)$ time, where $|A|$ is the size of an input alphabet and $|S|$ is the length of an input string. Moreover, such way created automaton is a homogenous finite automaton with the number of states $|Q| = |S| + 1$ and $|Q(a)| = |S|_a$. Therefore, the first step of presented algorithm can be done in $O\left(\sum_{i=1}^{m} |A| \cdot |S_i|\right)$ time, where $|S_i|$ is the length of the i-th input string.

As far as the common subsequence automaton is created as an intersection of subsequence automata (it accepts the intersection of languages accepted by subsequence automata), its set of states is a subset of cartesian product of states of subsequence automata. Since an intersection of homogenous automata results to a homogenous automaton, common subsequence automaton is homogenous too. Thus, the estimation of number of states of common subsequence automaton is at most $|Q_c| = \sum_{a \in A} \prod_{i=1}^{m} |S_i|_a + 1$. Therefore, the second step takes $|Q_c| = O\left(|A| \sum_{a \in A} \prod_{i=1}^{m} |S_i|_a + 1\right)$.

The time complexity of the third step is the same as the time complexity of second one. Thus, the time complexity of presented algorithm is

$$O\left(|A| \left(\sum_{i=1}^{m} n_i + \sum_{a \in A} \prod_{i=1}^{m} |S_i|_a + 1\right)\right).$$

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# Text Processing by Binary Neural Networks

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**Abstract**

The amount of information stored in electronic formats is quickly increasing, with the growing familiarity of population with computers. The consequence of that is the need to be able to search in large amounts of data for particular information. Various techniques have been developed for the text searching task. Many techniques are very fast and sophisticated. Speed is the one of the most important criteria. But it is not the only one. The other one is ability to deal with somehow corrupted text. Text could be corrupted, for example, when we do not know exactly what we are searching for, or if the text is the result of OCR or speech recognition.

In our article, we describe rather less traditional technique for the text searching task. The technique is based on a binary neural network called CMM (Correlation Matrix Memory). We have tested CMM on a problem of finding a particular word in a single text document. Searching gives all occurrences of the word. Although the technique is able to search approximately, here we focus on exact searching. Usually, one of the fast conventional techniques is used for text searching task; for example Boyer-Moor or Shift-or algorithms. Conventional techniques go through text and compare it with a searched pattern. Our technique is based on storing associations between words and their location in the text. This approach is similar to techniques like inverted file lists or hash tables. It operates in two phases – the learning and the recalling. The learning phase stores associations between words and their positions in the text document. The recalling phase searches for a query word. In fact, there is no search during the recalling phase; it simply recalls a proper association. The associations are stored in the Correlation Matrix Memory that is an associative memory. The associative memory has similar properties as other forms of neural networks: ability to learn, ability to generalize, inherent parallelism. We use the correlation matrix memory with binary elements. This type of CMM is called weightless or binary CMM. Because of binary processing, CMM is a fast neural network. While some other neural networks require a long time for training, its learning process is not iterative.

The important part of the described technique is transforming of input words into a binary form. We need to impose some restrictions on input data in order to make behavior of the matrix better. The input data should be sparse and orthogonal. It allows filling the matrix regularly (with uniform distribution). It increases capacity of CMM (measured as a number of possible stored patterns) and also gives better ability to deal with corrupt patterns. The real text without any preprocessing has not these optimal properties.

In our experiments, we have tested three methods of coding. The first one is a simple coding. It divides input words into letters that are then coded independently. Each letter on a particular

position is assigned with the only one logical 1 in the binary vector. This coding is not efficient. For example, the most frequent letter 'e' is 81 times more frequent then letter 'z'. Therefore, it generates saturated locations in the matrix at the learning process. These locations consequently cause faults when recalling. Next two proposed methods of coding aim to eliminate the inappropriate properties of real text. The first proposed coding is called “coding by equal intervals”. The advantage of this coding is that it keeps the ability of the matrix to recall incomplete corrupt patterns. The second proposed coding is called “coding with random shift”. This method adds a pseudorandom number to each letter in the pattern. This coding is simple and efficient. Unfortunately, this method cannot work with a corrupt word.

In order to search approximately, we can use the ability of CMM to deal with corrupt patterns. However, CMM does not measure exactly the distance between patterns. It tries to find the most similar pattern during the recalling process. CMM does not ensure that it responds correctly to every pattern with a certain Hamming distance from the trained pattern.

Next problem of this technique is how to deal with the different length of the words. The correlation matrix has the constant size, while words in text have different length. The solution could be using several matrices. Each matrix would store words with a particular length. Another solution is to use one matrix and complete the words to the length of the longest one.

**Conclusion**

The conventional techniques used for pattern matching are designed for solving many types of text searching problems. The technique based on CMM has some limitations and it is suitable for only some types of text searching problems. CMM is suitable for tasks where we need an efficient tool for searching in case that the precision of the answer is not critical. The advantageous property is its ability to work with noisy data. The other advantage of the technique is fast processing. We have shown that coding of input patterns significantly affects capacity of correlation matrix memory. We have proposed two coding schemes. Both of them give good results because of their nearly uniform distribution. In the future, we want to study and improve coding of input patters. Next, we want to use this technique for approximate searching problem. We also want to use more advanced architecture (more CMM) to get better results of processing.

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# Integrated "Paper" and Electronic Course in English for Civil Engineering

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Education worldwide is currently undergoing serious changes. Among other things, these are found in the design of innovative didactic aids, including electronic instruments. Electronic learning management systems, such as Blackboard, or WebCT, are devised as leverage transformation of education. These systems support a complex spectrum of learning/teaching styles and methods, and optimize intellectual and technological resources. They are planned to facilitate access to education by meeting the needs of students for studying in a flexible and economical manner.

The need for this pedagogical project grew from general conditions of foreign language learning at the universities of technology in the Czech Republic. This has led to an unsatisfactory level of English communication skills among civil engineering students who will, however, need to possess a solid command of general, as well as special language means after entering the practical work domain. It is felt that incorporation of modern technology in language learning/teaching can positively influence its outcome. But employment of technological equipment available at CTU in language courses has been insufficient so far.

Given the conditions, the described project was aimed to reconstruct the compulsory English course for civil engineering purposes and make it more effective, individualized and accessible for students. Its goals were set to build a mix of instructional media, meeting the needs of the learner in a manner that is instructionally effective and economically prudent in order to activate learners and make them responsible for the learning process. The goals were further chosen to individualize learning, make it easier, less teacher-dependent, and better adjusted to students´ usual work/study methods, while offering convenient access to up-to-date learning aids (including off-site access).

It was planned to achieve the aims by combining traditional didactic procedures with innovative approaches, and exploiting the existing instruction facilities offered by CTU to a much greater extent. First of all, the university continuously invests in the building of its IT infrastructure. Besides, the school has bought the license for an electronic instruction system manufactured/distributed by WebCT, Inc and WebCT Canada (www.webct.com). It allows its users to design and run entire courses electronically, in a friendly, web-based environment and convert them partly or completely to distant-learning units.

The Integrated Learning Management System WebCT became the key didactic tool for modernizing the English course. WebCT provides a complex platform with a variety of functions for conducting, managing and facilitating instruction. The program complexity decided the step-by-step construction of the electronic component. In addition to administrative and management functions, the course employed the Quiz and Glossary authoring options.

The produced quizzes test professional terminology, enabling students to measure how they have mastered the covered language material. They are conveniently accessible, on-site and off-site, and students do them outside class, saving class time. The program responds immediately showing the achieved score. Both the student and the teacher have immediate feedback on the student's success.

Next, the online course component involves an easy-to-use glossary of professional vocabulary. Users move in it fast, clicking on hyperlinks while enjoying the convenience of hypertextual organization of the lexicon.

The project outcomes have brought about a complete reconstruction of English language training for future civil engineers. In all, the final product, the integrated course of English for civil engineering purposes, consists of three parts. In addition to the electronic component built mostly from self-tests and a glossary of professional vocabulary, it includes a print set with texts, exercises, and vocabulary lists; and finally, a sound component based on audiotexts.

Each section of the course can be, in case of temporary or permanent inaccessibility of computer networks, used separately. This up-to-date, integrated course matches the learning needs of engineering students at a more advanced level.

The integrated English course helps to increase the quality of instruction and make it more effective.

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# Experimental Dual Thread Processor Core

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Modern interpreted programming languages widely use an automatic deallocation of unused objects. The automatic deallocation is performed by a garbage collector.

In current computer systems, the garbage collector is not supported by the hardware at all. The garbage collector, a part of the memory management, is implemented in software. The garbage collector is encapsulated by the memory management and is transparent to the application. Execution of such garbage collector is usually mutually exclusive to the application execution causing the application execution being stopped. By accessing its data structures the garbage collector is spoiling the cache contents and decreasing the performance of the applications. Although the best garbage collector algorithms reach an optimal time complexity, the overhead is high. Because of the relative complexity of the garbage collectors, small embedded systems usually do not use garbage collection, they rely on static analysis to allocate the maximum of the memory needed.

Several hardware garbage collector implementations were published (e.g. [1], [2]) trying to avoid the software disadvantages in the garbage collector execution overhead. Their common architecture is the garbage collector connected to the computer system as a peripheral device via the system bus (PCI, NeXT-bus). The hardware garbage collectors are usually written in some high level language (e.g. C) and they are executed by the auxiliary processor, sufficiently fast to not to slow down the applications. Such collectors need the auxiliary processor that serves the requests of the memory management and maintains the garbage collector structures of the memory objects and performs the garbage collection. Then the whole hardware garbage collector consists of a normal commercial processor and the dedicated memory. The cost of additional hardware resources and higher inferred bus communication traffic caused such garbage collectors not to become widespread.

A hardware support of garbage collector has to be implemented into single processor systems (personal computers) without increasing their price. A full hardware garbage collector built inside the microprocessor is the ideal case, nevertheless it is lacking the flexibility to change its functionality easily. Even the memory management routines ought to be sometimes modified according to changing strategies. Our analysis ([2]) shows that the new garbage collector has to be split into the two layers, a hardware layer performing fast operations upon the garbage collector structures (allocation, deallocation of collected objects) and a software layer providing the interface to the memory management and applications.

Assuming that the hardware garbage collector layer is performed by the dedicated hardware units within the processor, the software garbage collector layer requires an execution resource. Without any special requirements, it would be one of the regular threads among the operating system threads. In the case of the new hardware garbage collector, the software layer should be processed as one system thread common to all the applications. Such thread suffers from all the properties of the multitasking environment: interprocess synchronization; task time slice granularity; task switching and scheduling overhead, etc. On the contrary, the analysis of the garbage collector activity shows that the garbage collector functions are invoked more frequently and consume much less processor time when compared to the execution time intervals applied in the scheduling of the pure

software tasks. Therefore, there is a need to find a better computational architecture the hardware garbage collector can be run more efficiently. The software layer preserves easy partial modification, tuning and switching between the upper level routines.

This paper describes the first stage of the hardware garbage collector development – to obtain the experimental processor core as a suitable host platform the hardware garbage collector could be built in.

Today's modern processors have 64 bit wide operands and they introduce quite few new software capabilities, they are often an orthogonal extension of the 32 bit processors. The property which changes rapidly is the processor internal architecture (chasing well known Moor's law) and the technology process of the manufacturing. One of the architectural enhancements is the multithreading, introduced in 70-ties ([3], [4]) as one of the possible techniques to increase the performance of the microprocessors. The multithreading allows the execution of more than one thread at a time, these threads compete for the microprocessor resources, the execution units. To obtain a maximum performance the instructions must be properly scheduled to the execution. The multithreading requires multiple thread context register fields, multiple decode units, multiple issue units and an appropriate dispatcher. Due to these requirements the multithreading was rarely used, a successful implementation can be found in Intel Xeon family of processors. The performance is claimed to achieve up to 30% speed-up compared with single thread version.

The experimental processor meets the minimal requirements of modern processors, it implements the 32 bit CISC/RISC instruction set, its internal architecture is pipelined in 5 stages (fetch, decode, issue, execute, write-back). The experimental processor is capable of executing two threads in parallel (at the thread level). In such dual thread architecture, a thread scheduling priority can be dynamically balanced between the hardware garbage collector thread and the application thread, depending on the garbage collector workload. This solution avoids the thread switching overhead. The processor is not superscalar to keep it simple.

In the next stage, the hardware garbage collector unit is planned to be built in. It will be placed at the same position as the standard execution units (integer units, load/store unit, etc.), competing with them for the same data resources. The source of the garbage collector operated data is delivered by the special instructions the application instruction code is interleaved with. The information delivered in these instructions is prepared during the application compilation. This information includes a pointer operand labeling and pointer movements, object creation and stack frame manipulation.

Presented experimental dual thread processor core handles minimal sufficient requirements to provide the platform the experimental hardware garbage can be run and evaluated.

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# Differential Measurement Methods in Global Satellite Navigation Systems

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Global navigation satellite systems (GNSS) provide position information anywhere on Earth surface or near to Earth with precision from several meters to tens of meters typically. The Global Positioning System (GPS) owned by USA is only one fully functional GNSS at present, the Russian system GLONASS is partially functional, and the EU system GALLILEO is in preliminary phase yet. Several GNSS features may be improved locally by differential measurement methods. The position determination precision can achieve up to subcentimetre resolution, system integrity and some other properties can be improved too.

The reference station and data communication channel are the fundamental components of a real-time differential system. The reference station receives signals from GNSS satellites; it measures signal parameters in real time and evaluates quantitatively GNSS signal parameters errors, which are correlated in given locality. Obtained information is transformed to form of raw observation records or corrections and the data channel to differential GNSS users transmits it. The users can subsequently use this data for correlated system error compensation and for current GNSS security and functionality confirmation.

The real-time differential system quality is affected significantly by parameters of used data channel. Wireless radio-communication channels are suitable for mobile GNSS users. Radio-packet networks, especially GSM-GPRS is recently known as proper for differential data transmission. The interconnection of GSM-GPRS network to Internet can be utilised. The differential system using Internet connection of mobile equipment via GSM-GPRS appears as useful improvement of existing mobile positioning sensors.

Any free open and effective differential GNSS protocol suitable for Internet and GSM-GPRS has not been published in worldwide yet. An experimental differential GPS system using modified Internet radiobroadcast and multimedia technology is tested in EU countries, but this system was not optimised for using via GSM-GPRS network yet. The main disadvantage of this system is seen in excessive operational costs caused by system requirement of huge volume transmitted data via GSM network. For general cost acceptability accomplishment (especially in situation of Czech Republic), the information transmission efficiency improvement of such system is necessary.

The works realised in grant GAČR GP102/01/P037 in 2002 were focused on efficiency improvement of differential GNSS data generation algorithm. The main focus was given to study and develop of real-time methods for GNSS data volume reduction via entropy suppression. As the other work theme the study of optimal algorithms for dividing of GNSS data time series into Internet UDP datagrams was provided.

The entropy of GNSS raw data records (observations) can be suppressed by sequential applying of these algorithms: Interparametric decorrelation, quantisation, time series decorrelation and optimal coding. As a first step, the decorrelation between different parameters of one measurement is performed. For example, the pseudorange measured from signal envelope is correlated significantly with integrated Doppler frequency offset.

Quantisation of observation parameters is the next step of entropy suppression process. This step is very forcible and efficient, but it makes a potential risk of measurement quality loss. Tolerable intervals for qantisation have to be assigned separately for each sort of applications and differential measurement methods. Evaluation of quantisation impact to measurement quality is very difficult, but it is necessary for algorithm verification.

The time series decorrelation process is provided consecutively. It is very efficient and it causes no additional information losses. As a last step of entropy reduction process an efficient coding algorithm based on Huffman coding is developed. This algorithm includes effective expression of several frequently repeated items, as is i.e. the list of satellites contained in the observation.

The data transmission efficiency is affected by transmission datagram frequency. The UDP and IP headers are appended to each datagram. Therefore, each ones is elongated by 24 bytes (for IP version 4). The length of heads increases transmitted data volume and worsens the transmission efficiency. From the point of view of efficiency, the encapsulation of several observations into one datagram is advantageous. But, this is applicable in nearly-real-time solutions only due to considerable additional data transmission latency. The precision position information in nearly-real-time systems is obtained consequently with delay from several seconds to several tens of seconds.

It is necessary to verify the designed algorithms in real operation conditions. Therefore, these algorithms are implemented in DGPS/DGLONASS reference station operated on the Department of Radioelectronics at the CTU FEE. The experimental broadcast of reference DGPS data and correction via Internet and GSM-GPRS is prepared. This project is supported by GAČR and T-MOBILE Company. The main goal of this prepared experiment is system developing, system verification in practice conditions and presentation of differential measurement acquisition. We expect the developed system will have utilisation for precision and high quality position information in wide domains, including transport, precision farming, environment protection and others.

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# Innovation of the Computer Laboratory for Basic Study Students

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Project of innovation of the computer laboratory was proposed with aim to realize complex hardware reconstruction of obsolete equipment (last technical upgrade in 1995) of existing laboratory and access OS Unix/Linux platform and software to wide range of students. Project covers also installation of the new Linux server with specialized software for theoretical, experimental and applied physics (including necessary advanced graphical tools) utilized in the mentioned fields of study programs and/or research activities in basic as well as post gradual study. This idea stem from fact, that study in the faculty is widely based on the physics and mathematics, physical and technical subjects, computer science, simulation techniques, etc., and that important part of research activities is oriented on the international cooperation in the field of theoretical, experimental and applied physic (see e.g. wide collaboration on CERN laboratory projects, and others).

Proposed solution were oriented to the effective utilization of the expended funds, simplification and minimal cost of the system administration, maintenance and SW (HW) upgrades, system security (protection against attacks from outside as well as illegal activities from inside) keeping maximum free access to the information sources, etc. Physical security and computer laboratory access authorization is solved by installation of the card system that uses the CTU student identification magnetic cards.

Technical solution was based on the Sun system consist of 16 maintenance-free terminals SunRay 1 and 2 coupled SunFire V100 servers. System is completed by the server of shared resources, i.e. I/O devices (terminals are not equipped by input device) and mentioned powerful Linux server for specialized applications. Old Linux server is also connected to the system, is administrated by students (independently on official lab servers) and used e.g. for student's web pages etc. The computer laboratory internal network (including Sun and shared resources servers) is connected to the faculty LAN (and WAN) through firewall/NAT to protect the authorization communication data flows. Whole system administration is supported by experienced authorized students.

Linux server for applications offers in this time wide scope of software for radiation and particles transport simulation (MCNP, Geant, Penelope, EGS, Beam), experimental data processing (Root, PAW++), CERN scientific libraries, and is open for any next requested software.

Computer laboratory is used for existing Unix based courses in the faculty programme. New basic course of OS Unix (Linux) for beginners is prepared as well as course of selected Unix/Linux applications (Open Office, TeX, Emacs, tools for data processing, visualization and presentation).

As part of project the syllabus of new advanced course was prepared and subject "Simulation and Data Analysis in Experimental Physics" was entered into optional courses program. Course is dedicated for programme "nuclear engineering" and "physical engineering" and is

oriented to the simulations and data processing and analysis in experimental nuclear and particle physics, radiation transport, dosimetry and radiological physics in medicine. Course is drawn as lectures coupled with practical demonstrations and individual training. Course is based on the maximal routine use of computers and information technologies in the educational process. Programme of course is summarized in the following table.

| Week | Lecture/training |
|---|---|
| 1. | Principles of radiation (particles) transport simulation |
| 2. | Geant 3 – code basic philosophy, structure and properties |
| 3. | Geant 3 – introduction, code and data libraries |
| 4. | Geant 3 – geometry and material description, output quantities specification |
| 5. | Geant 3 – practical demonstrations, training tasks |
| 6. | Geant 4 – concept/language of new version of code, libraries and basic classes of G4, code structure in G4, tools for work with G4 |
| 7. | Geant 4 – geometry, materials, bodies, logical/physical volume, detectors, physics |
| 8. | Geant 4 – program run, run control (GAG), graphical output (geometry, particle tracks, macros, data outputs, demonstrations |
| 9. | MCNP – code concept (comparison with G3, G4), input file structure, geometry and materials description, tools for graphical output (plot, mcplot) |
| 10. | MCNP – source and tallies description, next model parameters, input files graphical editors – Vised (Sabrina) |
| 11. | MCNP – program run, output files structure, validation of results (statistical tests), plotting of results, demonstrations (comparison with G3, G4 results) |
| 12. | ROOT – code basic concept and purpose, interpreter basic commands, demos, graphical output interactive control, macros |
| 13. | ROOT – data reading/storing/archiving, processing and visualization of data from simulation programs, 2D and 3D histograms, graphical outputs, examples |
| 14. | Knowledge examination (training tasks evaluation), credit test |

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# Comparison of Exact SLE Solving Methods Using the GMP Library and Residual Arithmetic

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The solution of sets of linear equations is a very frequent task in numerical mathematics. We often meet the problem of ill-conditioned matrices of large dense sets of linear equations. In such cases the stability of solution cannot be ensured. Rounding errors during the numerical computations involved in obtaining the solution to the problem cannot be tolerated. Many numerical methods were developed trying, with more or less success, to minimize the influence of the rounding errors on the resulting solution ([e.g. 1, 2]). When selecting a method for solving a SLE exactly, the availability, costs and speed of the calculation method need to be considered. For comparison, we have selected two methods available free-of-charge that solve SLE without rounding errors: the method described in [2, 3] and the Gauss-Jordan elimination method using the GMP library [4].

The use of the GNU Multiple Precision Arithmetic Library (GMP) is the only difference between the usual Gauss-Jordan elimination in floating-point arithmetic and the Gauss-Jordan elimination utilizing the GMP library. On the other hand, the residual arithmetic method for exact SLE solution [3] is based on special SW. The basic principle of this method follows.

Solving of SLE using residual arithmetic is based on the fact that if a calculation is to be performed without rounding errors, one needs a long enough computer word, or modulus $M$, that allows such calculation. This means that the modulus $M$ must be larger than the largest intermediate result in the entire calculation to avoid loss of precision during the calculation that would result from rounding. The size of modulus $M$ used in an error-free algorithm based on modular arithmetic to solve SLE is usually given by Hadamard's estimation [2, 3]. Since the modulus $M$ estimated in this way is a very large number, its application to calculations would not be practical. Therefore, a known set of moduli $m_1$, $m_2$, ... , $m_r$ is used. The moduli must fulfill the following conditions: $m_1 m_2 ... m_r = M$, each modulus is prime and $m_1 < m_2 < ... < m_r < (2^p-1)$, where $p$ is the length of the actual computer word in bits. The calculation SLE using residual arithmetic operates according to the following algorithm (start with $i = 1$):

1. Convert the elements of the SLE to residue class code with modulus $m_i$.
2. Solve the given SLE in residual class code applying Gauss-Jordan elimination with pivoting performed in modular arithmetic with modulus $i$.
3. Test: if $i$ less than or equal to $r$ then go to 1.
4. Convert the resulting vectors and determinant from the residue class codes to rational numbers.

In step 1, before the real values of the elements of SLE are converted to integer numbers modulo $m_i$, the elements are normalized. The normalization of an element $e$ of SLE is given as: $\mathrm{Norm}(e) = e.2^{g+1}! \, |min|$, where $min$ is the minimum element of the SLE and $g$ is the length of the mantissa in bits. In such a way numerical damage to input data by their conversion to integer numbers is minimized. In step 2, operations of the Gauss-Jordan elimination in modular arithmetic modulo $m_i$ are carried out. In step 4, the results are converted from the residue class code to rational numbers by algorithm introduced in [1].

Practical experiments show that one disadvantage of the above method for solving SLE using residual arithmetic is an excessively large modulus obtained from the Hadamard's estimation. This results in unnecessary SLE computing in residual arithmetic for redundant moduli, slowing down the total SLE solution. Due to this fact, SLE solution calculations using GMP were in some cases even several times faster, with comparable precision of the solution. We propose a method that avoids this drawback by testing the end of calculation in step 3 according to the following criteria. For representation of an integer number $s$ in standard mixed-radix system and its associated standard residue system for moduli $m_1$, $m_2$, ... , $m_r$, it holds that $s = d_0 + d_1(m_1) + d_2(m_1m_2) + \ldots + d_{r-1}(m_1\ m_2\ \ldots\ m_{r-1})$, where $d_0, d_1, \ldots, d_{r-1}$ are standard mixed radix digits. From this formula and from the algorithm for converting numbers represented in residue class code to integers [1], it follows that for certain $j$ the radix digits $d_j$ to $d_{r-1}$ are zero. Thus, the residual arithmetic calculations performed for the moduli $m_{j+1}$ to $m_r$ are redundant. It is clear that for a sequence of certain length $q$ of mixed-radix digits $d_j$ to $d_q$ equal to zero, we can decide with certain probability to terminate the calculation in modular arithmetic (steps 1, 2, and 3 of algorithm) for the next moduli $m_{j+1} \ldots m_r$. The value of $q$ is then determined by the size of the SLE being solved, the size of the smallest prime modulus $m_i$, and the probability with which we want to decide that the modulus $M' = m_1\ m_2 \ldots m_j$ is big enough for the calculation of the SLE solution.

Using this method, the computation of the complete SLE solution is significantly faster. For comparison, we present the calculation of a SLE based on $n3n$ Hilbert matrix using both our method and the GMP-based Gauss-Jordan elimination. The SLE solution using modular arithmetic is calculated in 1.85s for $n = 50$ and in 10.24s for $n = 100$. The GMP-based calculation finishes in 1.91s for $n = 50$ and in 11.24s for $n = 100$. Precision of the GMP was set to 512 bits. All tests were performed on computer with AMD Duron 600 MHz processor and 192 MB SDRAM at 100 MHz under Windows 98 operation system.

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# Error-Free Parameter Extraction Using GMP Library and Maple

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The parameter extraction process is a process where we fit experimental data with a mathematical model of given measured data set. Thus, the parameter extraction process returns parameters of mathematical model that sets the model up with given error. We can then reuse the estimated model instead of data we have measured and predict the values at states we have not measured. The extraction process and its statistical analysis can calculate the goodness of the fit, a level of confidence in each parameter, the degree of coupling between parameters and the sensitivity of the model with respect to each parameter [1, 2]. The typical use of parameter extraction is to fit the Bipolar Junction Transistor characteristics [1].

During the parameter extraction process, a set of linear equations (SLE) is usually solved. The SLE solving originates in the task of the optimization algorithm. This algorithm minimizes the nonlinear least square function with respect to the extraction parameters, that means minimization of the *rms* error in the fit of the model to the measured data. Least square method usually generates an ill-conditioned matrix and even the smallest errors during the parameter extraction process have a big influence on the parameters being extracted. On account of this fact we are looking for highly precise software that is able to solve SLE exactly and is easy to use. The other criteria for choosing appropriate software can be the availability, costs and speed of the calculation. We have chosen Maple [3] that is commercial, easy to use, very powerful, but a bit expensive. The counterpart we have chosen is GMP [4]. This C library is not as easy to use, but is free to anyone.

To estimate the model, we have to define the mathematical model and its error function first. Let m($\boldsymbol{x}$,$\boldsymbol{p}$) be a mathematical model, where $\boldsymbol{x}$ is vector of independent variables and $\boldsymbol{p}$ is parameter $q$ elements vector, and be $f_i(\boldsymbol{p})$5(m($\boldsymbol{x}$,$\boldsymbol{p}$) – $y_i$)/$w_i$, $i$51,…,$n$, elements of $n$ dimensional weighed residual vector $\boldsymbol{f}(\boldsymbol{p})$, where $w$ is weight and $y_i$ are measured data samples. By minimization of the nonlinear least squares function $\Phi(\boldsymbol{p})5\left\|\boldsymbol{f}(\boldsymbol{p})\right\|^2$ with respect to the vector $\boldsymbol{p}$, the extraction of the parameters as elements of vector $\boldsymbol{p}$ is carried out. The minimizing of the nonlinear least squares function of several variables is based on a Taylor's series expansion of the vector $\boldsymbol{f}(\boldsymbol{p})$ for ($k$+1)-th iteration step, where we take its linear part: $\boldsymbol{f}(\boldsymbol{p}^{(k+1)}) \approx \boldsymbol{f}(\boldsymbol{p}^{(k)}) - \boldsymbol{J}\Delta\boldsymbol{p}^{(k)}$, where $\boldsymbol{J}$ is the Jacobian matrix of the residual vector $\boldsymbol{f}(\boldsymbol{p})$ with elements $J_{i,j} = \angle f_i(\boldsymbol{p})/\angle p_j$. The optimization algorithm with the objective to minimize the nonlinear least squares function $\Phi(\boldsymbol{p})$ can be combined with the steepest decent and Gauss-Newton method [1]. Hence, it ensures faster convergence. This optimization method represents an iterating process solves of a typical ill-conditioned SLE. The ill-conditioned SLE matrix is the product of $\boldsymbol{J}^{\mathrm{T}}3\boldsymbol{J}$, where $\boldsymbol{J}$ matrix is of size $n$ points x $q$ parameters [1, 2]. Consequently, we need highly precise tools for solving ill-conditioned SLE during the parameter extraction process.

Maple itself uses fractions where possible so it is very precise; however, it does have internal variable called Digits, which can specify the actual number of decimal digits used for evaluations (Digits := N;). During the parameter extraction process, hundreds of digits are commonly used.

For C/C++ parameter extraction, we use MPFR, a part of the GMP library. We use MPFR because it implements commonly used functions such as sin, exp, log, and sqrt so we don't need to create them. We have built a C++ classes atop of MPFR so we don't need to worry much about MPFR functions since almost everything including matrix algebra is written as C++ classes and/or methods and there is no further need to interact with MPFR since all this interaction is made by our classes' methods. However, this is not very optimal since C++ produces lots of redundant code and compilers are often unable to strip it. MPFR uses a special function called **mpfr_set_default_prec**, which allows us to set the precision of all MPFR types created after issuing this call.

For comparison, we present the calculation of a fit based on mathematical model represented by a combination of polynomial of second degree with an exponential function $m(\boldsymbol{p}, x) = p_0x + p_1x^2 + p_2\exp(p_3x^2)$ using both Maple and GMP library. The optimization algorithm using GMP evaluates the parameter extraction process for 200 simulated data samples and four parameters approximately in 20 steps. With Maple, the same problem was calculated in more than 30 times longer time. On the other hand, Maple is simpler and more user-friendly.

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# Algorithm for Computing Modular Inverse Using the Montgomery Almost Inverse – Hardware Implementation

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Modular arithmetic is becoming widely used in a number of fields. First of all, we should mention cryptography, where modular arithmetic plays a significant role in public key cryptosystems, key exchange schemes, digital signature systems, and so on. Other uses involve systems for solving systems of linear equations exactly, capable of finding the correct solution even in ill-conditioned cases.

An important operation in the modular arithmetic is the modular inverse. In particular, it can be used in computing the point operations on an elliptic curve defined over a finite field $GF(p)$, to speed up modular exponentiation in the so-called addition-subtraction chains, in certain key-exchange schemes, or in decipherment of the RSA algorithm. In this work, we present a hardware implementation of a modular inverse algorithm that uses the so-called Almost Montgomery Inverse to calculate the classical modular inverse in a finite field $GF(p)$, where $p$ is prime.

Using its classical definition, the modular inverse of an integer $a \in \langle 1, p-1 \rangle$ modulo the prime number $p$ is defined as the integer $x \in \langle 1, p-1 \rangle$ satisfying the condition $ax \equiv 1 \pmod{p}$. Often, the notation $x = a^{-1} \pmod{p}$ is used. However, sometimes it is advantageous to represent numbers in a way other than usual. One such representation, called the "Montgomery domain", is proposed in [1]. Using this representation, the Montgomery inverse [3] is defined as the integer $y = a^{-1}2^n \pmod{p}$, where $n$ is the number of bits in $p$.

Papers [2] and [3] detail an algorithm that computes the modular inverse in the Montgomery domain, given the inputs $a$ and $p$ in the usual representation. The algorithm runs in two phases. The first phase calculates in $k$ iterations the so-called Almost Montgomery Inverse (AMI), that is, the integer $z = a^{-1}2^k \pmod{p}$, where $n \le k \le 2n$ is the number of iterations and $n$ is the word size (number of bits) of the used computing platform. The second phase converts this result to the Montgomery modular inverse $y = a^{-1}2^n \pmod{p}$ with a series of $k–n$ halvings (rights shifts), adding $p$ beforehand if the value to be halved is odd. In case of the integer domain, $k$ is the number of deferred halvings in the second phase. Hence, the modular inverse $x = a^{-1} \pmod{p}$ is computed by $k$ halvings modulo $p$. Such an algorithm for computing the modular inverse using AMI is suitable for implementation in hardware since the halving operation is equal to a binary right shift.

Of course, published algorithms exist that output the classical modular inverse by default, such as the ordinary extended Euclidean algorithm (EEA), or the Penk's binary algorithm derived from EEA with the aim to allow an easy implementation in hardware. The ordinary EEA is not suitable for hardware implementation since it requires division, which is a very resource-consuming operation.

The choice of the best algorithm for the computation of the ordinary inverse in hardware depends on the influence of the different time complexity of shifts vs. additions/subtractions [4]. For long words used in cryptographic systems, the binary right shifting algorithm derived from the Montgomery algorithm works better. The Penk's algorithm is only faster for short words and in hardware systems that don't take into consideration the difference in complexity of shift vs. addition/subtraction operations [4].

Considering the above reasons, we have used the more universal algorithm that uses AMI and modified its second phase to output the classical modular inverse, that is, the previously mentioned integer $x = a^{-1} \pmod{p}$. We have devised hardware architecture suitable for the calculation of $x$ and described it with a generic, synthesizable VHDL code. We have also written a C code that simulates the hardware architecture and used it to benchmark the algorithm in terms of counting the clock cycles and certain critical operations.

Our multiplexer-based hardware architecture uses a "butterfly" structure consisting of two main parts. The master part (MP) consists of two work registers $u$ and $v$, the register $p$, the output register $x$, an $n$-bit adder/subtracter, a right-shift unit, and three multiplexers. The slave part (SP) consists of two loadable shift registers $r$ and $s$, and a $n$-bit adder. In addition, there is a control unit consisting of a finite state machine (FSM) and the up/down iteration counter $k$, and some auxiliary combinatorial logic.

During the first phase of the calculation, the MP computes $\gcd(u,v)$ using the binary EEA and the SP computes the AMI $z = a^{-1}2^k \pmod{p}$. In each iteration, the FSM selects the appropriate operation in MP: $u \leftarrow u/2$, $v \leftarrow v/2$, $u \leftarrow (u - v)/2$, or $v \leftarrow (v - u)/2$, and the corresponding operation in SP: $s \leftarrow 2s$, $r \leftarrow 2r$, $r \leftarrow (r + s)$ and $s \leftarrow 2s$, or $s \leftarrow (r + s)$ and $r \leftarrow 2r$, and the counter $k$ is incremented. This phase ends when the register $v$ reaches zero. During the second phase, the intermediate result $r$ is divided by $2^k \pmod{p}$. This is achieved by a series of $k$ right shifts, adding $p$ beforehand whenever $r$ is odd. During this phase, only the MP is active.

Our implementation of this algorithm comes with several drawbacks. First, it is the necessity to compare (= subtract) $u$ and $v$. In about 50% of the cases, the result is not useful as the opposite operation is needed, and a clock cycle is "wasted" – this totals to about 11% of clock cycles being wasted on average. This can be avoided with a third adder (increases hardware complexity). Then, it is the need to correct odd numbers in the second phase and many shift operations; however, these problems are not easily avoided.

On average, our hardware calculates the inverse in $3.2n$ clock cycles (min. $2n$, max. $5n$ in very rare instances). The cycle length (and thus the operating frequency) is mostly determined by the $n$-bit adder carry chain. Depending on the target platform and the VHDL synthesizer, carry look-ahead or other techniques can be used to accelerate the addition. Hardware complexity in terms of the equivalent gate count depends greatly on the synthesis software and its optimization strategy. Using the free WebPack ISE design suite by Xilinx, Inc. and optimizing for area, the total equivalent gate count is roughly equal to $124n + 350$.

Our future work will concentrate on development and implementation of even faster modular inverse algorithms that use a different approach to the problem, on algorithms for other operations in modular arithmetic, and on using the designed hardware in real-world applications.

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# Courseware Development Tool Sets for E-Learning in Exact Sciences

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E-learning is gaining momentum in both corporate and academic settings as an effective way to provide high-quality learning .For e-learning developers, creating quality learning interactions and assets is an uneasy task. This paper describes results of the study of software tools for building rich learning contents with consideration specific features of e-learning in exact sciences **[1],[2]**.

Two specific tool sets have been selected : (1) Simple and inexpensive set of programs for beginners / occasional users (**TAB. 1**) . (2) A powerful set of industry-leading authoring / multimedia tools for advanced developers / professionals (**TAB. 2**). Both sets allow to choise smaller / cheaper subsets for specific / less complicated applications.

| **TAB. 1 : WEB WYSIWYG DEVELOMENT TOOLS : SET 1** | |
|---|---|
| Office Software | Office XP Professional |
| HTML / XML | **FRONTPAGE 2002** |
| Graphics / Animation | *PHOTOIMPACT 8 ,GIF Animator 5* |
| Formulas / Scientific Visualization | *MathType 5, Advanced Grapher 2* |
| Java / ICS | *Physlets*, CALCULATION CENTER 2 |
| Assignments | *Respondus Lite*, *HOT POTATOES 5.5* |
| ***Comment :*** *Italic* = Freeware / Shareware | SMALL CAPITALS = An acceptable subset |

| **TAB. 2 : WEB WYSIWYG DEVELOPMENT TOOLS : SET 2** | |
|---|---|
| HTML / XML/ PDF | Contribute |
| | **DREAMWEAVER MX**, UltraDev MX |
| | Acrobat 5 |
| Graphics / Multimedia | Fireworks MX, Freehand 10, FLASH MX |
| | Photoshop 7, CorelDraw 11, Premiere 6 |
| Formulas / Scientific Visualization | *MathType 5* / Scientific Word 4 |
| | Matlab 6.5 / *Scilab 2.6* |
| Java / ICS | *Physlets, EJS 3.1, Open Source Physics* |
| | MATHEMATICA 4.2 / Maple 8 |
| | webMathematica / mapleNET |
| Alternative Approaches | Authorware 6.5, Director MX |
| Assignments | *Respondus 1.5, Test Make Pro* |
| | COURSEBUILDER, Learning Site |
| Learning Management Systems | WEBCT CE 3.8/ BlackBoard,Learning Space |
| Special Servers | ColdFusion MX, Flash Commun. Server MX |

| ***Comment*** **:** *Italic* = Freeware / Shareware SMALL CAPITALS = An excellent subset |
|---|

Two special courses for e-learning developers in the area of exact disciplines based on this study are under development : (1) *Computer Supported Transfer of Knowledge* : One-semester course taught since academic year 2000/2001 at the Faculty of Nuclear Sciences and Physical Engineering CTU (co-teacher M. Šiňor) (**TAB.3**). (2) *Courseware Development Technologies for E-Learning in Physical Sciences* : A short course / workshop for physicists (in English), a preliminary version has been presented for the participants of the 3rd European Conference on Physics Teaching in Engineering Education (PTEE 2002), Katholic University Leuven, Belgium, June 5 – 7, 2002 (**TAB. 4**) **[3]**.

| **TAB. 3 : COMPUTER SUPPORTED TRANSFER OF KNOWLEDGE** | | |
|---|---|---|
| 1. Introduction : Styles & Tools | | 5. Student Project |
| 2. Programmer's Approach | 3. Author's Approach | |
| 4. Expert's Approach | | |
| 6. Conclusion : Project Presentation Seminar | | |

| **TAB. 4 : COURSEWARE DEVELOPMENT TECHNOLOGIES FOR E-LEARNING IN PHYSICAL SCIENCES** | |
|---|---|
| 1. Introduction | |
| PART 1 | PART 2 |
| 2. A Bit of Philosophy at the Beginning | 4. Inspect & Enjoy Available Resoutces |
| *2.1 E/OL Learning : Dreams and Reality* | *4.1 Free Materials for E/OL in PS* |
| *2.2 Specific Problems of E/OL in ES* | *4.2 Commercial Materials for E/OL in PS* |
| 3. Courseware Providing for Teaching ES | 5. Look and Try Real Development Work |
| *3.1 Strategies for CW Providing for E/OL* | *5.1 Set A : Demonstration & Application* |
| *3.2 CW Development Tool Sets for ES* | *5.2 Set B : Demonstration & Application* |
| 6. Conclusion | |

*Extended e-version of this paper (e-poster) with relevant live URLs is available. Please, look the web page given in* **[4]**.

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# Intelligent Database of Solved Problems for Knowledge Sharing across the Internet

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Modeling and simulation of dynamic systems is an important engineering activity. However, it requires a great amount of knowledge, which is often tacit, and thus hard to represent and transfer. The aim of our project was to develop a comprehensive software system that would facilitate capturing, storing and delivering knowledge. The system is intended to be used by both practicing engineers and students.

The anticipated system falls into the group of so called knowledge-based systems. It exploits techniques from disciplines like knowledge engineering or artificial intelligence. Its task is to provide software support for the whole life cycle of processing of knowledge in modeling and simulation. A prototype of such a system has been developed within this project. The prototype is currently focused on providing search services on the top of a knowledge base. It also provides some basic support for managing the knowledge base.

The system inlcudes the following components:

- Ontology and lexicon
- Knowledge base
- Knowledge base index
- Search subsystem (user's interface)
- Maintenance subsystem (administrator's interface)

The heart of the system is the *ontology*. Ontology is a formal specification of concepts in given area of interest, modeling and simulation in our case. It contains taxonomy of important concepts of our domain, as well as axioms (constraints) that define the meaning of these concepts. We have developed a first version of an engineering ontology that covers concepts from our area of interest. This ontology should facilitate the process of building of the knowledge base index as well as the dialogue between the system and the user. Our ontology has been implemented in SUO-KIF language, and it is based on general-purpose (upper) ontology SUMO (Suggested Standard Upper Ontology).

The ontology is accompanied by a *lexicon*. Lexicon forms an intermediate layer between concepts in the ontology and the natural language. Lexicon allows to refer to concepts in the ontology using English words. We have reused well-known general-purpose lexicon – WordNet. However, many domain-specific words are missing in this general-purpose lexicon. These were added to our system by embedding them directly into the ontology using special relations.

Next two components are the knowledge base and its index. Knowledge base is a distributed collection of documents available through the HTTP protocol, and identified by a URL. Knowledge base index facilitates retrieval of documents from the knowledge base that are relevant to the given query. Knowledge base index assigns each knowledge-base document a set of properties (metadata) that represent it during the search. There are some domain-independent metadata, like title, name of author, date of publication, document category (homepage, metapage, article, book, book section, glossary, solved example...), application domain (physics, numerical mathematics, power electronics...), and keywords. Keywords are

represented as concepts from our ontology. There may be also some application- or category-dependent metadata. For example, documents in a collection of solved simulation examples may be annotated with attributes such as modeling technique, physical domain, simulation engine, etc. The ontology formalism provides means of expressing such a complex structure of metadata.

The search subsystem allows the end user to retrieve documents relevant to his or her query. We have developed two prototype interfaces. First interface searches the collection of simulation examples according to domain-dependent attributes. The second interface allows to search the whole knowledge base given some keywords. The keyword-based search service demonstrates the improved quality of search of ontology-driven search engines with respect to ordinary full-text search services. Full-text search services suffer from limited recall and precision, which is caused by the ambiguity of natural language, namely by synonymy (a concept having multiple words that represent it), and polysemy (a word that represents multiple concepts). These problems are avoided by annotating documents in our knowledge base by word meanings (organized into ontology) rather than by words. The problem of limited recall caused by synonymy is overcome by associating an ontology concept with all appropriate English words (synonyms). This allows to find a document using e.g. keyword *engine* even if the document author has used a synonymous word *motor*. The problem of limited precision caused by polysemy is overcome by two-level search. When user enters a word (e.g. *engine*), the system responds with the list of all possible meanings of the word (each word meaning is defined by a short gloss.) System then retrieves only documents relevant to selected meaning(s).

The maintenance subsystem provides support for amending the ontology and knowledge base index. Since maintaining the knowledge system is a time-consuming task, it is desirable to automate the process to the maximum possible extent. For example, knowledge base documents sharing some properties (metadata) may be logically organized into groups, and the common metadata are specified at single place. This allows fast importing of a large collection of similar documents, and then amending only the differences. The system also allows extracting some properties of documents, such as document titles, from their content automatically. Another experimental feature is comparing the vocabulary of given document(s) with the current version of the lexicon and proposing ways how to extend the lexicon and/or the ontology by missing words or concepts.

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# Comparation of Formal Approaches to Data Reverse Engineering

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The term data reverse engineering evolved from the more generic term reverse engineering. Reverse engineering is a process to achieve understanding of the structure and interrelationships of a subject system. It is the goal of reverse engineering to create representations that document the subject and facilitate our understanding it what it is, how it works, and how it does not work. As a process, reverse engineering can be applied to each of the three principal aspects of a system: data, process, and control. Data reverse engineering concentrates on the data aspect of the system that is the organization. It is a collection of methods and tools to help an organization determine the structure, function, and meaning of its data.

The database community constructed number of models describing different levels of database abstraction, starting at conceptual schema, going through logical schema, ending with implementation. These models help designing database and they correspond engineering tasks very well. However, the models are not suitable for reverse engineering purposes which require other properties of description. The main goal of data reverse engineering models is to facilitate the engineer in several ways. High degree of model equivalences is required to express inter-schema mappings appropriately. Feasible description offers mathematical characterization of transformations and brings possibility of precise verification and validation. Also, systematic approach to parameterization must by used enabling model conformation for the particular task. On the other hand, no process is substitute for expertise of software engineer, so the model specification must provide the possibility to precisely state the moments of human knowledge and decision utilization.

There are several formal approaches that can be utilized with various features and applicability. The first way presents individual model creation adjusted to data reverse engineering processes. The second approach applies algebraic specifications for model description and relevant algebraic operations for transformations. The third alternative considers type theories.

Individual model is designed with respect to avaiable models and techniques. As an example, unique, generic, schema specification model has been created adopting transformational approach and encompassing all traditional levels of abstraction. This model and its transformational operators are intended to support forward as well as reverse engineering, to express conceptual, logical and physical schemas, as well as their manipulation, and to support and DBMS model ant the production and manipulation of its schemas. The model includes three layers: the organizational layer, which describes higher-level structure of the specification, the conceptual layer, which is limited to data structure specifications (at the level of ER model with some extensions), and the technical layer, which includes constructs that pertain to the description of logical and physical data structures. The unique, generic, schema specification model has been used in the DB-MAIN project.

Algebraic specifications offer very sufficient means for data reverse engineering formalization. Database models can be described using complex algebraic structures. Transformation between models can be presented as algebraic operations. Characteristics of

the operations allow model equivalences evaluation. Moreover, algebraic specification usage is well supported by means of specification languages, such as OBJ3.

Type theory presents modern area of mathematical science. The theory encompasses equality of propositions and types. The relationship to programming languages has been already used in several reverse engineering projects.

Ongoing research in the area of formal approaches to data reverse engineering will analyze all consequences of model characteristics and will undertake several practical case studies to proof their applicability.

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# Methods for Cooperation and Coordination of Multiple Autonomous Robots

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The cooperation and coordination of multiple autonomous robots is a complex problem that is investigated at research center in the whole world. The methods of artificial intelligence are mainly used for coordination of team of robots [1][2]. To compare different approaches to this problem the competitions are organized, where the team of the robots has to fulfill predefined goal. The most popular competition to test the robots coordination and cooperation is the robot soccer [3].

Robot soccer is a game similar to the "classical" soccer (football). Each team consists of several players; one of them is the goalkeeper. Robots have to be fully autonomous, controlled by the computer. The color camera connected to the computer is used for gaining the information about the position of individual players and the ball. The game between two teams (each having its own camera and computer) is running without the human intervention, with the exception of foul or stalemate situation, when the game is interrupted and a free kick or penalty kick is called.

Although this project may look like the funny game at the first glance, it is a serious interdisciplinary research problem involving areas like microelectronics, robotics, control, image processing, communications, and artificial intelligence.

The idea of robot soccer is originated in 1995, when prof. Jong-Hwan Kim of KAIST, Korea, initiated an international organizing committee for Micro-Robot World Cup Soccer Tournament (MiroSot). After the MiroSot game rules were given in 1996, the first MiroSot '96 championship was held at KAIST. Since that time MiroSot tournaments are organized regularly every year at various places in the world. Teams interested in robot soccer are joined together in Federation of International Robot-soccer Association (FIRA) [4].

In 2000 the first Czech team RoBohemia was founded at Department of Control and Instrumentation, Faculty of Electrical Engineering and Communication, Brno University of Technology (see http://www.fee.vutbr.cz/UAMT/robohemia/). In cooperation with this team the new version of robots for robot soccer was created.

Robot has predefined fixed size 6,5cm×6,5cm×6,5cm and is powered from nine AAA NiMH accumulators wired in series. The radio module output is connected to serial asynchronous interface input, so the microcontroller can receive packet transmitted from control PC. Microcontroller decodes desired velocity values corresponding to the given robot number from the received packet, recalculates them to the desired number of encoder counts and writes these values to the DC motor controllers.

Motor controller possesses interface for connection to microcontroller, trajectory profile generator, programmable PID filter and PWM output. In this application the controller works in velocity mode, its task is to maintain pre-determined velocity. The motor controller gets the

difference of the actual position (feedback position) from the desired profile generator position. The resulting position error is processed by the digital filter to drive the motor to the desired position. The motion controller outputs two 8-bit PWM signals, a sign and magnitude. These signals are run to a H-bridge, which sets a proportional voltage relative to the pulse width of the magnitude signal with a polarity related to the sign of the PWM signal. The motors are coupled to optical encoders that provide two square signals. These signals are fed back into the DC motor controller in order to close the control loop.

The Department of Cybernetics now has 6 robots ready to robot soccer. The software that controls and coordinates the team of robots is not finish yet. The main modules as the communication unit, the camera grabber unit and basic camera segmentation unit were created by students work. This shows that this project improves the education of mobile robotics at Department of Cybernetics.

The control system uses the system developed for simulation league of robot soccer. This system is based on the rule system with fixed set of the rules. The rules can use user-defined functions, which can classify the state of the game and/or can produce the output to the hardware. This system was created as a diploma thesis.

The main achievement of this project is to enable students develop and test algorithms for coordination and cooperation for team of the robots. At present four students are using developed robot platforms for student's projects and one student is preparing his diploma thesis for the theme of coordination and cooperation of team of autonomous robots.

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# Fault Injection for Time Triggered Architecture (FIT)

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The novel time-triggered architecture (TTA) is gaining growing acceptance in the industry as a generic architecture for highly dependable hard real-time systems. As a consequence, a number of semiconductor companies have expressed serious interests in manufacturing VLSI devices in support of this architecture, in particular for the real-time communication protocol TTP/C that is at the core of the TTA. In the future, TTP/C chips could be the heart of many high-dependability real-time applications in different industrial fields (e.g. automotive, aerospace, railways, industrial control, and medical electronics). It is thus of eminent significance for the industry and society in general, that the design decisions that are at the core of this architecture are validated by all possible means.
A prototype micro-programmable version of a TTP/C controller chip has been designed and implemented during the ESPRIT project TTA. It is the objective of the "Fault Injection into the Time-Triggered Architecture (FIT)" project to experimentally validate the system concepts of the TTA, taking this prototype TTP/C controller chip as the basis.

In particular it was planned to

- determine the error-detection coverage of the TTA in a realistic application by different hardware and software based fault-injection methods:
- Pin-level forcing
- Heavy-ion radiation
- VLSI-model-based fault injection
- Micro-program based fault injection
- Software-based fault injection.
- locate weaknesses in the architecture and to search for and evaluate design alternatives to correct these weaknesses.
- find the optimal parameter set for the error detection mechanisms (e.g. length of the end-to-end CRC) under techno-economical constraints.
- compare the effectiveness of the different fault-injection methods in activating the fault-tolerant mechanisms.
- develop a conformance test suite such that the fault-tolerance of different silicon implementations can be validated.

FIT have used all applicable hardware and software based fault-injection methods to locate weaknesses in TTA and to search for and evaluate design alternatives to correct these weaknesses. VHDL and C-Sim simulation models, pin level, heavy-ion and software implemented fault-injection techniques will be applied. Electromagnetic radiation has no impact on the architecture but only on a particular physical implementation and is not within the scope of the project. Laser radiation is not relevant for the technology used. Scan chain based injection can not be applied because of stringent timing requirements in real time systems.

The base line of the FIT project will be the set of fault-injection experiments that have been performed successfully on the MARS architecture during the PDCS (Predictably Dependable Computing Systems) projects. The PDCS experiments will be extended by VHDL- and software-based injection experiments.

CTU and UWB research group participating in this project, did not use the real TTP/C cluster, but were done on its software model in C-Sim.

The C-Sim based FI method uses discrete-time process-oriented simulation model of a TTP/C cluster as a subject of fault-injection. The source code of the model has two basic SW layers:

- *C-reference model of TTP/C protocol*: contains C-language coded TTP/C specification, including data types (CNI, MEDL) and functions (TTP/C services),
- *C-Sim code of a program of (abstract) TTP/C controller activity*: this program serves as a template to create the required number of TTP/C processes (i.e. abstract controllers) as a part of the TTP/C cluster model

The process-oriented form of the simulation model enables us to include easily other processes, like e.g. application processes (host computation including TTPOs), processes of controlled object (vehicle model in BBW testing application), etc.

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Motorola
Volvo Technological Development
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# Optimization of Simple CPU Core for FPGA

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Programmable logic arrays (FPGAs) containing CPU core and custom logic present a viable implementation platform for the current generation of embedded systems. This approach offers higher flexibility and lower cost comparing to traditional implementation of separate microcontroller and glue-logic. Important design decision is the choice of the right CPU core. Current market offers large number of CPU cores ranging from tiny 4-bit cores to 32-bit RISC CPUs. These cores are typically compatible with some commercially available microcontroller family. Various clones of the popular Intel 8051 micro are most commonly used. However, experience shows that these cores contain a large legacy overhead and most importantly do not offer a good compilation model for high level languages like Pascal or C. Resulting implementation is either large and inefficient program or difficult to maintain program written in assembly language. A simple 16-bit CPU core called DOP was developed on our department to enhance programmer productivity together with efficiency of implementation on FPGAs. This paper presents discussion of several architectures implementing DOP instruction set and their implementation properties on the current generation of FPGAs.

Design of CPU consists of two steps. Instruction Set Architecture (ISA) definition is followed by implementation of data path and controller. It is known that ISA imply the major properties of the resulting data path and controller but even for a single ISA could exist different architectures of data path and controller. To explain the design decision made for DOP, instruction set and programming model will be discussed briefly.

DOP ISA development, started in 1993, was driven by two major requirements. Firstly the resulting CPU should occupy a small area of to-date programmable logic. Secondly the CPU should offer a good compilation scheme for high-level languages like C or Pascal allowing compile short and fast programs. This two requirements lead to accumulator style of ISA with easy access to operands in memory allocated mainly on the stack. As a result it contains only a small number of programmer visible 16-bit registers – program counter PC, stack pointer SP, working register (accumulator) W, source address register S and destination register D. Three general purpose registers W, S and D could be used during expression evaluation and also to access operands in memory. Most commonly used addressing modes supported by instructions include post-increment and pre-decrement types. DOP also contains 16-bit program status word PSW register divisible to two parts: 8-bit loop counter allowing implement short cycles efficiently and 8-bit flags register. DOP is connected to unified byte addressable memory of 64 kB. Little Endian scheme was chosen for storing of multi byte operands and I/O devices are memory mapped. DOP ISA supports 16-bit integer operands as well as shorter 8-bit operands and provisions are made for easy synthesis of operation with operands longer than 16-bit word. Instructions use variable encoding scheme of 8-bit operation code optionally followed by 8-bit or 16-bit immediate. DOP supports 192 instructions divisible to 21 instruction groups. It was demonstrated that this ISA leads to short and efficient programs compiled from HLL.

First implementation of DOP was fairly straightforward. Analysis of the instruction set leads to decision implement PC, SP, S, D and L registers as unidirectional or bi-directional

counters with load. W register was implemented separately as a part of the ALU. Target implementation platform was Xilinx XC4000 family of FPGA. Therefore the whole data path was interconnected by a single 16-bit tri-state bus. CPU was connected to memory by 16-bit address bus and 8-bit bi-directional data bus. Internal bus is separated from address bus only by a single tri-state buffer. External data bus was connected to input and output buffering registers implementing 16-bit memory accesses by two 8-bit bus transfers.

First data path architecture was augmented by hardwired controller for first version of DOP and by microprogramed controller for educational version called DOP-v. Both controllers implement a large FSM containing of almost 100 states. First version of DOP including hardwired controller fitted in XC4010 FPGA device but it featured significant routability problems. Manual place and route design succeeded in 1994 to implement DOP in XC4010 device but the clock frequency was only 1 MHz. Automatic place and route tools did not succeed to route the design until XC4036 device which was only 15 % full and this problem persists even when the DOP was synthesized to Virtex family of FPGAs. Educational version of DOP-v including microprogrammed controller surprisingly achieved better implementation than hardwired one. DOP-v routes easily in XC4013E device, which is 80 % full and clock frequency, is 15 MHz. However, this was achieved for the price of slower instruction execution (CPI is higher for DOP-v).

The reason for routability and performance problems is in fact that DOP data path and controller architectures do not respect FPGA features. Firstly – internal tri state bus interconnecting counters consumes a lot of routing resources especially long lines. Second reason lies in complex controller, which contains a lot of unstructured combinatorial logic. It is significant that more structured combinatorial logic of microprogrammed controller fits better in FPGA. Therefore the more optimized data path and controller architecture called DOP-e was developed in 2002. All registers are implemented by dual port register file. The register file is connected to two-input one output ALU that performs all operations including address incrementation and decrementation. Only L and F registers are implemented from flip-flops. Data and address input and output buffers now include also address counter and this part could work in parallel to ALU. All interconnections in datapath are done by unidirectional wires and multiplexers. Second change was a novel architecture of controller – complex FSM was decomposed to two parts – main internal controller and I/O controller. These controllers could work in parallel and more importantly are smaller than a single complex FSM. Outputs of controller are registered allowing faster clock frequency. Resulting implementation fits in XC4010 device (almost 90 % full) and achieves clock frequency of 30 MHz (with better CPI than original DOP) in the XCV100 (25 % full) it achieves the clock frequency of 50 MHz.

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# Simulation of High Speed Networks Using Ns2

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This paper provides an overview of problems with simulation of high speed networks. When we want to build some network, simulations can help us to determine what topology and node interconnections we should use. Simulations can show us behavior of our design without any physically realizations, it can save us money and time by unhide some bad or unplanned behavior.

Ns2 is world wide known simulator of networks. There are some others simulators but ns2 has best reputations and is world wide used by various groups. Ns2 is easy to adapt due to its distribution with source code. It is free to use and modify. Ns2 simulator can simulate many different protocols and environment. Topology is programmed and configured via OTcl script language and main simulator is implemented in C++. OTcl language enables easy creating, reconfiguring and modifying topology without any compilations because ns2 contains interpreter of this script language. Simulators source code availability allows arbitrary modifications. My project is specialized to modify parts of Ns2 which are dedicated to simulate TCP/IP protocol over physical layer with collision detect availability.

As development continues, speed of network interfaces increases. In this case we need a simulator for high speed networks. Some basic modification of TCP protocol is to use big window, larger than standard maximum size 64kilobytes, which is far fewer than capacity of high speed interconnections. Capacity is computed as multiply of latency and bandwidth. Latency is measured as time interval between send requests on one side and receives response from other side on the same side. For example: interconnection with bandwidth 10 GB and latency 20ms (1kilobit is 1000bits) have capacity c. 190MB (1megabyte is 1048576bytes). In normal TCP environment sender sends maximum size of receiver window, which is usually 64kB, and is waiting for response. In meanwhile sender can sends some data, but it is limited by size receiver's window. Therefore basic TCP is improper for use in high speed networks. Modifications of TCP are described in RFC1323 and known as Window Scale Option. This modification allows use full capacity of interconnection and rapidly increases transfer rate. Backward is when error occurs, sender must retransmit part of window, but this part can be very large.

Ns2 recognize window scale option and allow us to set window size beyond 64kB limit. But there are for high capacity connections (hundreds megabytes) some limitations. Because each packet on line is different, ns2 must handle each of them. This results in very large operation memory consumption. Ns2 stores packets in memory without its data parts; in spite of memory consumption is still unbelievable. This is due to implementation of ns2 in object oriented language (C++) and very ineffective source code. Code may be human readable, but it is not optimal for compiler and computer. But for a project of such a size is important to be human readable to easy catch and repair errors and bugs.

Next limitation of ns2 is its serialize design. Performance of main processor is limited, but in one system can be many processors. Ns2 still utilizes only one of them. There are no mechanism to adapt and map simulated topology to physical computer layer while this can increase performance and decrease time needed for compute large simulations. There is some

modification of ns2 to going into parallel executing, but with some important limitations. First, this modification depends on some special parallel executions oriented library RTIKIT. Next, version of ns2, which are modified, is from year 2000, no more recent versions are adapted. Finally, topology mapping is not transparent to OTcl script, where is defined topology, and is static, no adaptive scheduling or dividing problem to processors.

My project is aimed on efficient implementation interconnections. So TCP large window sizes could be real. And adaptive transparent parallel mapping of simulated topology to processors. At first stage I implemented only nonadaptive and nontransparent simple topology to two processors, where simulated net will be divided to two equivalent parts. Next stages would be hard to implement because adaptive parallel scheduling is not easy. Transparency to script means correct recognizes topology and intelligent divide problem to computationally equal parts. Solutions are mostly to expensive to implement so work in this is go on.

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# Modeling a Rail Wheelset for Radial Position Control Analysis

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Reducing the journey time is nowadays the most predominating requirement in rail transport. This reduction can be achieved mainly by increasing the travelling speed. In this way, rail transport improves its competitiveness with air transport. Stability in vehicle movement has become the most important issue, given that an increase in speed must not incur any reduction in safety. Another important consideration in rail transportation is to reduce operating costs. Maintenance and replacement of worn wheels and rails forms an essential part of operating costs for all companies providing rail transportation. For this reason wheelsets with radial positioning have been introduced. Their successful application requires not only the design of a powerful control mechanism for wheelset turning in the curves but above all a deep knowledge of all factors leading to the occurrence of friction forces, ways describing them mathematically and a design which will eliminate or at least reduce them. Due to the high costs, this complex task cannot be studied purely on an experimental basis, and needs support from computer simulation. Experience from previous applications of simulation models using the MATLAB/SIMULINK program led to the suggestion to apply the same tool as appropriate for this task.

## A Turning Wheelset

The wheelset is the most important part of the vehicle chassis. A standard railway wheelset consists of an axle and two wheels firmly interconnected with the axle. The common axle guarantees the same angle velocity for both wheels. In the first approach, the driving surfaces of the wheels can be taken into consideration as surfaces of the rotating cones with a common basis. From the Law of Inertia it follows that the wheelset continues in a straight direction when it comes into a curve. This causes the wheel on the outer side of the curve to run on a large radius with a larger circumferential velocity while the inner wheel makes the same motion in the opposite direction resulting in a reduction of its circumferential velocity. The difference of the circumferential velocities at the two points of contact with the rail divided by their distance provides the angular velocity of the wheelset in the perpendicular plane. Under optimal circumstances, this velocity is the same as the speed of the driving motion and the axis of the wheelset rotation is directed at the centre of the curve. This position of the wheelset is called the radial position. Simply stated, the wheelset designed in this way turns itself while trying to achieve the radial position. This self-controlled setting of the exact radial position is fully successful only in exceptional cases. Usually, the motion of the wheelset is connected with slipping at the points of contact with the rail, and with the occurrence of friction forces between the wheel and the rail. This leads to increased wear.

**Mathematical Model and SIMULINK**

A suggested solution for improving the stability of the radial positioning, especially in direct segments of a track, is active support for the wheelset positioning. The correct design involves carrying out numerous simulation experiments. For this simulation a mathematical model was derived under the assumption consideration that the Scheffel system will be used for basic radial positioning and certain additional wheelset turning provided by a hydraulic servomechanism will be used in an attempt to achieve the optimal wheelset position. The mathematical model is derived from the equilibrium of the forces or moments about the axes of the local coordinate system of the wheelset. In this way, a system of six nonlinear differential equations arises, where the following symbols are assigned to the projections of the forces and moments:

O – centrifugal force from the driving motion of the wheelset
K – combination of the forces from the spring deformation and damper
D – dynamic forces from the relative motion of the wheelset
MD – dynamic moments from the relative motion of the wheelset
F – slipping forces operating at the point of wheel contact with the rail
Q – reaction forces in the contact
U – reaction forces in the contact in the linkage of the wheelset with the frame of bogie

The choice of SIMULINK as a simulation tools was influenced by quite good experience with its use. It provides responses to simulated changes in physical variables and phenomena that are not measurable in real conditions, but that are important due to their effect on the economy and safety of wheelset operation. Typical physical variables in real situations are: changes in curve radius, changes in friction coefficients in both contact points, changes in parameters of springs, dampers, etc. The results obtained from the simulation experiments are in accordance with existing knowledge originating from real situations of wheelset behaviour

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# Subjective Quality Aspects of Image Compression in Multimedia

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The subjective image quality evaluation and criteria are of increasing importance in modern multimedia systems. New and very efficient image compression techniques are useful for very high compression rates and the multimedia technology in general exploits extensive variability of transmission channels with very different data rates and capacities. The Quality-of-Service QoS parameter describes the overall quality incl. coding, transmission, recording, processing etc.

In multimedia the image quality seems to be a crucial. Standard objective quality measures such as MSE or PSNR are very suitable for distortion levels just above the perception threshold. The TV broadcasting is an example of image (video) distribution network where the MSE is applicable. In other multimedia systems e.g. videoconferencing, CCTV monitoring etc. the acceptable distortion levels are much higher and the applicable quality criterion differs esp. when some special task with the highest priority e.g. face identification has to be fulfilled.

In the audio part of multimedia systems the subjective perception principles are widely applied esp. for the audio compression. The most important is the masking effect represented in audiocodecs by audio perception models (NICAM and following) enabling adaptive modification of coding process. Mostly the frequency masking is exploited.

In the video part of multimedia systems the application of such principles is not so advanced because of higher complexity of image perception. There are multiple effects with significant impact on image perception which are still not exploited. Apart of masking effects similar to the audio we can list e.g. predictive mechanisms, influence of receptive fields, compensation mechanisms etc.

In our work we have tested impacts of image compression techniques frequently used on a special class of still-image data evaluated by a human observer. The compression standards as JPEG, JPEG2000, LuraWave and 2D KLT (algorithm developed and implemented by Dr.Páta) have been applied to various image data sets. The above mentioned standards have been selected because of their different compression principles. The JPEG standard is based upon the DCT (in video technology also used in MPEG-1,2), JPEG2000 and LuraWave upon the WT. As it is demonstrated the artifacts and distortions introduced by different compression principles are of different subjective perception importance. [1,2]

Basically two typical practical example sets of image data important in the security field have been chosen. The first one relates to the numeric display reading [1] and the second one to the car plate and face identification [4]. In such cases the image compression technology is applied when image transmission through narrow channels is required and/or large image databases have to be created. The image compression must not affect the required information content evaluated by a human observer.

The seven segment display is an example of applied CCTV systems where the videosystem is used for independent checking of large information displays at railway stations, airports etc. The achievable compression rate depends strongly on the background texture and display/background amplitude ratio. During subjective evaluation procedure (three independent

attempts and three observers) the identification thresholds have been detected and relevant compression rate expressed for each compression technique. In order to get exact comparison to a standard image test the LENA picture has been compressed under same conditions and the subjective image quality has been evaluated by the HVS model derived in [3]. The results show and confirm a dominant effect of the background info. The experimental dependencies for selected compression standards and backgrounds have been derived: compression rate vs MSE, compression rate vs identification threshold, compression rate vs subjective image quality. Three forms of background have been chosen:

A – random field with Gaussian distribution
B – dark field with texture
C – grey field with more apparent texture

The research activities will continue in order to understand deeply the influence of background and noise level.

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# Laboratory Exercises for "Tools of Automatic Control"

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Submitted education project is focused on establish of specialised workplaces in laboratory of "Tools of Automatic Control. These new experimental workplaces are placed on Department of Instrumentation and Control Engineering. They are used by education of this subject. From grant amount has been established top workplaces for demonstration of properties of modern PID controllers, actuators, filters, and their applications. These workplaces are identified to progress and increasing research efficiency and developing works and their use in education. The mentioned workplaces are development also with the view of counselling workplaces, in some case of workplaces for conferment of certificate about deuces. Reach of this level was by aim of submitted project. This equipment made partly professional safeguard measurement in other consequential experimental projects and at the same time contribution to improve the quality of education in theme "Automatic Control " and in related themes. The next paragraph summarise brief contents of any reached results:

1. Workplace for properties demonstration of compact regulators. The main aim of this place is to learn how to use these regulators, to know their software and experimental settings parameters in conjunction with various types of dynamical systems. Here are four standard compact PID controllers (Siemens, Yokogawa, Omron and Teco). Together with it can be tested internal algorithms for automatic and adaptive settings. Dynamical systems controlled by these regulators are simulated using Matlab in conjunction with laboratory cards as input/output.
2. Workplace for project various types of analogue filters, designing them and measurement their frequency characteristic. For this aim was designed special equipment. Measured characteristics are compared with calculated values.
3. Workplace for demonstration of basic properties of CAN bus, designing and debugging software for controllers using this type of bus for communication.
4. Workplace for learning properties of actuators based on synchronous drives with smart control system OMNUC W model R88M-W/R88D-WT produced by Omron. The servo drive has three control loops: position, speed and torque. Depending on the control mode being used, these loops are closed either in the controller or the amplifier. In the torque loop command comes from speed loop or analogue torque input and feedback is from current transformer. In the speed loop command comes from position loop or analogue speed input and feedback is from the encoder (frequency of pulses). In the position loop command comes from a controller program or pulse train and feedback is from encoder (number of pulses). There are tree options of the tuning for stabilisation the control of the system:, auto tuning (when the load inertia does not change during the operation), on-line auto tuning (when the load changes significantly during the operation) and manual tuning (when application require very high performance). The students learn, how to set parameters of this system depends on the load.
5. Integrated workplace for controlling water flow using knowledge's of automatic control, technical measurement and related topics for design controlled system. This

task is to introduce theoretical as well as practical parts of measuring and regulation as the dependence of measurement accuracy and regulation on the errors of converters speed and sampling. The task construction enables to acquire a mathematics model by approximation from transient characteristics, which may be used for algorithm design of a regulator and result of simulation confronted with measured data. The flow is one of the most frequent measurements in industry. The given task is structured as a closed circuit with measuring and referential flowmeters, while the measurement instrument serves for the reference purpose. The inductive flowmeter with the most diffused outputs is used for flow measurement. It includes digital output (TTL logic), current output (from 4 to 20 mA) and communication port RS 232 C. In addition, display is also attached. These transfer connections are unique for their specific parameters, which assign each for its individual use in a specific case. Rotametr as a indicator compares the accuracy of flow measurements. Three way valve operated by a servomotor is used for control. The scale of the control signal is calculated in accordance with a given algorithm in control software. The gradual perfomance selection pump serves as a flow source. Measurement range varies from 2 to 20 l/min. Its setting is defined by selected pump permormance and programming of two-adjustable valves. The expansion tank is used for bleeding and filling. This solution offers the option of future extension and modification. Data transfer for the purpose of PC evaluation (feedback) and servomotor control are provided by a measuring laboratory card.

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# Artificial Life Simulation

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This paper reviews CZAR (Czech Animal-Like Robot) architecture. This hybrid Autonomous Agent Architecture was designed for the usage mainly in the Artificial Life domain and combines knowledge-based and behavior-based approaches. Its structure, strengths as well as weaknesses, and roots in biology are presented. CZAR has arisen as a result of a number of applications, where real robots with variety of control systems were tested and several biological systems were simulated. During this iteration process, basic principles common to mobile robotic applications and common to real animals were identified and embodied in the resulting architecture. This article highlights these principles and provides detailed description of the CZAR architecture. Basic building blocks include perception, actuation, internal state model, cognition, action selection and a special importance is put onto attention selection. Particular focus is also placed on learning and adaptivity. A simplified ecosystem was created to test features of CZAR architecture.

There has been now a growing interest in the design and theorization of Artificial Intelligence (AI) systems concerned with modeling, simulation and building of the so-called *adaptive autonomous mobile* agents or rather the *behavior-based* intelligent robots. The idea of decentralization can be understood as a variant of *bottom-up* approach. This category has been termed also as *"behavior-based AI"* as opposed to mainstream *"knowledge-based AI"*. The behavioral approach consists of *expanding* the simple capabilities of well-understood agents instead of the *top-down* effort of the classical artificial intelligence to *reduce* complicated and only poorly understood agents (intelligent animal beings e.g.) to a form manageable by computer architecture at hand.

The idea of the bottom-up approach has been used during the recent few years in different ways. In artificial intelligence, the classical *deliberative* paradigm of viewing intelligent tasks as *reasoning* processes on *internal representations* of knowledge only has been shown to be unrealistic for embodied autonomous intelligent agents. The new paradigm of *emergent functionality* views intelligence as an emergent attribute of interactions of agents with their environments and with other agents and focuses on models of intelligence that share certain common characteristics with biological information processing systems. In its context, the bottom-up approach allows to achieve higher-level cooperation among simpler systems by creating societies of robots [1]. The main problem consists in finding some transparent mechanisms how individual behaviors of agents may result in an *emergent behavior* of the society without referencing some metaphysical attributes like consciousness and so on. The complexity of a behavior needs not necessarily be a product of an extremely complex control system. Rather, it is much more a reflection of the complexity of the dynamic unpredictable environment than of its own internal complexity. The field of *ethology*, the science of behavior of living creatures inspires this idea. Ethologists have stressed that an animal's behavior can only be understood and only makes sense in the context of the particular environment it inhabits [2]. Such system tries to satisfy a set of time-dependent goals or motivations. Interaction dynamics between an agent and its environment leads exactly to the appointed emergent structure or the emergent functionality.

A behavior is defined here as regularity observed in the interaction dynamics between the characteristics and processes of a system and the characteristics and processes of an environment. The "classical" AI approach defines intelligence in terms of knowledge: A system is intelligent if it maximally applies the knowledge that it has (cf. principle of rationality). The "behavior oriented" approach defines intelligence in terms of observed behavior and self-preservation or autonomy [3]. Essence of biological systems is their capacity to continuously preserve and adapt themselves: *The behavior of a system is intelligent to the extent that it maximizes the chances for self-preservation of that system in a particular environment.*

In the ninetieth, a multidisciplinary subgroup within the AI community has started to stress *embodied* intelligence and made teamwork with biology, psychology, sociology, medicine and research on so-called Artificial Life (AL). A major goal of AL research is to *gain insight into both life as it is and life as it might have been*. As such, AL issues span potentially a very broad range, from the role of chaos and prebiotic chemistry, to the emergence of animal intelligence. The drive towards self-preservation applies to all levels of complexity: genes, cells, multicellular structures, plants, animals, group of animals, societies, species. Behavior-oriented ALife approaches focuses upon the behavior of organisms of the complexity of animals. Systems of this complexity are called agents. When several of them cooperate or compete, we talk about multiagent systems. *A system is capable of adapting and learning if it changes its behavior so as to continue maximizing its intelligence, even if the environment unexpectedly changes.*

Members of Mobile Robots Group - Behavior Based Research at FEE CTU in Prague, since 1992 supervised by author Pavel Nahodil, have focused on understanding the essence of intelligent behavior from the Artificial Life perspective. It was built a number of robot platforms and simulators here[2], [4]. Most of designed approaches were tested on group of real robots. Several AL systems were simulated, too. These tasks commonly require social interaction / cooperation [2]. We are interested in how AL - based approach to synthesizing intelligent behavior guided by biological perspective could reflect Mother Nature [4]. These systems are the results of billions of years of evolution and complex developmental / learning processes. Performed successful CZAR architecture resulted from our long-time research.

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# Auction Algorithms for Large Scale Linear Sum Assignment Problem

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One of the classic combinatorial optimization problems is the *linear assignment problem* (LSAP). Its inputs are two distinct sets of *n* persons and *n* objects and a *cost matrix* $A_{i\times j} = [a_{ij}]$, where $a_{ij}$ is the cost of the assignment of object *j* to person *i*. The LSAP output is a permutation $\Pi = \{\pi_0, \pi_1, \ldots, \pi_{n-1}\}$ such that $\sum_{i=0}^{n-1} a_{i\pi_i}$ is minimum. It can be also formulated using graph theory terminology as a *minimum weight matching problem* in bipartite graphs.

A classical direct application of the LSAP is the assignment of personnel or jobs. Further applications include modeling optimal engine scheduling in railway systems, locating or tracking of moving objects in space, or problems in telecommunication earth—satellite systems. The LSAP is frequently used as a subproblem in more involved combinatorial optimization problems, such as quadratic assignment, traveling salesman, or vehicle routing problems.

The memory complexity of a LSAP with *n* persons and objects is $\Theta(n^2)$. For instance, a computer with 1 GB RAM can solve problems up to $n = 10000$ with having the whole data structure in the main memory. However, for larger *n*, the effect called *memory swapping* drastically slows down the computation and a distributed memory implementation with distributing the data among more processors is the only feasible solution.

Several various parallel algorithms for LSAP based on parallel versions of primal-dual shortest path, primal simplex, and *auction algorithms* were published. In the following text, we focus on the auction algorithms (AAs), which are considered the most suitable for implementation on distributed memory parallel computers.

First parallel AAs were implemented on shared memory parallel machines [1]. We have found only 2 papers describing parallel AAs on a distributed memory computer or a cluster. One parallel AA implementation on a MEIKO parallel machine was reported in paper [4]. However, this is not a distributed algorithm, since each node has a whole copy of the cost matrix. This allows to reduce substantially the communication among processors, and not surprisingly, this solution provides speedups up to 3 on 5 processors. However, if the problem size exceeds the capacity of the main memory, swapping drastically decreases the time and efficiency. In paper [3], there is a comparison study of AA implementations on various parallel architectures. The authors also consider a distributed memory implementation of a forward AA on a cluster of workstations with 10 Mb Ethernet. They used columnwise mapping of the cost matrix. The paper does not give any specific performance results. Our understanding is that the

results were disappointing due to the slow interconnect and expensive broadcast and reduce operations and led the authors to a conclusion that a distributed memory implementation is not worth considering. They have not considered the swapping issues for large instances of problems.

We have developed and implemented a forward, reverse and forward-reverse distributed memory parallel AAs for the LSAP on a homogeneous distributed memory parallel computer [2]. We propose several optimizations of the communication among processors. The algorithms allow scalability of the bidding increment and adaptivity of the size of the block of free persons bidding in parallel.

Our algorithms are able to solve large-scale instances of LSAP very efficiently. We just need to eliminate the memory swapping effect by allocating enough nodes with enough RAM memory. For example, our 16 node Myrinet cluster (each node had Intel Pentium III processor at 733 MHz with 256 MB memory) solved a $n = 20000$ full dense LSAP instance with random data in about 2 minutes. Our results confirm previous observations on optimal settings of AA parameters with respect to the characteristics of input data. The best results have always been given by hybrid AAs with block size adaptivity. To our best knowledge, a distributed memory forward-reverse has not been reported in the literature so far.

Other future work will consist in investigating distributed memory auction algorithms for huge instances of linear network flow problems such as maximum-flow problem and transpotation problems.

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# The Need of non Conventional Clustering Techniques

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Web mining involves application of data mining techniques to discover patterns from the web data. The likelihood of bad or incomplete web data is higher than the conventional applications. Clustering is one of the important functions in web mining. The clusters and associations in web mining do not necessarily have crisp boundaries. Researchers have studied the possibility of using fuzzy sets in web mining clustering applications. This paper introduces the proposed adaptation of Kohonen self-organizing maps based on the properties of rough sets [1], to find the interval sets of clusters. The art of interval set clustering give the ability to say that the element can be member of group I or group J. Web mining can be broadly divided into three classes: content mining, usage mining, and structure mining [1]. Web usage mining applies data mining techniques to discover usage patterns from the Web data, in order to understand and better serve the needs of Web-based applications. Web usage mining consists of three phases, namely preprocessing, pattern discovery, and pattern analysis. While content mining and structure mining utilize the real or primary data on the web, web usage mining uses secondary data generated by the users' interaction with the web. Logs of web access available on most servers are good examples of the data sets used in web usage mining. Results of web usage mining are used by E-commerce companies for tracking customer behavior on their sites. Clustering analysis is an important function in web usage mining, which groups together users or data items with similar characteristics. The clustering process is an important step in establishing user profiles. User profiling on the web consists of studying important characteristics of the web visitors. Due to the ease of movement from one portal to another, web users can be very mobile . If a particular web site doesn't satisfy the needs of a user in a relatively short period of time, the user will quickly move on to another web site. Therefore, it is very important to understand the needs and characteristics of web users. Clustering in web mining faces several additional challenges compared to traditional applications, the clusters tend to have fuzzy or rough boundaries. The membership of an object in a cluster may not be precisely defined. There is likelihood that an object may be a candidate for more than one cluster. In addition, due to noise in the recording of data and incomplete logs, the possibility of the presence of outliers in the data set is high. Therefore the conventional clustering techniques may not suitable to accommodate the needing to analyze such applications, so it is very important to find the techniques, which have the abilities to solve these difficulties. The interval set clustering using a modification of the Kohonen self-organizing maps based on rough set theory [1], was used to find cluster intervals of web users. The notion of rough set was proposed by Pawlak[2]. Rough sets theory has the ability to approximate the sets into an equivalence relation; equivalence relations partitions the set into disjoint subsets. If two elements belong to the same equivalence class, we say that these two elements are indistinguishable. Instead, its lower and upper bounds may represent the set The following section describes the results for experiments with web logs of the visitors on an educational web site, which represents the attendence of one course. Total visits were 23,754. The visits that didn't download any class-notes were eliminated, since these visits correspond to either casual visitors or workers. The modified Kohonen clustering was applied to the remaining

7,673 visits. Visits from students attending this course could fall into one of the three categories; Studious these visitors download the current set of notes, Crammers these visitors download a large set of notes, Workers these visitors are mostly working on class or lab assignments or accessing the discussion board. The elements in $\underline{A}(cluster)$ represent lower bound, which definitely belong to that *cluster*, while elements in the $\overline{A}(cluster)$ represent upper bound, which may or may not belong to that cluster. The boundary region represents the difference between the upper and lower bounds, which calculated as, $BND(cluster) = \overline{A}(cluster) - \underline{A}(cluster)$. From these results we can say that, in certain applications, concept of a boundary region may be useful. The objects in a boundary region may potentially belong to two or more clusters. So non-conventional clustering techniques has to be paid more attention in such applications. Therefore we can say that the non conventional clustering techniques may be more suitable in such applications.

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# Data Consistency of the KOS Database in a Heterogeneous Client Environment

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The component KOS IS stores data into the Oracle SQL database. Its data scheme consists of standard database objects like tables, views, sequences, stored routines and triggers. The semantics of data is partially expressed by integrity constraints, which correspond to study regulations. Let's adduce one example. A given student can register for the seminary of some subject in a timetable, when:

- the given subject is offered
- the student is registered for the subject
- the enrollment doesn't conflict with another one
- the given timetable window is not fully occupied
- the student has accomplished some additional requirements, etc.

Full data semantics can't be expressed by declarative integrity constraints only. Some complex study rule must be coded in algorithm of application function.

The most effective organizational precaution for preventing data inconsistency is to set the only one provider of the DML actions. Whether you want some new function, maintain some old function, or to make some ad hoc DML intervention, choose the same provider. This method does not give full warranty. But it facilitates to blame the only one culprit.

From the programmer point of view the possibility of data inconsistency will brew up when some algorithm is coded in more KOS services (Oracle forms, batch jobs, etc.). For example a registration of a student for some next school term course can be done by

- a student
- a faculty study administrator explicitly or by changing the student's study state
- a timetable administrator of the department by withdrawing the course's offer
- a batch task.

When the algorithm will change, authors must apply the change on all its instances. The code redundancy like this may brew up as a consequence of the division of labor between more implementation teams with insufficient coordination. On the FEE CTU we had a period, when employees of the faculty (customer) were admitted to impinge the source code of some applications. It was very disagreeable and expensive experience. It should not be repeated.

In the period "before KOS", at the faculty of transportation sciences, they ran the isolated Web form for registering students for course exams. This function was, in principle, based on some inconsistencies, but graphical user interface was friendlier then Oracle forms and users "could not forget" it. Employees of the faculty decided to implement for students their own WWW functions working upon the KOS IS database. Admitting another author team broke the rule of

unique authorship of the data manipulation functions. The danger of the disruption of data consistency was eliminated by this solution:

1. The data consistency blame must not be shared. From obvious reasons the origin author company - TRIL was set as responsible.
2. TRIL's workers have rewritten relevant KOS routines and have stored them into the database as parts of schema objects - packages. This library of routines is split into two levels.
   The inner level consists of library packages that serve all KOS data manipulation operations (for example registering for course exams or registering for next school term courses). The EXECUTE privilege for routines of this level is granted to their owner only. No other user is granted.
   Each package of outer level implements interface to one type of application programs (KOS Oracle Forms, WebKOS forms, KOSI forms). Packages of the outer level check privileges of the calling user and if the user's demand is correct, the package accomplishes the demand by calling KOS service from the inner level). Rules for granting EXECUTE privilege for outer level are set for each type of client environment individually.
   Division of the library into two levels enables to keep functionality of KOS on the only one place. Checking of access privileges and calling details can vary according to which client application is calling a KOS service. For example in the interface package for Oracle Forms appropriate checks are based on knowledge of the user role of the calling user. The strategy of checks for given client environment may vary in time pertinently without affecting the access from the other client environments.
3. Users working through the client application are not granted any access privileges to tables in the KOS database scheme. For each user role TRIL created a set of SQL views over the KOS scheme. Users are granted the Select privilege to these views according to their user role.

At the VIC CTU the KOSI application with WWW clones of original Oracle Forms was developed and it is practiced simultaneously with Oracle forms and WebKOS.
Using the technique described in this paper ensures reasonable grade of protection against formation of data inconsistency in the KOS database.

besides

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# Experiences with Jobs Queueing and Scheduling on a Multiuser Linux Cluster

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Computer clusters built of the cheap commodity components have become a very popular and promising platform for performing long CPU-intensive computations. In contrast with mainframes, the clusters offer comparable performance for a considerably lower price [1].

In this article, experiences with the real Linux cluster under multiuser environment are described. The cluster is running NPACI Rocks distribution. Applications executed on the cluster were written using MPI library. Portable Batch System was used to queue and schedule jobs originating from many different users.

Linux is an open-source operating system with growing popularity and importance. Nowadays, it has become one of the mostly used operating systems in the area of computer clusters.

NPACI Rocks [2] is a toolkit built upon RedHat Linux, one of the most popular Linux distributions. Its main benefits include fast, easy, and automated installation of large number of computing nodes.

Portable Batch System (PBS) is a powerful and highly configurable job queueing system. It operates in a multiuser environment and allows users to submit jobs to one or more queues. The jobs are then scheduled to individual computing nodes with respect to the required resources.

PBS has a plugin architecture, thus, it can work with several different schedulers. Besides the Portable Batch Scheduler, which is the part of the PBS distribution, Maui scheduler is often used to improve scheduling efficiency [3].

Message Passing Interface (MPI) has become the most important library for developing parallel applications. It has various implementations, in this paper, MPICH implementation is concerned [4].

The cluster used in our experiment consisted of sixteen computing nodes, each of them having one 730 MHz Pentium III processor and 256 MB of physical RAM. The nodes were connected with 100MBit Ethernet switch and also with a fast Myrinet network. One extra node with symmetric multiprocessing, two 1 GHz Pentium III processors, and 1 GB of RAM was used as a frontend to the cluster.

In the experiment, the cluster was utilized by students of the course "Parallel Systems and Computations". Almost one hundred parallel applications were implemented as semestral projects and their performance was evaluated under various conditions, involving varying problem size, number of computing nodes used, etc. Applications were implemented using the MPICH message passing library.

To make the performance analysis worthwhile, parallel applications should run on a dedicated subset of nodes. Therefore, users were only allowed to work on the frontend node. The direct usage of computing nodes was forbidden and PBS had to be used to access them. Users

submitted jobs into PBS queues together with specifying the number of requested nodes. The jobs were then scheduled to individual nodes.

The first observation compares two schedulers. We have tried both Maui scheduler and PBS native scheduler. Although Maui is considered to be more powerful and usually outperforms PBS scheduler [3], our experience is different. The easy configuration of PBS native scheduler allowed us to specify job priorities according to our intentions. For instance, we wanted to prefer short jobs to longer ones, in order to allow students faster debugging of their applications. On the other hand, Maui prefers longer jobs, which are generally harder to schedule. Although it is possible to configure this behavior, we were not able to set it to match our needs exactly. Moreover, we were experiencing unstable PBS states when Maui scheduler was active.

The reasoning of our conclusions being opposite to the results described in [3] can be found in the specific conditions of our experiments. The cluster was used to perform extremely high number of jobs with very similar behavior and requirements (all semestral projects were of a similar nature and were evaluated using the same criteria). Thus, very simple PBS scheduler was sufficient to utilize the computing nodes using simple FIFO-based algorithms. On the other hand, Maui complex scheduling could not bring any significant additional benefits.

The cluster was monitored for 15 days during the Christmas holidays. The maximum number of jobs in the PBS queue was 672, the minimum number 59, and the average number of jobs was 261. Almost 9000 jobs were processed by PBS during this time, their running times varied from one second to 32 minutes, which was the limit allowed for a single job. Also the number of computing nodes required by a single job varied from a single node to all 16 nodes available. The average number of utilized computing nodes was almost 14, which means the overall utilization of the cluster was 87 percent. This value is quite high considering the fact that most of the jobs required much more than two processors. Thus, if there were only two computing nodes idle, it was often impossible to schedule another job to them.

Our experience shows that using batch queueing and scheduling systems such as PBS can provide a flexible high-performance environment. All users can benefit from having the possibility to use the dedicated set of nodes, without being affected by other users. If the administrator chooses a proper scheduling policy and sets the job priorities accordingly, the utilization of the cluster can be very good.

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# Invariant Modifications for Generation of Benchmark Circuits

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Today's field-programmable gate arrays represent very complex devices that require specialized design tools to implement a user-defined circuit. Many physical design tasks are NP-hard and cannot be solved by deterministic algorithms that can always guarantee an optimal solution.

A common method for testing physical design algorithms is based on using benchmark circuits. These are standardized circuits taken from the industry. Although this method of creation makes sense, these circuits show several disadvantages.

Another method of creating benchmark circuits is to use a parametrized circuit generator that generates random artificial circuits [1],[3], or creates benchmarks using existing circuits [2]. The major disadvantage of this approach is the impossibility to implement these circuits in real chips and the difficulty to prove that the set of created circuits is representative for all or at least a class of circuits for a given application, since usually not all aspects are modelled in a realistic way [3].

The majority of generators don't use memory elements [4]. The last method described in the literature modifies a structure of a logic circuit so that its function as well as size remains the same [4]. The major disadvantage is a lack of sufficient control over the modification algorithm.

The method of benchmark creation presented here tries to eliminate the above disadvantages. It is based on performing predefined operations that alter the circuit without changing its function. The resulting netlist is more complicated, but in the ideal case the resulting implementation should be the same as the one of the original circuit. The differences between the two implementations depend on the nature of the modifications performed and on the ability of the design algorithms to eliminate them. This idea makes it possible to use circuits designed by the end-user, to verify the functionality of the modified circuit and to take into account different demands at different workplaces.

The method presented here can be viewed as a (functional) mapping of a suitable original circuit to another supported by invariant modifications. The quality of a design algorithm is determined by processing the original circuit, processing the modified circuit, and comparing the implementation results (in terms of area requirements and critical signal path delays). The implementation of the original circuit represents a good sub-optimal solution that should always be achieved for circuits with the same function. Sometimes it is possible to have a modified circuit with better implementation results when the modifications correspond to the internal structure of the FPGA used.

The invariant modifications that form the approach presented here can be divided into three groups according to the nature of elements (subcircuits) they operate on: combinatorial (gates), sequential (gates and flipflops), and memory (registers). These are determined mainly by the logic primitives used in the circuit netlist. To be specific, from now on we will assume netlists in the Xilinx netlist format.

The simplest modification of a combinatorial circuit is a duplication of a logical gate or of a whole subcircuit, using the Boolea Algebra or replacing a gate witch a multiplexor.

Memory elements can be modified in three ways: duplication of a memory element, extending the address bus and extending the data bus.

Sequential circuits contain memory elements in addition to combinatorial logic. We may view these groups independently and use methods for combinatorial circuits to modify the combinatorial parts and memory elements may be modified with Duplication of a D-type flip-flop, replacement of a D-type flip-flop by an equivalent connection of logic gates or modifying the whole circuit.

To test the described approach to testing design algorithms we created a tool (called XNFInvar) that applies some of the modifications described above to circuit netlists, namely: replacement of all, or randomly chosen gates by two-input gates (decomposition) or by multiplexors, replacement of all, specified, or randomly chosen blocks by a parallel connection of its copies connected by AND, or OR gates connected in series or parallel, duplication of a whole subcircuit given its maximum logical depth and width (number of pending inputs), replacement of all, or randomly chosen D-type flip-flops by an equivalent connection of logic gates.

The modifications to be done are passed as command-line parameters to the program. Blocks to be changed are specified by their names from a netlist, or by a (uniform) probability of their choice. As an option, the total number of blocks modified may be specified. The input circuit is specified in the XNF format.

The presented approach was tested in several experiments. For demonstration purposes, we chose the Xilinx XC4005E-1-PC84 FPGA, and the Xilinx Foundation F3.1i design system. We checked whether the proposed modifications are strong enough to affect the results of a professional design implementation tool.

From the executed experiments it can be concluded that the presented approach to benchmark generation proved to be applicable. As a side-effect it was observed that the Foundation software does not perform sufficient logic optimization on a netlist level. One objection might be that such duplicated gates can be hardly found in industrial designs, but one would believe that any design implementation tool should be able to handle such simple circuits.

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# Influence of Noise to Quality of Image Segmentation

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**Introduction:**

Image segmentation is one of the most important parts of segmentation-based coding. During the segmentation, we analyse a given image and we try to find homogenous areas in a certain sense (for example colour or grey level). After this process are obtained areas and borders coded in various ways. The resulting quality of the segmentation-based coding depends on all parts of the process, but the segmentation method predetermine the resulting compression ratio, sensitivity to noise and formation of the coding artifacts. It means we have to select carefully the image segmentation method for our application.

**Image segmentation methods:**

The image segmentation process can be based on various mechanisms. In our research we examined two of them.

The first one is based on region analysis. This method splits or merges the regions in the image. Which regions should be split or merged is determined by similarity of these regions. The similarity is measured using some characteristics of these regions. The second segmentation method is based on watershed algorithm [1]. During our research we found out, that these two methods can be used together.

The main issue using region-based algorithms is to produce the initial regions for merging, in other words the initial splitting of the region. In our research we used watershed algorithm for this purpose. After this, the regions created by the watershed algorithm were processed by the region merging process.

**Testing of image segmentation:**

The main part of our research was aimed to test these segmentation methods against noise resistance. We have chosen seven test images and we applied all selected segmentation algorithms methods on these test images with four different levels of noise. We have also used two types of preprocessing median filters for testing.

After this, we evaluated the quality of the segmented images. A lot of segmentation quality measures have been developed. The measure, which we have used, is as follows:

The Edge-order Coincidence evaluates the overlap the edges found by using an edge operator (in our case Sobel edge operator [3]) relative to the area borders produced by the segmentation method. We took the top 15% pixels obtained by the Sobel operator as edge pixels (i.e. thresholding). Exactly, let $E$ is the set of pixels found by the edge operator after the thresholding and $S$ is the set of pixels of the areas borders, which are produced by the segmentation algorithm:

$$E = \{p_1, p_2, ..., p_E\} = \{(x_{p1}, y_{p1}), (x_{p2}, y_{p2}), ..., (x_{pE}, y_{pE})\}$$

and

$$S = \{q_1, q_2, ..., q_S\} = \{(x_{q1}, y_{q1}), (x_{q2}, y_{q2}), ..., (x_{qS}, y_{qS})\}.$$

Then, the Edge-border Coincidence is defined as follows: $EBC = \frac{n(E \cap S)}{n(E)}$,

where $n(A)$ is the number of elements in the set $A$ and

$$E \cap S = \{(x_k, y_k), k = 1, ..., m : (x_k, y_k) \in E \ \wedge \ (x_k, y_k) \in S\}.$$

**Conclusions:**

In our research we have implemented and evaluated two types of segmentation methods. Our results show that using the region-based method combined with the watershed algorithm we can achieve the best results. The preprocessing of the image, according to our results, also valid step in the segmentation process, especially when the input image is affected by the noise.

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# Simple Gossiping in Wrapped Butterflies

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Collective communication operations frequently occur in parallel computing, and their performance often determines the overall running time of application. One of the fundamental communication problems is gossiping (also called total exchange or all-to-all non-personalized communication). Gossiping is the problem in which every processing unit $p$ wants to send the same packet to every other $p$. Said differently, initially each of the $n$ processing units contains an amount of data of size $h$, and finally all processing units know the complete data set of size $n*h$. Gossiping is used in all applications in which the processing units operate autonomously for a while, and then must exchange all gathered data to update their databases. Many aspects of the problem have been investigated for all kinds of interconnection networks [2].

We are considering wrapped butterflies, *wBF*. They form a parametrized class of networks. The $k$-th network has $k*2^k$ nodes of degree 4. The nodes are indexed by two-tuples $(i,j)$, $0 \le i \le 2^k-1$ and $0 \le j \le k-1$. They are connected by straight and cross edges. Straight edges connect nodes $(i,*)$ into $i$ lines. These lines are connected by cross edges. Nodes $(*,j)$ we call rows.

In the telephone communication model, a processing unit can communicate with only one of its neighbors at a time, but it can both send and receive during this communication. In this paper we assume this communication model. We also assume that in one communication round two communicating processing units can exchange all available data. This is called the unit-cost model, which is considered in most theoretical papers on gossiping.

In the unit-cost telephone model we are considering, giving a gossiping schedule of length $l$, amounts to giving a sequence of $l$ matchings: matching $i$ gives the set of edges that are used in communication round $i$. In our case we will work with a small set of matchings $M_i$. To represent a long regular sequence of such matchings, we use the following notation for regular expressions. A term $[x]^k$ means that $x$ is repeated $k$ times. A term $\{xy..\}^k$ means that the regular expression is starting with $x$, is of length $k$, and is composed from $x$ and $y$ which are used alternatingly. A term $\{..xy\}^k$ means that the regular expression is ending with $y$, is of length $k$, and is composed from $x$ and $y$ which are used alternatingly.

Even more, for gossiping we define two following operations: Going-straight down or up means using only straight connections, moving up or down. Distance $x$ is covered in $x$ rounds. Braiding up or down means using alternating using straight and cross edges, moving up or down. A distance $x$ is covered in $2*x$ rounds.

For gossiping in $wBF_k$ we use four matching, covering all edges of $wBF_k$ exactly once. We denote them as follows: $M_0$ contains all edges between $(i,2*j)$ and $(i,2*j+1)$, $M_1$ all edges between $(i,2*j-1)$ and $(i,2*j)$. Hence, together $M_0$ and $M_1$ contain all straight edges. $M_2$ contains all edges between $(i,2*j)$ and $(i+2^i,2*j+1)$, and $(i,2*j+1)$ and $(i+2^i,2*j)$, $M_3$ all edges

between *(i,2*j-1)* and *(i+2^i,2*j)*, and *(i,2*j)* and *(i+2^i,2*j-1)*. Hence, together $M_2$ and $M_3$ contain all cross edges.

Gossiping in $wBF_k$, $k \geq 4$ and is even, can be done in telephone model in *5*k/2-2* rounds using $[M_0M_2M_1M_3]^{k/2-1}M_0M_2M_3\{M_1M_0..\}^{k/2-1}$ that improves result presented in [2].

Wrapped butterfly *wBF* is vertex symmetric network. It is possible to describe gossiping for any node and due to this symmetricity this description holds for every node. Without loss of generality, we describe gossiping for node *(0,0)*. Gossiping starts by braiding using sequences $M_0M_2$ and $M_1M_3$. Each of these sequences doubles number of informed nodes on every next row. After *2*k-2* rounds braiding stops. In this moment matching $M_3$ is used which caused that one complete one row is informed by packet from source node *(0,0)*. More exactly, all nodes at row *(*,k-1)* are informed. Going-straight operation continues. Packet is distributed by matchings $M_1$ and $M_0$ in next *k/2-1* rounds until all nodes are informed. All together we need *2*k-1+1+k/2-1=5*k/2-1* rounds.

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# Neural Networks Used for Target Identification

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This paper discusses a possibility of moving object tracking in the sequence of images acquired from a non-stationary camera. The target can be a moving object or a part of the object. The target shape has not an influence on the tracking algorithm. This camera is held in the hand. This algorithm is developed for proper target detection for hand-carried camera. The aim of the process of image acquisition is to keep the moving object in the central area of the image. In this way we manually prompt the evaluation system to find and consequently tract the object concerned. The algorithm detects the position of the target and the center of the image. If the position of the target and the center of the image is the same, the algorithm reports its detection. The proposed method is based on the stabilization of a shaky image sequence and about finding the mean position of the center of the frame in the scene.
Let us emphasize that we do not know what is the real object we want to track. We do not know how big is the object, or if we track only small part of the large and shape complicated object. Only our human mind knows what we want to track. The only information about the demanded real object (or its part) available for the program is our effort to keep the center of the camera frame over the real object. In this way we prompt the system what area of the picture may be the target. Because of arguments described in previous section we do not find any exactly bordered object but only one point. This point is for us a representant of the target. Of course the point is related to the background picture and to the real object.

The main idea of the target detection follows four steps. At first, stabilize the image sequence (it is possible to calculate the shift between two consecutive images). The second step is to calculate average position of the image center over the stabilized image. Very important step is detection of static and dynamic targets with respect to the image background. The last step is to overlay indication of the image center and the target point
The actual algorithm of RAY1 method runs this way. From the given starting point N rays (line sections) in a fixed angle span are constructed. The object border is detected on each ray. The border of an object is grasped as a step gradient of intensity. The value of the gradient is computed step by step from the starting point along the ray and is immediately compared with the given fixed threshold value. First time the threshold value is exceeded, the process on the ray is stopped and the next ray is processed. The output of the Ray1 method is set of boundary points. It is very simple to calculate gravity centre of these boundary points. The gravity centre point determines the exact position of significant target part. The target doesn't need lie in the significant part of the area. For example we can aim to the head and not to the body. It stands to reason that head is closely connected with the body. But the head is not easily bordered because of eye, mouth etc. There is an idea to fix a target point to the gravity center of the body. Generally, it is a big improvement for tracking exactly to connect the part of target with its significant part. In the principle the target point lies at the end of a constant vector, which starts at the center of the significant part. This enable to track all moves of the target, and aiming will be more accurately.

The ray gradient method of target detection gives in special cases not very precise results. The special cases are for example situations, when the background has the same color as the

tracked object and the object is moved across this background. Another situation is when the quality of the sequence of images is very low especially when there are big differences between consequent frames.
In all this cases the shape of the tracked object is in each frame different. The difference of shapes can be very various. For a big difference mainly in one or two rays the center of gravity is very shifted and the object is incorrectly tracked. This problem can be eliminated when the information about the shape of the target is known. Let us emphasize that the shape is not known and is impossible to choose some predefined shapes. The tracked object can be everything and the searched shape should be corresponded in basic features to the real shape. The problem has significance only if the tracked object is moved. The influence of the background is by shifting eliminated, and is possible to learn the approximate shape of the object.
The main idea how to improve shape approximation during a time is to use filter on the approximated shape. The condition of correct work of the filter is freedom of filtered shapes. It is necessary to learn the shapes. For this seems to be very useful Kohonen's neural network. There is not use the full power of this network, it means the network is used only in learning phase and the learning parameters are constant, by the other words the network is used as a filter.
Network topology comes from the topology of border line founded by RAY1 method. Anyway the topology of the network is a closed chain of six neurons. Each neuron has got two neighbors and its weights are the coordinates of its position. The coordinates are there represented by vector whose reference point is a gravity centre of all neurons. The each neuron is closely connected with one ray. Ray has fixed angel, because of them the coordinate is represented only by the length of the vector.
Learned shape is used in method Ray1. The knowledge about the shape of the target significant part improve quality of the border detection. It works in this way. If the border point is detected, and this border point is far or near of the centre of gravity, founded point is ignored, and border position is replaced by value of neural network. This algorithm brings big improvement of quality of correct shape recognition.
The methods are very resistant to blur, noise images and to the shaky movement of the camera. The target tracking is not dependent on the object shape and size. The algorithm is also color independent.

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# Incremental Parsing Using Faster GLR Parsing

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Generalized LR (GLR) parsing is a fundamental parsing method and is used in Computer Science and Computational Linguistics. Given a grammar parsing takes a sentence as its input and returns the syntactic structure of the sentence, derivation tree, as its output. Standard batch GLR parsing is implemented by a pushdown automaton with two kinds of moves: shifting a symbol onto the stack, and reducing the top of the stack without reading any symbol. The shift reads one symbol from input whereas the reduction closes the parsing of a derivation subtree. The last GLR parsing move is the reduction according to the starting rule, which closes the parsing of the whole derivation tree.

The only possibility how to generate infinite context-free languages is to use a recursion in grammar, which generates sentential forms of the form $\alpha\beta^n\chi\delta^n\gamma$, where both strings $\beta$ and $\delta$ can be pumped $n>=0$ times. This possibility of infinite pumping is the theoretical reason for necessity to analyze context-free languages by pushdown automata (with theoretically infinite stack) instead of finite automata (with only finite number of states), which could handle all other parts of the sentential forms. However, standard (G)LR parsers use the stack for storing all the symbols of the grammar rules. This gap between the theory and the practice has been solved by faster version of batch GLR parsing presented in [1], which performs significantly fewer stack operations – each symbol pushed onto the stack corresponds to such a string $\beta$ that can be pumped infinitely as described above and the stack is not use in any other way. Moreover, all moves corresponding to reductions are precomputed beforehand and the parser reads one symbol on every move. Timings of first implementations show, especially for highly ambiguous grammars, the parser [1] is significantly faster than a standard GLR parser.

In this paper we focus on use of the faster GLR parsing [1] for incremental parsing. Incremental parsing deals with the reparsing process when a sentence *xyz* has been modified to a sentence *xvz*. It can be used in syntax-directed editors or interpreting environments for example. Incremental (G)LR parsers such as [2,4] use strategy in which in the beginning the sentence *xyz* is parsed and its derivation tree is stored. After a change of the sentence *xyz* to *xvz*, the incremental parsers try to reuse as many as possible of previously parsed subtrees without their reparsing. This reuse of the parsed subtrees corresponds to a new operation, which extends the standard LR parser: shifting a nonterminal symbol which is the root of the subtree reused. In this way, using the three operations: shift of a terminal, shift of a nonterminal, and reduction, the incremental parser parses string *xvz* from its first to the last symbol. Faster GLR parsing [1] can be used in a similar way while preserving its advantage over the standard GLR parsing: it is faster.

[3] contains a presentation of an idea of an incremental parser based on the faster GLR parser [1]. Further, this incremental parser differs from parsers [2,4] in that it does not reparse the whole sentence *xvz* with reuse of certain subtrees but it reparses only a prefix of suffix *vz* parsing of which differs from parsing of the corresponding prefix of suffix *yz* in the original sentence *xyz*. Parsing of the rest (already parsed) parts of the sentence, ie. of prefix *x* and of a

suffix of *z*, is reused without any reparsing. For the purpose of such incremental parsing the faster GLR parser is extended with another stack, which contains specific information on the sentential form being parsed. This information, especially the top symbol of this stack, is used so that we could fix the prefix of *vz* which is reparsed during the incremental parsing.

Like other incremental parsers, [2,4] for example, the incremental parser [3] uses memory storage linear to the length of the sentence.

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# Remote Control of a Laboratory Experiment Implemented as a Web Service

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Web services are becoming a standard in application-to-application communication. While they bring a long awaited unification of the programmatic interface between programs on different platforms, they also help programs to spread to new areas of use thus bringing many new possibilities. They allow previously unthinkable solutions to emerge. However, they also bring many new challenges. In the diploma work (Tamáš, 2001), the architecture chosen for Internet control of a laboratory experiment consisted of a client and a server application communicating with each other by means of a standard HTTP protocol running above the Internet protocol (TCP/IP). The experimental setup included a controlled system and a PLC controller connected to a standard PC. The controlled system was represented by a heat chamber with sufficiently slow dynamics to allow the delay of Internet traffic to be neglected. The controlled variable was the temperature inside the heat chamber heated with two bulbs being used as a manipulated heat source.

**Remote control of lab experiments**

Controlling laboratory experiments remotely is not a new concept. It has been tested and implemented many times and the associated initial challenges have mostly been solved. With the recent spread of the Internet, the remote control has become even easier to implement. Using the standard Internet protocols (TCP/IP with HTTP) is in many cases sufficient for a satisfactory. Lab experiments can now be controlled by students from their homes or by a remote control.

The advantages of such remote control are quite obvious. Laboratories accessed remotely (sometimes called virtual labs) provide better accessibility to students (sometimes from different universities cooperating on common experiments) and lower the costs associated with the preparation and maintenance of the experiments. In case of remote access to computer models, expensive hardware and software is not required on the client machines.

However, one of the problems with remotely controlled lab experiments is the fact that proprietary and often-incompatible application layer protocols of the OSI/ISO reference model are used. It is only possible to access such experiments from a given platform using given software programmed during development of such remotely controlled system.

**Remote control of a lab experiment using web services**

With the experiment being designed as a web service, such a problem is overcome as the interface between the lab experiment and the remote party is standardized. Because of the fact that WSDL (Web Services Description Language) allows future changes in the experiment without the previous implementations of the remote access software becoming incompatible, this approach can prove to be very useful. Not only that it allows different client types to access the experiment, but it also allows future changes in the experiment without disabling the operation of the current clients. New functionality can be added to the experiment allowing

new clients to take advantage of it while at the same time allowing old clients to function the way they used to before the change took place.

**Heat chamber experiment**

Experimental setup in lab 111 of Department of Instrumentation and Control Engineering consists of a heat chamber where temperature is controlled locally by a PLC connected to a PC by a RC-232 interface (serial port). The parameters that can be set remotely include not only the set point, but also all the other parameters that can be set on the PLC locally. The server also sends to the client information about a current temperature in the chamber in a predefined time interval. This experiment is used for the students to learn how to tune the PLC as well as to get a feel of what it is like to control temperature in a system of the second degree. However, the use of a given remotely controlled experiment can go beyond the intended aims. Having a standardized application layer interface using web services architecture (XML and WSDL), this system can be used to "simulate" tested behavior on a real system under specified conditions. Rather than running a simulation in Matlab, for example, one could run a test on a real system instead. Because of the fact that the interface between the user and the experiment is standardized, open and fully exposed, students are also free to develop their own clients connecting to the experiment and thus expanding the range of available clients. With limited changes on the server side, access to the experiment can also be made available for mobile devices such as cell phones without the need for the current client software to be updated.

**Safety considerations**

Implementation of the safety precautions is included directly on the server side, therefore no harm can be done to the experiment even if unpredictable behavior of the remotely accessing party takes place or the connection is lost. The communication between the client and the server is build entirely as a web service. This means that the server contains a WSDL file describing the service, it accepts web service requests in the form of XML files and it produces XML files as a response to those requests. The response depends on the type of request. It can be either a temperature in the heat chamber, confirmation of a successful change in the setup of controller parameters, current value of the set point variable, etc. Advantage of this approach is that new functions can be added later on in the future without affecting the function of the current clients.

Implementation of this solution solved not only a problem of scalability of one laboratory experiment, but the experience gained also allowed for progress with another project currently under development at CTU – an operator training simulator.

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# Hardware and Software for Developing and Permanent Actualization of English Textbook for Subject TECHNICAL DOCUMENTATION in Electronical Form

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The aim of the project is to create conditions for production of teaching text for the English version of the subject TECHNICAL DOCUMENTATION in the electronic version. The project belongs, according to the CVUT Statute of internal grant competition, §3 projects supported by IGS to the category D. projects of school function and infrastructure development, point a) projects of pedagogy development– PED (§9 Grants on pedagogy development).

The suggested project further develops the basic intention of the school to deliver a contemporary form of tuition with special respect to a structured tuition being prepared, taking into consideration a more practically oriented bachelor study. It aims to advance the effectiveness of the studies by creating a modern teaching text in electronic form with high number of vivid pictures for the English version of the subject TECHNICAL DOCUMENTATION.

The project wants to make it easier for foreign students, especially those who have not attained any practical experience in the field so far, to understand to the connection between the real objects and their technical representation and thus increase students' motivation for their studies, strengthen their study self-confidence and fellow-feelings regarding the professional field.

The project wants to contribute to a decrease of the proportion of students who, because of not fully understanding the matter, lose contact with the studies, and subsequently try to memorize the text as well as technical representation without fully understanding the technical principle of the phenomenon, thus they happen to are overloaded with the subject studied, get into a state they are not up to manage psychologically and this often leads to a premature leave of the study.

The subject technical documentation, that gives students an insight into norms and patterns used in technical representation, is, according to FEL CVUT curriculum, as a basic preparation subject also included in the English version of the first year of study to equip students with the knowledge, fundamentals and skills of the graphic representation in the extent needed for further advancement of the studies. It is the first practically oriented subject in the studies.

The subject shall first of all acquaint the students with basics of technical representation, teach them to express graphically, draw and read drawings and particularly draw sketches in order to be able to take minutes of the lectures of special subjects during the following years of study and to be able to record technical ideas and designs in their further expert practice, or hold a professional communication with their fellow-workers.

In the introductory phase of study the subject also strongly influences the development of the three-dimensional imagination as well as deepening of responsibility, conscientiousness and curiousness in work and contributes to a higher degree of tidiness and neatness of graphical manifestation.

By the influence of objectively given permanent rising of information in electrotechnics, electronics and computer sciences a gradual increase of the number of specialized subjects at the faculty occurs, and that leads to a tendency to reduce the extent of the existing subjects.

Because of the reasons mentioned above in school year 2000-2001 a further reduction of the subject to only one hour lecture and two hour constructional training a week occur.

Another subject reduction actually came before by implementation of the computer teaching of CAD on personal computers, with the same number of teaching hours. Currently a half of the constructional training is spent on tuition and practical use of the AutoCAD graphic editor.

By the permanent pressure for a continual reducing of the number of the subject tuition hours per week - primarily of the lectures - students are more and more dependent upon individual study. It means a necessity for at least a partial replacement of the decreasing direct contact with lecturer and the lectures where practical demonstrations of technical representation of objects in technical documentation and literature and their real appearance are presented and commented.

With reference to the continual legislative evolution and gradual acceptance of technical European and International standards EN and ISO with worldwide validity and at the same time respecting the changing structure of foreign students, who attend the English version of the subject technical documentation, the problem of English teaching text has so far been solved by the creation of an internal teaching texts with references to the pictures in the Czech textbook. Foreign students have often difficulty with orientation in the teaching text in English with references to pictures in the Czech textbook. Apart from that, the pictures that are sufficient for most of the Czech students are often too little vivid for foreign students, because they have never before been exposed to problems with technical representation.

That is the reason why from the school year 1999 – 2000 the English version of the teaching text has been amended with graphic pictures – again in electronic form. The pictures were mostly modified for a better clearness and some new ones were also created.

With respect to the character of the subject TECHNICAL DOCUMENTATION, where graphic pictures form an integral part of the teaching text, the pictures often account for a bigger part of textbook than the text itself.

The planned final extent assumes approx. 300 - 350 technical pictures, from the simplest, e.g. electrotechnic symbols, to more complicated ones - full assembly drawings of electrical machines, apparatus and electronic equipments.

The resources of the grant were therefore used to purchase the hardware equipment, which gives by its parameters, storage and mainly memory capacity a clear possibility to continue with the creation and continuous update of the teaching text. The existing hardware was modernized and a mobile computer (notebook) was also bought, which in present time is used for the creation of the text and graphic pictures and will be subsequently used for their presentation and verification during the lectures.

The allocated resources were used for the purchase of software, which apart from the creation of the basic text allows creation of vivid, three-dimensional pictures, that clearly support a higher clearness and thereby a better understanding to the relationship between technical picture and the real object. This is the basic objective of the teaching text being created. The parts of the teaching text for the subject TECHNICAL DOCUMENTATION created up to now show that they are a valuable source for foreign students in preparation for practical training, verification of continuous study and final examination. Students are given the parts immediately after their creation, or can access their updated version on the faculty computer network via the presentation pages of the department.

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# Spectral Compatibility of the Digital Subscriber Lines

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**Abstract**
The paper deals with spectral compatibility of digital subscriber lines (xDSL) systems because the application of several different systems in one cable may result in no small complications or even malfunction of some of the systems. The spectral characteristics of digital subscriber line systems are fundamental for their spectral compatibility in access networks. The function of the DSL system is mainly affected by the line attenuation (line length, wire diameter and type of insulation) and by cross-talk (NEXT, FEXT), which constitute the greatest problem of broadband signals.

**Introduction**
The metallic access networks have been recently using a variety of technical means that enable fast data transmission. The whole family of such systems is called xDSL. This category covers especially the following systems: ADSL (Asymmetric Digital Subscriber Line), VDSL (Very high-speed Digital Subscriber Line), HDSL (High-bit-rate Digital Subscriber Line) and other similar ones. xDSL systems have attracted attention mainly because data for high bit-rate digital services can be transmitted to the end user along the same transmission path (metallic lines) as employed in POTS (Telephone). These systems are used in the so-called "last mile", i.e. in the metallic section of the line (of the order of kilometres) between the central office and the end user.

**Coexistence of systems**
On local cables in access networks, systems with different line signals are generally operated. Their spectral character will determine their mutual interference due to cross-talk. The effect of cross-talks from co-existing systems can be divided as follows:

**Interaction of systems of the same type:** Near End Cross-talk (NEXT) is dominant in the transmission in the baseband with the transmission directions separated via echo cancellation (HDSL, SDSL). In the frequency separation of transmission directions only the far end cross-talk (FEXT) is of any substantial effect (ADSL, VDSL).

**Interaction of systems of different types:** Interaction occurs in the frequency band where power spectral densities overlap. Both NEXT and FEXT must be considered in the respective band. The values of cross-talk differ in dependence on the mutual position of pairs. The strongest couplings exist between pairs of the same quad and between pairs of adjacent quads. The weakest couplings exist between pairs in remote subgroups. The selection of pairs with lower cross-talk couplings in cables is becoming problematic and even insoluble with the increase in broadband digital systems. Moreover, deploying xDSL does not mostly mean adding a system on an available line but extending the existing access line, which has its position in the cable.

**Interaction between systems on local cable in the access network**

DSL and ISDN-BRA spectra overlap with the ADSL band up-stream but they do so in the frequency region where there is a comparatively high cross-talk attenuation so that they do not lead to any considerable constraint of the function.

The HDSL spectrum exhibits overlapping with ADSL bands both up-stream and down-stream, in particular in the lower part of the spectrum. To reduce interference, it is possible to go over to second-generation HDSL2 or to SDSL, which have better spectral properties.

The ISDN-PRA spectrum with a bit-rate of 2048 kbit/s and with the HDB3 code is very aggressive and it can be expected to interfere with the ADSL and VDSL systems. It is recommended to change over to HDSL or SDSL, which are able to transfer the 2048 kbit/s data flow in a much narrower frequency band.

With the frequency separation of transmission directions, ADSL interaction is only due to the far end cross-talk (FEXT), which grows considerably with the length of access line and is thus less dangerous than the near end cross-talk (NEXT). Only in the concurrence of standard ADSL access line and ADSL-ISDN (the beginning of ADSL band is shifted) is there partial overlapping of the spectra and thus influence NEXT; the deployment of ADSL-ISDN on a large scale cannot therefore be recommended. If a lower bit-rate is required (up to 1.5 Mbit/s down-stream), it is of advantage to choose the ADSL-lite mode, which occupies half the band in the frequency spectrum.

If VDSL coexists with ADSL systems on the same multi-pair cable, it is opportune to shift the lower cut-off frequency of VDSL band above 1.1 MHz to prevent interference between the systems mentioned.

Apart from cross-talk interference, background noise is considered as white noise uniformly distributed over the whole frequency band with -140 dBm/Hz density, referred to as the Additive White Gaussian Noise (AWGN). The superposition of AWGN, cross-talk interference or radio interference represents total noise, which shows on the input of receivers of xDSL systems. The basic parameter in the analysis of error rate in the transmission of digital signals and obtainable bit-rate is the signal-to-noise ratio (SNR).

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# Measurement and Evaluation of Specific Properties of DVB-T Indoor Reception

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The research within the grant project is focused on the study of some special problems connected with indoor reception of DVB-T signals. This project was designed to propose a theoretical general model for indoor reception quality evaluation and for comparison of this model with practical experiments.

In DVB-T systems there is used modulation named OFDM (Orthogonal Frequency Division Multiplex). The knowledge of signal level estimation is not sufficient enough for the OFDM case. Empiric estimation models are Keenan-Montley model, One-slope model and Direct Path model. Deterministic models for estimation indoor propagation are Ray-launching and Ray-tracing optical ray models and optical wave models. Dominant Path model and XYZ model are semi-deterministic models for indoor propagation. These models are very good for signal level estimation that can be used like the first estimated parameter. The demodulator receives many versions of the signal in multipath propagation, each with different time delays. If the delay is short in comparison with symbol period, then the additional signal may add constructively. The effects will be the same across signal bandwidth. We talk about a flat fade. If the delay is longer that the symbol period then there is constructive and destructive interference at different frequencies across the signal bandwidth. We talk about frequency selective fade. There will be also inter-symbol interference (ISI) when two unrelated symbols are presented at the modulator. Both these problems sometimes add additional redundancy to the signal channel coding.

In OFDM the available bandwidth is partitioned into N subchannels (2k or 8k) that are made orthogonal by using carriers with a spacing equal to the channel symbol rate. A binary data is coded and mapped to a sequence of complex data symbols. These symbols are split into frames. Carriers are modulated by the symbols and modulated carriers are summed before transmission. The loss of orthogonality between the carriers is caused by the dispersive channel and introduces intercarrier and intersymbol interference (ISI and ICI) at the receiver. Each frame is preceded by a guard interval of n samples containing a cyclic prefix. For modeling dispersive channel with this modulation you can use multipath Rayleigh fading channel and wide-sense stationary uncorrelated scattering (WSSUS) model. This model easily describes fading channels and it is valid for most radio channels.

Next partial model serve picture quality evaluation. Decoded picture income to the human visual system model from computer decoder simulation. We can use the quality metrics proposed by Stefan Winkler. These metrics are based on group of models from J. van den Branden Lambrecht.

We obtained basic qualitative information about the properties of receiving DVB-T and about the possibilities for DVB-T signal decoding by several experimentations in selected locations (the spaces in CTU area Dejvice and the spaces in Czech television area in Kavci hory rented by Czech Digital Group). Theoretical general model was proposed for the behaviour estimation for the signal propagation and for the circuits that process this signal.

This theoretical general model consists of four partial components. The first one is model for signal level estimation, next one is WSSUS model. These two models are complementary. Next one is computer simulation of signal decoding and last one is the model for picture quality assessment.

The product from this model is a picture quality in the specific location (in the place of receiving). If we would compare the results from experiments and results from proposed model we must declare that it is necessary to perform a lot of next measurements inside other types of buildings for better statistical predicative capability. It is caused by a large number of variable parameters for signal propagation inside the buildings and by the complicated simulation especially this signal propagation.

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# Intelligent Adaptive Web

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Given the extensive growth of the World Wide Web, the potential is great for user disorientation in such a large knowledge base. Moreover, problem with hypermedia navigation is that it is not specifically designed to differentiate between and to accommodate users with different interests, goals and needs. That is where the adaptive hypermedia systems comes into consideration.

Adaptive hypermedia systems are presently being designed and developed in recognition of the need to provide some system support and control to users. An adaptive hypermedia system aims to provide a solution to the problem of disorientation and the need to accommodate varied users by being capable of searching for and filtering out the information most relevant to the user's needs, goals and interests. Adaptive systems can incorporate domain knowledge (for example about a particular subject area such as mathematics) and knowledge about its users. An adaptive system might provide a different body of information, or a different level of abstraction or treatment based on characteristics such as user's age, language, geographical location or on whether the user is a novice or expert. Thus, such a system attempts to tailor its response to the user's needs. Brusilovsky, which is considered as one of the pioneers of Adaptive Systems, defined it as “all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the system to the user.”

There are two categories of Adaptive Hypermedia (AH) systems, depending on what we want to adapt:

- adaptive presentation or content-level adaptation: what and how to display given pages of information;
- adaptive navigation support or link-level adaptation: how to navigate users to information.

Depending on those categories, there are different techniques, how to achieve the adaptation, namely additional explanations, prerequisite explanations and comparative explanations for content level adaptation and conditional context, strechtext and frame-based technique for link-level adaptation.

For these to be achieved, there is the need of having models of users. These models can be based on different criteria like user’s knowledge goals, his background and experiences or his preferences. These models determines the amount of control that a user can have over the system, the information that have to be display to the user, the way how the user can navigate between these information. However, as the time passes, the users model may need to be changed and updated, that is why the AH systems needs to be intelligent. By intelligent system we mean a system that can learn during its existence. In other words, it senses its environment and redefines the different models of users whenever it is needed.

As it has been shown, AH is one of the promising application areas for user modeling and user-adapted interaction techniques. AH systems can be useful in any situation when the system is expected to be used by people with different goals and knowledge and where the hyperspace is reasonably big. As an illustration, let us imagine the situation in a medical

environment. For example, there can be three groups/models of users: patients, doctors, and insurance companies/agents. Patients normally need to know only what is wrong with them, what kind of disease they have, and they need to be informed in the normal „street language". As for the doctors, they need to know every detail of each disease in scientific terminology. The patient does not need these details, therefore he does not have to see them. The insurance agent can have access to the price of medecines.

A limited number of models or systems have been implemented so far. AH systems have a big potential for teaching and learning. At the same time, the notion of an adaptive system modelled on individual users or even on a class of users makes future exploitation of the web not only for educational purposes look very promising.

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# Electronic Library for Intelligent Transport Systems and Telematics

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Two years ago the new department on the Faculty of transportation was established. The name of the department is Department of control engineering and **telematics.** Transportation telematics and intelligent transportation systems are quickly developing branches, based on utilization of digital, control and communication technologies in transportation. Characteristic feature of these quickly developed branches is lack of available literature. In libraries on CTU and in State Technical Library there are several books and a very small number of journals concerning this problems. There is often a very difficult way for students to find necessary sources for their study and for their individual works.

On the other hand relatively great amount of literature is available on the internet. Young authors especially, very willingly puts their works on web pages to support greater impact factor. The main problem is that the web pages (both personal and institutional) have usually short lifetime. Authors changing their jobs and their personal pages with them, servers expires e.t.c. It is necessary to catch and store necessary information.

Second useful source of new information from this branch are scientific conferences. But proceedings from these conferences are now in their majority in electronic form (CD). It is difficult and with a great risk to borrow them to individual students.

Many universities solved this problem by creating own electronic library, which is accessible for university members only. This solve some legal problems with copyright and conditions of noncommercial utilizing of sources.

This type of library was created for teachers, students and graduated students of Faculty of Transportation Sciences. In initially state this library exists in two versions. The first version which will be mainly utilized by students is located on server of Laboratory of System Reliability (part of Department of control engineering and telematics K602). Here is relatively simple database, simple searchable with key words and author names. All items (papers, reports, thesis, books, electronic sources) are available in fulltext form. They are available either as a file on the disc or as a link on appropriate web page. Files stored on disc are stored on the conditions that we are sure that there will be no legal problems with copyright etc. (e.g. with permission of the author) Links are mainly to institutions with relatively stable servers like universities, governmental research institutes etc.

The second version is stored on specialized computer an it is not accessible by internet. This version utilized professional bibliographical database “Reference manager”, which enables more sofisticated search. The great advantage of this database is a possibility of very effective citation of literature sources and automatic generation of a final bibliography in cooperation

with standard text editors like Word etc. This version of a database, as we suppose, will be utilized mainly by graduated students and teachers. In this version all items are stored in fulltext form like files on local disc, to minimize possibility that the original server diminish. And from the point of view of legal conditions the sources are not published electronically on the web. The main majority of publications from this database is also stored in paper form like the last backup.

The student bibliographical database may be find on the address
http://www.lss.fd.cvut.ce./index.php
It will be utilised in practice for the first time in this year.. Authors are gratefully for all remarks and recommendations.

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Section 4

# ELECTRONICS
# &
# INSTRUMENTATION

# Probe for Aerometrical Devices' Calibration

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The probe is used for calibration of aerometrical devices of newly developed aircrafts in Aero Vodochody. It's dragged below the aeroplane and measures static ($p_{STAT}$) and total ($p_{TOT}$) pressure. Equations (1) and (2) demonstrate a connection between $p_{STAT}$, $p_{TOT}$ and speed (v) and altitude (h) of a flight.

$$p_{TOT} - p_{STAT} = \frac{1}{2}\rho v^2 \left[ Pa, Pa; {kg}/{m^3}, {m}/{s} \right] \qquad (1)$$

$$p_{STAT} = p_0 \cdot \left(1 - 2{,}25 \cdot 10^{-5} \cdot h\right)^{5{,}2553} \left[ Pa; Pa, m \right] \qquad (2)$$

$\rho$.....*density*
$v$.....*speed*
$h$.....*altitude*
$p_0$.....*pressure* at $h = 0$

The probe shall be equipped with pressure sensors. The main purpose of this project is to compare a usability of three kinds of sensors: two sensors of differential pressure, silicon based one (tensometric bridge) and capacitance pressure transducer and one micromechanical resonant sensor of absolute pressure.

There are two possibilities of construction of the probe. The first one is based on using of two sensors of absolute pressure. A difference between $p_{TOT}$ and $p_{STAT}$ would be counted. The result would be burded with high error (addition of two errors of measurement). An advantage of this design is a possibility of using of two similar sensors with two similar support circuits. The second possibility of construction is based on using absolute pressure sensor for $p_{STAT}$ and differential pressure sensor for ($p_{TOT}$ - $p_{STAT}$). A disadvantage of this design is a necessity of development of two different support circuits for sensors. An advantage is higher accuracy of ($p_{TOT}$ - $p_{STAT}$).

The only candidate for $p_{STAT}$-sensor is the micromechanical resonant transducer RPT 100, manufactured by a company Druck Ltd. It can be made only in a form of sensor of absolute pressure. Its function is based on a change of resonant frequency of resonator. This change is caused by mechanical tension induced by measured pressure. Its accuracy and extent are sufficient for altitude from 0 to 25 000 feet of I.S.A (according to international standards for altimeters). Output quantity is a frequency (33 ÷ 37 kHz) so it may be easily digitalized.

As I wrote, the difference ($p_{TOT}$ - $p_{STAT}$) can be measured by two ways. For the firs one RPT 100 could be used too. An accuracy of counted difference ($p_{TOT}$ - $p_{STAT}$) would be sufficient (max. error = 76 Pa, it means ±6 km/h). A disadvantage of this design is high price of RPT 100.

The second way of measurement is based on using differential pressure sensor. Two sensors were put at our disposal: capacitance pressure sensor Vegabar 14 and silicon based transducer with tensometric bridge by a company Druck Ltd. Vegabar is manufactured in a form of block with support circuit. Measured pressure causes a deformation of a membrane, which is one electrode of a capacitor. Its capacitance is therefore proportional to the pressure. An output is DC current (after processing by support circuits). Its extent and accuracy are sufficient for speed from 60 to 450 km/h (according to standards for calibrated air speed). Druck is a simple sensor (without support circuits). It consists of silicon membrane with four tensiometers connected to a bridge. Measured pressure causes a change of their resistance. Support circuits described in [1] were used. An output of this transducer is DC voltage. Its extent and accuracy allow using this sensor for speed from 600 km/h to 700 km/h (without a correction of temperature influence) or from 230 km/h to 700 km/h (with the correction).

**Conclusion**

The silicon-based sensor Druck is unusable for this purpose. Its temperature sensibility is too high. The transducer Vegabar seems to by usable. Unfortunately, its extent is too small. It can be used only for slow airplanes (e.g. UltraLights). The design with two RPT 100 seems to be the best. A disadvantage of this design is a cost of RPT 100.

In a view of an output signal, RPT 100 is the best choice too. Its output signal can be simply carried from the probe to the airplane and digitalized.

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# Formation of atmospheric aerosol from gaseous products of fossil fuel combustion: Nucleation of acid - water droplets

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Shock tube experiments are one of the favorite ways of investigation of condensation and two-phase processes. The shock tube method for condensation study is experimentally used since 1969. The main advantages of shock tube experiments are small consumption of experimental mixture, high super saturation rates, easily changeable experimental condition, short experimental time – adiabatic process and theoretically well-known temperature and pressure dependence in the shock tube. Pressure can accurately be measured by means of piezo-electric transducers. The temporal course of condensation is determined with an optical method based on the Mie light scattering and extinction measurement. For determination of droplet size dispersion course an inversion method to the measured data is employed.

The experimental shock tube in the Institute of Thermomechanics is designed for measuring condensation in mixtures of aggressive vapors with in the background gases. The shock tube is divided into two sections – the high-pressure section and the low-pressure section. Both sections are separated with a diaphragm. The low-pressure section is equipped with a local widening, which generates the so-called nucleation pulse. The high-pressure section is filled with the experimental mixture with desired pressure and temperature. The low-pressure section is filled with a dry background gas. After penetrating the diaphragm between both sections an expansion occurred and vapor in the experimental mixture begins to condense.

The duration of the condensation process is limited by returning of the reflected shock wave to the experimental section. In order to maximize the time of the condensation measurement, the experimental section is located close to the end of the high-pressure section. The experimental time is limited to about 37ms.

My contribution within the grant project was to design and construct an experimental apparatus for optical measurement to determine number of droplets and their size distribution as a function of time. These data is needed to determine nucleation and growth rates of droplets.

The optical method is based on Mie's (1908) theory of light scattering and it combines measurement of extinction on four wavelengths with constant-angle Mie scattering method by Wagner (1985).

The scattered light intensity computed on bases of Mie theory, appears like character of maxims and minims series, which are function of droplet radius. The best peak resolution occurs for the 90° scattered light measurement if the droplet radii dispersion is small. For broad size distribution function the peaks begins to overlap and droplet radii can not be distinguish. This effect is not so significant for smaller scattered light angles.

For determination of the size distribution function an inversion method was used. It is based on measuring of extinction coefficient $\beta_i$ at $n$ different wavelengths, and empirical finding size distribution function, that satisfise measured extinction coefficients. The best trial function for shock tube

experiments was described by (Walters 1980) as the well-known zeros-order lognormal distribution function. The method of minimizing the sum of squares of the deviations of the observed and theoretical extinction coefficient was used in order to find the best parameters of the unknown size distribution function.

The experimental optical set-up uses polychromatic linearly polarized collimated light source based on the Hg arc lamp. 90° scattering light measurements are done with photomultiplier with changeable measured wavelength. Extinction measurements are measured with photodiodes at four different wavelengths from UV to near IR. This measurement range decreases the number of measured wavelength required for inversion method solution. The extinction measurement is complemented with extinction and 15° scattering light measurement at 675 nm for determination of broad size distribution function. It appears as disappearing of scattered light peaks in measurement to 90° because it overlaps.

The design parameters of the experimental set-up were successfully verified after the manufacturing and competitions. The whole optical set-up is ready to use now.

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# Aircraft Aerometric System

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Time of aerometrical devices with aneroid boxes is over. At the present time aneroid boxes are used only for low-end category of devices, determined for small aircraft. These sensors are used for back-up device as well. The aneroid boxes are manufactured easily by common technology. Their disadvantages are wide dispersion of parameters, low sensitivity and big temperature dependence.

Progressive trend of modern devices is using transducers of a pressure to an electrical signal and signal processing by a microprocessor. The highest requirements of the pressure transducers are a low uncertainty, repeatability of a value and long time stability. Required pressure range of the transducers for barometrical altimeters is from 10 to 105 kPa. The highest requirement to precision of a pressure measurement is for lowest altitudes. For an altitude –1000 feet is maximal uncertainty 0.072 % of full range with respect of maximal possible error. For an altitude 35000 feet is maximal uncertainty only 0.2% of full range. This fact determines the maximal uncertainty of transducers better than 0.07% of full range 105 kPa.

Common used transducers for airborne aerometrical systems are transducers of pressure to a frequency of an electrical signal. These transducers have a high sensitivity and precision. Their advantage is a frequency as carrier of information, which is very simply to processing by digital circuits. At the present time are common used silicon micro-mechanical resonant transducers. Typical member of such transducers is RPT 100, produced by Druck Ltd. This sensor can sense a static air pressure with accuracy 0.01% of full scale. Big disadvantage of this type of the resonant sensors is high price, which exceed 1000 pound. This fact makes difficult using of these transducers for airborne instruments of low-end category, where the sensor price exceeds 60% introductory price of a complete device with an aneroid boxes.

There is an effort of use piezoresistive transducers for this category of airborne instruments. Advantage of this type of transducers is relatively low price. The precision of better transducers comes from 0.5% to 0.1% of full scale. This value is too high for airborne applications. The most relevant influence to this value is made by typical properties, which are big and non-linear temperature dependence, high offset of an output voltage, big drift of an offset with a temperature and the high temperature hysteresis. The most of these properties can by easy compensate. One of conditions for lowest uncertainty of an output signal is a precision supply voltage. This DC voltage has lower resistance to disturbing influence than the frequency, which is used by the resonant transducers. A DC voltage is heavily treatable with given precision by the digital circuits than the frequency.

This article is oriented to possibility of increasing of precision the piezoresistive pressure transducers by proper data processing. For this aim was chose a piezoresistive sensor of an absolute air pressure MPX2102AP, made by Motorola. The sensor is powered from a precision voltage source of 10.000V, stabilised by a precision voltage reference.. This sensor can sense an absolute air pressure in range form 0 to 102kPa, with sensitivity 0.4mV for kPa. Little disadvantages of this sensor are a temperature hysteresis ± 0.3%, a pressure hysteresis ± 0.1% and a non-linearity ± 1%. This sensor has a big temperature dependence of an output

voltage too. Therefore the sensor has a massive coat, the reaction to the temperature change is very fast. Great advantage of this sensors type is not requirement of an extern temperature sensor for the temperature compensation. If it is powered by a current source, the sensor supply voltage is depending on a sensor temperature, without dependence on a measured pressure. The sensor output voltage is function of an air pressure and a temperature with equal influence. Since I chose a voltage power, the sensor temperature is sensing from a sensor supply current.

At this sensor was executed several measuring series for check its parameters. Verification of a temperature hysteresis was executed at temperature range from –30°C to +50°C and an altitude range from –1000 feet to 35000 feet. There was measure dependence of the output voltage on an air pressure at temperature range from –30°C to + 50°C. From these characteristics is clear the catalog's parameters are observed. Bad it is important increase these parameters for using this sensor in the airborne applications, especially in an altimeter.

Methods of compensation of the non-linearity and the temperature dependence are known already, so I didn't deal with them in this article. Therefore the temperature hysteresis of piezoresistive sensors is low, the value 0.1% is too high for selected application. Bad if this sensor is operated in lower range, especially at range from –1000 feet to 20000 feet, the pressure hysteresis is extremely lower. This value is sufficient for a selected purpose.

The temperature hysteresis is a parasitic phenomenon adversely affects an accuracy of sensor. It can by partially eliminated by tempering to a highest working temperature. This method has very slow lead-in toa working state and the effect of hysteresis cannot be fully removed. From the measured characteristics was recognized non-dependence of the temperature hysteresis on the measured air pressure. The temperature hysteresis affects the output voltage of sensor, but a similar effect was recognized on a power supply current, which is depending on the sensor temperature. The temperature hysteresis of supply current is proportional to temperature hysteresis of the output voltage. This property can by used for additional hysteresis compensation, if the real sensor temperature is measured by an extern precision temperature sensor. From known real temperature and the sensor, current can by compute the value of the temperature hysteresis. The extern sensor is needed, because the proportionality between the real temperature and the temperature indicated form the sensor supply current is non-linear. From these two temperatures can by computed a correction of the dependence of the sensor output voltage on the measured pressure.

The methods of adjustments the accuracy of the piezoresistive sensor's precision can reduce the maximal uncertainty of the output signal to the required value. The sensor with these compensations can by used in low-end category of an airborne altimeters. The devices with this sensor probably will be qualified to operation in an allowable error range, given in directives by FAA and JAR.

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# Signals for ADC Modules Dynamic Testing

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Dynamic testing of analog to digital converters, more generally AD devices, sustain mainly in THD (total harmonic distortion) and SINAD (signal to noise with added distortion) evaluation, best sine fit test and histogram test. These test methods are standardized in IEEE Std. 1057 [1] and IEEE Std.1241 [2]. All motioned tests require sine wave signal pure of harmonic distortion and noise. Common commercially produced generators (such as Agilent 33250A) have a good short-term frequency stability, but their THD level is not sufficient for precise testing. Other generators' signals such as Stanford Research System DS360 do have sufficient noise levels and THD, but their frequency range ends at 200 kHz. This leads us to get developed RC based sine wave generators (at 500 kHz, 1 and 2 MHz), which have higher THD levels, lower noise. However, their weaknesses are in frequency instabilities and very high temperature dependency.

All these problems forced us to the decision to develop a chamber with constant temperature, where the generators and filters could be placed. The inner space of this chamber has dimensions of 116 x 182 x 210 mm. As a heat reflector copper shielding was chosen. This layer is surrounded by temperature isolating material. Between copper and isolation layer is placed heating, which function is controlled by electronic, situated outside of controlled space. Front side of this device is made of pure glass, so inner space could be easily inspected. A space for signal lines is placed in rear right corner and it is made such a way, that lines could be easily replaced. Measured characteristic of temperature stabilities of inner space resulted as change of inner space temperature of 0.04 $^{O}$C while changing outside temperature by 20 $^{O}$C within ½ hour. Measured characteristic will be presented at poster. The supply voltage for heating is 12 V DC.

Another issue is the measurement of signal parameters. Good signal generator, such as SRS DS 360, have better signal to noise ratio (SINAD above about 100 dB) then evaluating devices (SINAD usually about 60-80 dB). We use VXI digitizer Hewlett Packard E1430A (sampling at 10 MSa/s with resolution 23 bit} with adequate controller (HP E8491A with maximum sample size at 8 MB) and software [3], or AD transfer standard (with the possibility to use different AD converters) or lock-in amplifiers from Stanford Research Systems (SR 844RF working at frequencies 25 kHz to 200 MHz and SR 830DSP working at frequencies 1 mHz to 102 kHz) for these purposes. These devices are capable of measuring signal at levels max. 60 up to 100 dB below main signal, so when the actual noise levels are at 120 dB, there is no other option then deterministically suppress the main signal by a notch filter. For some task it is suitable to use combination of notch filter and band pass filters together to lower both levels of main harmonic to be able to measure the signal, and band pass to lower noise and clear the signal of higher harmonics. It is question of different task when to use active and when passive filters. Previously mentioned problems are in more details discussed for example in [4]. Both types of filters are temperature dependent too, so inner

space of previously mentioned chamber is designed such a way both generator and filters could be placed in together.

Standalone question is the signal transmission path. Normally signals are processed as unbalanced, trough standard 50 Ω coaxial cables (signal line connected to inner line and common line to shielding). New filters and interfaces' design allows performing so-called balanced measurements (using standard 50 Ω coaxial cables or synch ended shielded cables). In this configuration, signal is connected to inner line of first cable and common line to inner line of second cable. Shielding of both cables is connected together and also optionally to shielding or cases of generators and/or digitizers. This design allows experimenting with the shielding in order to get the best noiseless signals.

As the conclusion we could state that the developed temperature stabilizing chamber allows us to use RC based generator and active notch and band pass filters in full scale with the achievement of lower frequency and voltage instabilities. Newly developed notch filters allow the measurement of signal and device parameters at different frequencies.

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# Modern Methods of Vector Measurements

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## Introduction

The paper deals with a sort of promising methods that make microwave vector measurements less expensive. Their common feature is that hardware part of the measurement system is as simple as possible while moving the complexity of the problem to the software.

The term "vector measurement" suggests that the scope of the measurement is to get an information consisting of two components (e.g. magnitude and phase) as opposite to scalar measurements. Device under test (DUT) described by means of its complex *N*-port parameters then represents a corner stone of any computer-aided design of microwave circuits.

The problem becomes complex when moving towards higher frequencies. In particular, phase is much more difficult to obtain than magnitude. Apart from manually operated instruments, automatic vector network analyzer (ANA) became the most widely used instruments capable to get such an information. Based on heterodyne receiver, they give the user unbeatable performance. However, their superiority is outweighted by their price.

## New methods

Since 1970s, researchers have been developing novel methods of vector measurements that completely absent frequency conversion. It can be compared to a receiver with direct detection. While the "classic" ANA gives phase information by itself, the use of the new methods requires extensive calculations. Thus, computer becomes a necessary part of the equipment.

Two distinct groups exist: multiport reflectometers (MPR) and multistate reflectometers (MSR). The word "reflectometer" shall suggest a similarity with the original meaning of the word, that is an instrument consisting of a coupler and two detectors that is used to measure magnitudes of forward and backward waves on a transmission line. In order to get vector information, other detectors must be added (multiport type), or the coupler must be changed into a more general resettable (multistate) linear network.

## Multistate reflectometers

Most of the literature dealing with reflectometers analyzes the multiport version. However, it seems to be less suitable at high frequencies, particularly at millimetre-wave and optical, especially because of higher power demands. On the other hand, the idea to enhance scalar network analyzer by means of a simple variable two-port thus forming a multistate reflectometer [1] makes the other group really attractive for a wide group of researchs. For more interested readers, [2] can be recommended as a classical paper on the multistates.

Reflectometers of the latter type have been studied at the Department of EM field FEE CTU for more than seven years. It started with the simplest structure published in [1]. However, this paper reports on another instrument of this kind developed by the team.

It is a computer-controlled standalone instrument with integrated generator that aims to:

- achieve low cost,
- test various calibration methods appearing in the literature or developed by ourselves,
- verify wideband performance of one particular linear network,
- present the topic to the students,
- help PhD students to get access to vector measurements.

The instrument consists of the following blocks:

- synthesized continuous-wave generator in the frequency range of 1.0÷2.1 GHz,
- bank of electronically interchangeable low-pass filters to improve spectral purity of the signal,
- resistive bridge circuit with attached diode detectors,
- two-state 45-degree differential phase shifter,
- power calibrator.

To form a complete measurement system, an ordinary personal computer is required. It controls the instrument and processes measured raw data.

A typical measurement session consists of two steps. First, calibration is performed. Our system requires two procedures to be done: nonlinear transfer characteristics of the detectors are found by using the internal calibrator with precise output power level, while to determine parameters of the linear network requires the use of impedance standards (hereby called simply standards) connected in sequence to the DUT port. When the calibration is completed, the system is ready to start the measurement.

The most difficult step is the impedance calibration. From hardware point of view, it requires typically six distinct standards for one-port measurements, which is not every time easy to achieve. Then, raw data is processed to obtain parameters of the linear network, one set for each setting (in our case, for each state of the phase shifter). However, a set of nonlinear equations arises with no explicit solution.

**The results**

Preliminary measurements demonstrate good agreement between expected and achieved parameters of the individual building blocks of the instrument. To test performance of the whole system, we need to perform more complex tests in conjunction with applying the appropriate calibration method(s). Our intention is to demonstrate concrete results during poster session of the conference.

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# Development of the GMI Permalloy Sensor and its Practical Aplications

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A magnetic field sensor based on Giant Magneto-Impedance effect in Permalloy material and a simple magnetometer was developed. The response of the GMI material to magnetic field is unipolar and thus the working point must be shifted by a biasing field to the linear part of the characteristic that makes bipolar response possible. Achieved parameters of the developed magnetometer comprise offset stability of 0.2 μT and resolution of 200 nT. Both DC and AC biasing was implemented and tested. AC biasing brings improvement of linearity error to 1.3 % in +/- 60 μT range.

While the most frequently used materials for construction of Giant Magnetoimpedance sensors are the amorphous wires [1], it was recently re-discovered that cheaper materials as Molybdenum-based Permalloy wires [2] or strips [3] can also be used. A prototype of GMI sensor was developed using Permalloy material supplied by Kovohutě Rokycany. Two strips made of 0.06 mm thick tape of PY 79M material, 3 mm wide, 20 cm long, were cut and then conventionally annealed in dry hydrogen atmosphere to achieve good soft magnetic properties. The characteristics of the material were measured using a precise LCR meter HP 4285A up to frequency of 1 MHz. Rather flat maximum of GMI sensitivity exists for frequencies of 200-300 kHz. There is only weak dependence of GMI sensitivity (usually defined as ratio of impedance change to the saturation field impedance) on the level of measurement current (tested up to 20 mA). A prototype of GMI sensor was constructed [4], using two strips mechanically in parallel and connected electrically in series. Both strips were equipped with bias windings (providing fields of 0.25 mT in opposite directions shifting the working points). Voltage drops on both strips that correspond to the material impedance (and thus to magnetic field) are processed by differential amplifiers and then by synchronous detector.

Firstly, a simple magnetometer (with squarewave excitation current 100 kHz / 10 mA rms) was tested. A HEXFET switch bridge controlled by a PIC microprocessor was used for driving the sensor. The parameters comprised linearity of 9.5 % in the +/- 80 mT range. The magnetometer resolution was 200 nT and zero stability was 1 mT.

An effort was aimed at improving these parameters and some design optimization led to better results. The offset stability of 0.2 mT and linearity of 5.3 % in the +/- 80 mT range has been achieved. The linearity is better in the +/- 60 mT range (3.3 %), since the non-linearity of the characteristic is pronounced only for higher fields.

Further development was aimed at implementation and testing of AC biasing. While in the normal (static) mode of operation the bias coils wound around the two strips are supplied with DC bias current, in the AC mode the current is squarewave and the polarity of the bias field changes periodically. The frequency of AC bias field is 250 Hz, the amplitude is the same as for DC bias.

The signal processing is slightly more complicated in the latter case, since the synchronous detector must accommodate also the changing polarity of the bias and not only the polarity of pre-processed signal.

Some parameters - like linearity - were improved by AC biasing. In the range up to +/- 60 μT, the linearity was improved from 3.3 % for DC bias to 1.3 % for AC bias. However, for the range +/- 80 μT, the improvement is negligible (the nonlinearity is pronounced for higher field values mainly due to hysteresis).

Temperature testing of the sensor was performed for the offset (in cooled/heated magnetic shielding) and for the sensitivity (in Helmholtz coils). The main problem is the large variation of impedance (and thus sensitivity) due to temperature dependence of resistivity typical for metals. Another problem of the current design is the unsatisfactory robustness and stiffness of the mechanical parts (coils, GMI strips).

Further development will be focused on improving the temperature stability of the sensor and also on comparison measurement with other types of GMI materials. Newly developed automated system for magnetic measurements with computer-controlled equipment will be used to characterize the properties of the materials and sensors in detail.

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# Speech Enhancement for Impaired People

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The speech enhancement for hearing impaired people is a wide area with many particular problems. The problems caused by the special demands of the final users – like for example the requirements on portability, minimisation of the hardware solution, long life power supply, no directional reception of the user or the impossibility of the standard co-operation of the system designer and the end-user are, broaden out the standard set of the problems associated with speech enhancement in noisy environment.

The work presented here tries to solve some problems of the area mentioned above using the multi-channel speech enhancement systems. The selected problems are: the problem of no directional reception of a patient, the problem of strong dependency of speech enhancement performance on noise type and the problem of subject reception tests. The restrictions given by portability and hardware solution are considered.

Some of the requirements are obviously incompatible so that it is necessary to divide the problem solution to several separated parts:

- Analysis of existing speech enhancement algorithms and selection of the algorithm convenient for next modifications.
- Modification of the selected algorithms in order to reach high noise reduction level as well as high directivity level and respecting the hardware restrictions.
- Analysis of the possibilities of the modification leading to the independence of the system features on the noise character.
- Proposal of the objective criteria of the system performance leading to minimisation of the necessity of the complicated subjective reception tests.
- Proposition and compilation of a test signals database used for testing and evaluating of the multi-channel speech enhancement systems.

The listed problems were solved separately:

Analysis of the multi-channel speech enhancement systems including the delay and sum beamformer (DAS), the superdirectivity array (SA), the beamformer with adaptive post-filtration (BAP), the generalised sidelobe canceler (GSC), linearly constrained beamformer with adaptive constraint values (LCB) and coherence filter (CF) was completed. The noise reduction (NR), speech distortion (SD) and directivity index (DI) were used as objective criteria to compare these structures. The SA, LCB and CF structures were selected as perspective structures to next work.

The new systems – combination of the SA and the CF and modification of the LBC using the CF, were proposed. The system based on combination of the superdirectivity array and the coherence filter was proposed to rise the directivity index and the noise reduction of the speech enhancement system with small number of channels. Acceptable parameters of computational load enable hardware implementation to the hearing impaired people aids. The system based on modification of the linearly constrained beamformer with adaptive constraint values by the coherence filter brings higher independence of the noise reduction preserving signal distortion and directivity index. Disadvantage of this system is higher computational load which complicates the hardware implementation.

The objective criteria used to compare existing systems and to design new systems – NR, SD and DI do not report the subjective end-user impression of the system performance. The subjective reception criteria are usually used to express this characteristics. The problems with the subjective reception tests realisation appear since there is not possibility of the realisation of the statistically valuable number of the tests with hearing impaired peoples. Also there is not necessity of correlation between the tests results realised with group of well hearing peoples and with hearing impaired peoples. The objective criterion based on the monitoring of the speech processor stimuli outputs changes dependence of coding strategy on the input noise level was proposed to solve this problem. This criterion seems to be correlated with the subjective reception tests so that the necessity of the test is minimised in case of testing new algorithms. The criterion and the formerly mentioned criteria will be used to evaluate the proposed system and to compare them with existing systems.

The evaluation of the existing as well as the proposed systems would be impossible without the existence of test signals database. Since the tested systems are multi-channel algorithms for usage in various environment, the database must contain synchronous multi-channel signals recorded in common used environments as for example public traffic, streets or offices are. The special requirements for recording of the database signals were fulfilled by construction of the portable four-channels recording system. This system enables the recording of suitable four channels signals which can be used to testing of the mentioned systems.

This work was realised as a part of the doctoral studies at Department of Circuit Theory, Faculty of Electrical Engineering, Czech Technical University in Prague. The authors are members of the Biological Signal Laboratory.

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# Capillary Discharge Circuit Optimization

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Our goal is to find out the optimum conditions for the lasing effect in polyacetal ablative capillary discharge. We performed the computer modeling consisted of three steps: electrical circuit modeling, magneto-hydrodynamic plasma description and ion kinetics evaluation. The criterial parameter is the gain factor of $C^{5+}$ ion α-Balmer transition. We intend to explain the impact of electric current pulse shape on the plasma behavior and to design optimized capillary discharge circuit.

We evaluate the current pulse-passing trough capillary via solution of Kirchhoffs´ equations for double resonant circuit [1]. The feeding capacitor $C_1$ is a part of the first loop and the capillary is placed in the second loop. Both loops have common capacitor $C_2$ that is not initially charged. The current pulse passing through the capillary may be modified by variations of $L_1$, $C_1$, R, $L_2$, and $C_2$ circuit parameters. The resulting current shape may be fitted by the formula:

$$I(t) = I_1 \sin(\frac{\pi t}{2t_1}) \exp(-\frac{t}{t_2}) + I_2 \frac{t_3}{t_1} \sin(\frac{\pi t}{2t_3}) \exp(-\frac{t}{t_4}),$$

where $I_1$, $I_2$, $t_1$, $t_2$, $t_3$, $t_4$ are the fitted parameters.

This formula is compatible with the input form of the driving current pulse shape *I(t)* applied to the MHD code [2]. This code provides radial and time dependences of plasma electron density $N_e$ and temperature $T_e$. In the subsequent step the time dependences of ionization fractions and energy level populations for lithium-, helium- and hydrogen-like carbon and oxygen ions are evaluated by means of postprocessor code FLY [3]. The gain factor is than simply evaluated if populations of selected $C^{5+}$ ion laser levels are known.

The elementary process of collisional recombination pumping involves fully striped carbon ions and two electrons. Thus the discharge plasma should contain high concentration of fully strip ions $C^{6+}$. This means that the discharge plasma should be initially heated up to $T_e^{max}$ > 150 eV. In the same time the efficient three-body recombination pumping requires temperature $T_e^{low} < 30 \div 40$ eV. The discharge electron plasma cooling should be quicker than the ionization relaxation processes. For this reasons the ideal current pulse should have high peak value and suficiently high FWHM, but abruptly falling down back edge.

We have studied in detail the dynamics of the circuit with parasitic inductances $L_1$ = 55 nH, $L_2$ = 50 nH, resistance R = 1 Ω and with variable capacitances $C_1$, $C_2$ presuming that the capacitor $C_1$ is initially charged to $U_0 \leq 60$ kV. In the case $U_0$ = 60 kV, $C_1$ = 8 nF and $C_2$ = 4.8 nF the quasi-half period of the signal is substantially longer than first current peak duration. In such a case the first current maximum of 18 kA is achieved at 48 ns. Proper approximation corresponds to $I_1 = I_2$ = 15.97 kA, $t_1$ = 2 $t_3$ = 42.5 ns, $t_2 = t_4$ = 200 ns, if the time axis is shifted by 21 ns. The first maximum of the approximated current curve is found at 27 ns of the new time scale. If this current pulse passes through the polyacetal capillary with 1.1 mm diameter initially filled by 200 Pa of residual gas then the rapid pinch occurs. The MHD simulation gives us information about radial and time dependences of plasma parameters, namely, compression

ratio, electron temperature and density. If we pursue the plasma development on the axis only, we can see that first peak of plasma volume density, caused by pinch effect, is formed at 30 ns. The peak value of plasma electron temperature $T_e^{max}$ = 460 eV at 21 ns and precedes the maximum plasma compression. In the following period the plasma is cooled due to both pinch decay and input of cold plasma ablated from the wall. The axial plasma temperature $T_e$ becomes < 40 eV at 80 ns. At the same time the value of electron density $N_e = 3.10^{18}$ cm$^{-3}$.

The peak value of electron temperature $T_e^{max}$ decreases remarkably if the initial gas pressure is increased, e.g. for $p_0$ = 1.33 kPa, resulting $T_e^{max}$ = 137 eV. And, according to the FLY code prevailing concentration of $C^{6+}$ on the time interval 35 ÷ 80 ns is calculated. The inversion population on $C^{5+}$ α-Balmer transition is achieved during a long time interval started from 70 up to 120 ns. The resulting peak value of the gain factor $g$ = 0.119 cm$^{-1}$ is achieved at the time about 96 ns. For higher initial pressures ($p_0$ > 1.33 kPa) the temperature peak values $T_e^{max}$ are not high enough to create necessary concentration of $C^{6+}$ ions and the resulted gain factor is substantially reduced.

Further increase of the gain factor may be achieved by the increase of the charging voltage, further modeling taking into account variations of capillary diameter and initial pressure is needed.

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# Multimedia Text Book

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We are developing a new tool which is helpful for both teaching and learning. It is a special material on the Web which may be used by a teacher when lecturing in a classroom equipped with a data projector, as well as by students when preparing for class at home. This Textbook may be accessed via the Internet or may be distributed on CD ROMs.

We started to create a multimedia textbook for a course on Laser Systems, which is a requirement for the Bachelor's degree in Laser Technology and Optoelectronics and an elective course for the Master's degree in Physical Electronics at CTU, FNSPE. We developed a special environment based on dynamic HTML 4.0, Java Skript and JAVA. Every chapter or paragraph of the textbook is accompanied by a concise (encyclopedic) title explanation which provides a quick reference that is useful for beginners and managers. Some chapters include sample exam questions. Any picture placed in the text may be enlarged when it is clicked. This feature is useful for full screen projection when teaching in a classroom. Beside static pictures there are also short interactive movies (flashes), which are used for explaining dynamic effects. Each chapter contains "clickable" references to other parts of the textbook as well as to external web sources. The contents of the textbook, index and lists of pictures, movies, tables and equations may be listed in a stand-alone frame of the textbook screen; links are also "clickable", i.e. each item can be found and displayed.

The Multimedia Textbook environment is client-side application, which should run on any Internet browser which supports frames, such as JavaScript and Java Virtual Machine. The main user interface is managed by applet (class: prostredi.gui.Titulek) which launches HTML coding of the Textbook. In creating a new material, the "Titulek" first reads and prepares the Textbook structure and its own style (color scheme, placement of interactive elements), using files in a specified directory. Then "Titulek" displays the content of the Textbook and waits for user actions. In each Textbook one can use an unlimited number of applets that displays the structure of the Textbook (e.g. one for navigation, another for the list of contents). All applets are united by one static object (class: prostredi.mozek.MozekSkript) which holds the whole structure of the Textbook (class: prostredi.struktura.Struktura). Communication between applet and the Internet viewer (e.g. loading html pages, processing user actions in main frame, numbering of images, tables, equations) is managed by JavaScript code that is placed in a single file named "funkce.html". The author of the Textbook content can prompt selected actions (e.g. inserting an image, creating a link to another place of the Textbook, adding items to the index, making references to the bibliography) by inserting simple fragments of JavaScript code into an already prepared document.

Preparation of a textbook in this form is time consuming and needs tight cooperation between the technical writer and the web administrator. We wrote the first part of the textbook during the year 2001 with support of a grant from Higher Education Development Fund [1]. We realized that our program environment may be used also to prepare other textbooks for other courses (on other subjects). For this purpose some guiding material for a teacher as well as for an administrator are needed. Consequently, we set the following goals last year:

- Extending and updating the Textbook for a course on Laser Systems.
- Creating a guide for administrators who would be facilitating further development of Text Books of this type.

- Preparing the program environment and creating a guide for textbook writers (teachers) who would be producing new texts, pictures and movies.
- Creating a quick reference manual for users (students).
- Inception of a Textbook for a course on Laser Spectroscopy.

All our results may be viewed at the Internet address http://space.fjfi.cvut.cz/web/vrbova/. We present three textbooks in Czech entitled *Laserové systémy, Příručky pro tvorbu skript* and *Laserové spektroskopie.* All of them are written in the same multimedia environment. The HTML pages were created by means of the Front Page; the pictures were drawn by Corel Draw, and the movies by Macromedia Flash MX.

The first textbook was tested in a course on Laser Systems in the summer semester of the academic year 2001-2002. Presentation of the full screen pictures and movies (flashes) was well received by students. Individual tasks based on Internet search were assigned to students. Some of them worked out proper HTML pages and their pages have been included in this textbook. All the advantages of Web pages are used The textbook may be continuously developed and improved; student solutions of exercises may be easily added; links to laser producer addresses may be used and easily updated.

The second textbook consists of guide books for web administrators, professional writers, and student users. The book has just been finished and its testing is planned for next year. Students will be asked to create HTML pages compatible with the textbook as their individual projects. The Web administrator's guide is divided into two sections. The first section "Běžná údržba" (Usual Maintenance) describes how to create another copy of Textbook environment without detailed understanding of the JAVA language. The second section "Programování" (Programming) describes all implemented classes. As for the Writer's guide, the first section ("Návrh struktury" (Designing of structure)) describes how to define the structure of a new textbook (*.toc), to prepare the bibliography (*.lit), and to manage the index file (*.tof). The second section "Psaní textů" (Writing of texts) contains a list of JavaScript fragments which can be used when designing textbook pages. The reader's guide explains the textbook environment capability: how to display full screen images, change actual chapter, and showing bibliographical links).

Writing of the third textbook has been started recently. The first trial for teaching is expected in the winter semester of the academic year 2003-2004 when three themes will be completed.

We believe that our Multimedia Textbook is unique compared to a laser web [2] which is thematically very similar, but relates only to laser physics. The well-known WebCT [3] is a well-developed program-package which has quite a different structure and is more suitable for distance-learning than for reading lectures. We intend to extend our type of textbooks to other topics and subjects and to develop the program environment further by adding other features such as full text word retrieval.

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# MP-SENS: Multipurpose Photonic Sensor System

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In the last years, systems of automatic monitoring, control, decision making, warning, etc., have become one of the most quickly developing areas of the modern technology. With its increasing complexity, more and more authority had to be dedicated to lower structural levels of technological systems, since an increasing data flow necessary for the proper function has to be evaluated. The core control part of recent technological systems constitutes some type of an artificial 'intelligence' unit – usually electronic processing unit, reducing and evaluating the incoming data and communicating with the higher levels of the control system.

The complementary part of any automatic control system is the sub-system of data collection composed of various sensor units attached to data transmission links. Depending on the particular application demands, recent sensors utilise enormous number of transducer principles [1]. With the progress in photonic technologies, still growing part of sensor system is built up on optical principles. They are applied both in construction of transducers and transmission of data. Besides the well known advantages of high communication speed and capacity, the optical sensors can also provide detecting solutions in situations when electrical systems are hardly or not at all applicable, for instance in environments with a high ignition risk and/or with an extreme level of electromagnetic or electrostatic interference. From the point of physical principle, the presence of an evanescent light field component (accompanying the process of light transport in optical waveguides) provides a handy tool to construction of various types of transducers. They can be based on variation of the passing light intensity and its spectral composition, specific fluorescence creation or quenching, chemo-luminiscence induced by the reaction of analyte with reagent, etc. Depending on the applied construction geometry, the optical transducers can be localised (point sensors) or continuous (distributed sensors), 'turnstile' or reflecting, intrinsic or extrinsic, etc. (for overview of evanescent sensor types see e.g. [2]).

Our contribution aims to provide reader with a brief description of functions and parameters of the Multipurpose Photonic SENsor System (MP-SENS) being recently under development in collaboration of Lukas Industrial Research, s.r.o. (LIR), and Department of Solid State Engineering, FNSPE CTU in Prague. MP-SENS combines recent achievements in fields of photonic devices (optical fibres, electro-optical parts) and microelectronics, with the research and development results of the partners in fields of applied organic and polymer chemistry, waveguiding optics, and material science. The first results obtained during the project solution were already reported in [3]. Architecture of the MPP-SENS generally comprises the following main parts: external sensing head, connecting fibre optic cable, portable electronic controller and output data link.

Two types of portable universal electronic units (UEU) are already available in form of functional samples , both suitable for continuous monitoring. The UEU1 has been designed for simple signalling purposes - it sounds alarm or switches an external relay when the pre-set signal level from the attached external sensor head is reached. The UEU2 enables an 'intelligent' signal analysis. The built-in single chip μ-processor compares the incoming data

with the calibration ones (individual for the particular sensor head) stored in its internal non-volatile memory, and provides the purged values of the monitored quantities. The results are then shown on LC display and optionally passed to a superior control system via the analogue (0 – 5 V) and/or serial (RS-232) outputs. The operating power for the both unit types can be supplied by an internal battery/accumulator and/or an external net adapter. Thus, a simple and flexible SW program change is only necessary to adapt the unit for use with range of sensing heads.

According to their application and operating principle, the developing sensing heads belong to the following groups: thermometers, level sensors, chemical sensors, and refractometers. The following table summarised the principal characteristics of the sensing gauges.

| | |
|---|---|
| Thermometers | total covered range: 20 - 180C (precision 0 .1C); fast response time; no galvanic connection with measuring point. |
| Level sensors | selective and safety detection of liquid level (water, combustibles); rain drops counting - low unit price allows for instalment of dense monitoring networks. |
| Chemical sensors | analysis of ion concentration in water ($Hg^{2+}$); monitors of irritating gasses ($NH_3$). |
| Refractometers | determination of sugar content in aqueous solutions; identification of liquids. |

Construction of the transducers is based on specific interactions of evanescent light field with polymer optical coatings, individually designed according to the sensor target function. Novel optrode structure utilising special curved waveguides results in the high sensitivity and temporal stability of the sensing heads.

The reported research work has come to a stage of prototype testing (thermometers, level sensors) or construction of demonstrating devices (chemical sensors, refractometers). A further steady research and development work, as well as extended co-operation with industrial partners is expected to accomplish mature of all the developing gauges, and optionally propose next promising MP-SENS application areas.

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# Digitalization of the Fluxgate Magnetometers

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Fluxgate sensors are known as the most sensitive magnetic sensors working at the room temperature. They are mostly used for high-performance magnetometers such as, for example, military systems (localization of unexploded ammunition under the ground) or satellite systems (study of the Earth and interplanetary magnetic fields). All these systems require digital output data for post-processing. Up to now, these magnetometers have mostly been analog feedback systems (feedback is used for suppressing of sensor non-linearity and hysteresis and for increasing of measuring range) with consequential digitization of their analog outputs. This solution has two main disadvantages – although these magnetometers use high-quality circuits, their parameters are depended to temperature and other physical conditions; and change of the magnetometer parameters (for example measuring range, frequency response, etc.) is quite complicated. These disadvantages lead to attempt of the digital signal detection. Furthermore, miniaturization of the fluxgate sensors brings the possibility of integration whole magnetometer to one chip and it opens the door for design of smart magnetic sensor. And digital signal detection seems to be the best candidate for its realization.

At the present time we can recognize two basic ways of the fluxgate magnetometer digitization:

- application of delta-signa modulation to the negative feedback loop
- fully digital signal detection realized in the digital signal processor

The first of these principles uses analog signal detection and delta-sigma modulator integrated to the feedback loop. Thus, the output signal of this magnetometer is modulated bit-stream. The main advantages of this system are high-dynamic range, high-linearity (both given by generally known basic attributes of $\Delta$-$\Sigma$ modulation) and flexible post-processing of output bit-stream – it can be analog or digitally post-processed to obtain the analog signal or the digital data.

Up to now, magnetometers with $\Delta$-$\Sigma$ modulation have been designed for micro-fluxgate sensors only [1]. The resulting parameters of this system are limited by the parameters of used sensors, not by the parameters of the interface. And because the margin of the interface potential is still substantial, we have tried to use this principle for standard-size high-precise fluxgate sensors. Our system consits of a sensor, a front-end amplifier, an analog switching-type phase-sensitive detector, an analog integrator, a $\Delta$-$\Sigma$ modulator, a 1-bit D/A converter and an analog low-pass filter. The DAC and LPF are used for the reconstruction of the feedback signal. We can use two different $\Delta$-$\Sigma$ modulators – 2nd-order one, designed and realized by prof. Kawahito and Mr. Aramaki from Shizuoka University and 4th-order one, commercially available circuit made by Analog Devices. Output bit-stream is digitally post-processed by the commercial digital filter also made by Analog Devices. A one-channel analog magnetometer designed for previous project is used for the sensor signal detection.

All necessary subsystems were designed and realized and whole system has been tested. The main problem of its realization is stability of the feedback loop.

The second principle of the fluxgate magnetometer digitization directly comes out from the analog feedback magnetometer, where the analog signal detection is completely substituted by the digital signal detection realized in DSP.

Probably the first fully digital magnetometer was realized by Pederson et al. for the Astrid-2 satellite [2]. The results from this project show that the main limiting factors of this magnetometer are A/D a D/A converters non-idealities.

Our fully digital fluxgate magnetometer consists of a precise sensor, a front-end amplifier, a high-speed 16-bit A/D converter, a 16-bit fixed-point DSP, an 8-bit host-processor, a slow-speed precise 20-bit D/A converter, a feedback current driver and a sensor excitation circuitry. Output signal from the sensor is pre-amplified a and digitized. Output data from ADC is fed to the DSP, where whole signal detection is realized in the digital form. Resulting data are given to the host-processor, which is mainly used for communication with PC and system status indication. The data from host-processor is passed to the PC and also to the DAC, which is used for the feedback signal reconstruction. Analog output from the DAC is converted into feedback current, which supplies the feedback coil of the sensor. This system also allows us to change the ADC sampling frequency for studing of the sampling frequency to resolution dependence. Because we use a tuning of the sensor excitation signal and also sensor output signal , the sensor excitation frequency has to be still the same. This frequency is derived from the sampling frequency to prevent from the leakage of digitally detected signal.

Fully digital fluxgate magnetometer described above was realized and at the present time it has been programmed and tested.

Our work on the grant *CTU0211313* was presented at the conferences [3] and [4].

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# Computer Aided Education of Courses Signals and Systems and Digital Communications Theory

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The Signals and Systems course introduces to students ground categories of signals and describes their properties in the mathematical context. The description includes signal specifications in both time domain and spectrum domain. These signals are also seen from power and energetic point of view. Students meet the basic sampling theorem and its aspects. In the part Systems, the introduction into the basic classification of systems is done. The properties of systems with the accent to linear time invariant system is presented to students again in both time domain and frequency domain. The basic introduction into the problem of stochastic signals and systems in done. The Digital Communications Theory course presents to students topics of design of the digital communications systems. Main part of the course is dedicated to digital modulation methods, their description and classification. Next part is aimed to digital communication channel, its properties and specification. Another part is dedicated to system design of the optimal and sub optimal detection methods together with their analysis. These courses use similar approach to the signals and systems problems, therefore the topics of computer aided education is valuable for both of them.

The computer aided education is realized mostly in the computer classroom of the department. This classroom is equipped with 12 workstations for students and 1 workstation for the lecturer. All workstations are running in two most used operation systems: Microsoft Windows and Linux. These workstations can run in stand-alone mode, but main power of them resides in terminal mode when connected to the educational server of the department. Each of students, attending one of the two courses gets account at the server. Within this account, the student can use a shared disk space at the server for storage of his data related to course and can run and use software packages installed at the server. This access is done via network connections, therefore it is possible to work with the same data and software packages from different places (computer classroom of the department, other computer facilities at the university, home, campus, etc.) without the need of data transfer. Thanks to unified access the students can be focused more on solving the tasks from the courses than on the solving problems with access and different versions of software.

The classroom is hereafter equipped with shared laser printer, slide projector, video-recorder and data projector connected to the lecturer workstation. Therefore both lecturer and student can present their work to the audience.

Software packages installed at he server include presentation software Adobe Acrobat, LyX (LaTeX), mathematical and simulation software Mathematica, Matlab, Maple, and Ptolemy (the Maple is open-licensed for students, LyX and Ptolemy are distributed under GNU license) etc.

The lecturers can use these packages to create presentations and demos for their courses and these demos distribute to students at the server. These demos are built in the software common both to lecturer and students; therefore students do not need to consult implementation tasks instead of the course topics.

The main aim of the project was to complete the educational/research chain:
**Problem – acquiring information – solution design – verification by simulations – presentation of the result**.
The **Acquiring information** task led to concentration of the information sources from the signals and systems area, therefore the number of books and information concerning signals, systems, communication theory, channel description, etc. are available for the students attending these two courses (e.g. Proakis: Digital Communications, Kay: Fundamentals of Statistical Signal Processing, Biglieri: Principle of Digital Transmissions, and others). The database of these sources was built and is available to the authorized students via web interface.
For the **solution design** task can be used the above described software packages, available in the computer classroom. These packages were also used for building demos for Signals and Systems course. The main purpose of these demos was to create interactive contact between student and solved/educated problem. Demos in Signals and Systems course used mainly Matlab and Maple. For every lesson of the course were prepared demonstrative examples of implementing the mathematical background to the real signal. These demos were available to students from the www page of the course. This task was together with the previous one main aim of the project.
The **verification by simulations** task is connected with the previous task. In the course Digital Communications Theory the simulations were acquired within student's semester project. Some demonstrations of usage of the simulation software were also presented during both courses.
The **presentation of the results** task was realized for example during semester project in the both courses.
By completion of the described solution chain are students, Ph. D. students and academic staff provided with the concentrated environment for the education and research.

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# Miniature Silicon Transducer with a Non-planar Back Plate

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The electroacoustic electrostatic transducer as a sensor is usually formed by a thin circular or, in the case of silicon sensors, square membrane or plate and a planar back electrode with holes. The diaphragm displacement distribution of a thin circular membrane in fundamental symmetrical mode (and below it) is approximately parabolic and only the central area of the diaphragm produces the main contribution to the capacitance changes. For this reason it is possible to make the back plate shape also, for example parabolic (paraboloid of $n^{th}$ order), simultaneously preserve the sensitivity of the transducer and modify the acoustical impedance of the air-gap and thus the damping of the diaphragm.

The previous study of the transducer with a non-planar back plate is in [2], [3], [4], [5]. Our contribution extends and complements this study with new results. The contribution deals with the description of the behaviors of the electrostatic transducer with a thin circular membrane loaded by an air-gap, taking account of effects such as inertia, compressibility and shear viscosity. The effect of heat conductivity is not considered. The study leads to the equivalent lumped element circuit, analytical description of the transducer and its optimization.

In order to obtain the open circuit voltage of the transducer as a microphone of $0^{th}$ order, we start from the assumptions presented in [2].

From the basic equations of an electrostatic transducer we derived the equation for the output circuit voltage of the transducer (with constant charge) with respect to the displacement of the diaphragm for n = 2, n = 4 resp., and $R > R_e$

$$u = \frac{U_o \xi_o}{l_o}\left(\frac{\rho^2(1+\alpha^2)}{(1+\alpha^2\rho^2)\ln(1+\alpha^2\rho^2)} - \frac{1}{\alpha^2}\right), \quad u = \frac{U_o \xi_o}{l_o}\frac{1}{2}\left(1 + \frac{\alpha\rho^2(1-\rho^2)}{(1+\alpha^2\rho^4)\operatorname{arctg}(\alpha\rho^2)}\right) \quad (1), (2)$$

where $U_0$ is the polarisation voltage, $\alpha$ is the shape coefficient of the back plate, $\rho = R_e/R$ is the ratio of the radii of the back plate and the diaphragm, $\xi_0$ is the central deflection of the diaphragm and the diaphragm and $l_0$ is the central distance of electrodes.

From the basic equations of electrostatic transducer we can derive two equations for the transducer as a four-terminal network:

$$\begin{bmatrix} F \\ q \end{bmatrix} = \begin{bmatrix} K & -S_n \\ C & -K \end{bmatrix} \begin{bmatrix} u \\ \bar{\bar{\xi}} \end{bmatrix} \quad (3)$$

In Eq. (3) K is the transducer coefficient, $\bar{\bar{\xi}}$ is the mean membrane displacement, C is the capacitance and $S_n$ is the negative stiffness:

$$K = \varepsilon_0 U_0 A_0 \qquad S_n = \frac{\varepsilon_0 U_0^2 A_3}{\bar{\bar{\xi}}} \qquad C = \varepsilon_0 A_1 \qquad \bar{\bar{\xi}} = \frac{\varepsilon_0 U_0 A_2}{K} \quad (4)$$

where $A_0 = \iint \frac{dS}{l^2}$, $A_1 = \iint \frac{dS}{l}$, $A_2 = \iint \xi \frac{dS}{l^2}$, $A_3 = \iint \xi \frac{dS}{l^3}$.

From the above analysis we can derive the equivalent circuit of the sensor as a electrostatic microphone of the zeroth order. The equivalent mass and compliance of the circular diphragm

we can find in [2], [6], [7]. Because the transducer operates with a constant elctrical charge the negative stiffness is zero. The coefficients $A_0$, $A_1$, $A_2$ and A for n=2 are:

$$A_0 = \frac{\pi R^2}{l_0^2}\frac{\rho^2}{1+\alpha^2\rho^2}, \qquad A_1 = \frac{\pi R^2}{l_0}\frac{\ln(1+\alpha^2\rho^2)}{\alpha^2} \qquad (5), (6)$$

$$A_2 = \frac{\pi R^2}{l_0^2}\xi_0\frac{1}{\alpha^2}\left(\rho^2\frac{\alpha^2+1}{1+\alpha^2\rho^2} - \frac{\ln(1+\alpha^2\rho^2)}{\alpha^2}\right), \quad A_3 = \frac{\pi R^2}{l_0^3}\xi_0\rho^2\frac{1-\frac{\rho^2}{2}+\frac{\alpha^2\rho^2}{2}}{(1+\alpha^2\rho^2)^2} \qquad (7), (8)$$

For the circular diaphragm we can find the resistance $\overset{=}{r}$, the mass $\overset{==}{m}$ and the compliance $\overset{=}{c}$ of the air-gap for n=2 [2], [6], [7].

$$\overset{=}{r} = \mu\frac{\pi R^4}{l_0^3}\frac{a}{\Xi}, \qquad a = \frac{3}{2}\frac{1}{\alpha^4}\left(\rho^2\frac{2\alpha^4\rho^2+3\alpha^2\rho^2+2}{2(1+\alpha^2\rho^2)^2} - \frac{\ln(1+\alpha^2\rho^2)}{\alpha^2}\right) \qquad (9)$$

$$\overset{==}{m} = \rho_0\frac{\pi R^4}{l_0}\frac{g}{\Xi}, \qquad g = \frac{1}{8\alpha^4}\left(\frac{1+2\alpha^2}{\alpha^2}\ln\frac{1}{1+\alpha^2\rho^2} + \rho^2(1+2\alpha^2) - \frac{\alpha^2\rho^4}{2}\right) \qquad (10)$$

$$\overset{=-1}{c} = \kappa p_0\frac{\pi R^2}{l_0}\frac{d}{\Xi}, \qquad d = \frac{(1+\alpha^2)\ln(1+\alpha^2\rho^2)-\alpha^2\rho^2}{\alpha^4} \qquad (11)$$

where $$\Xi = \frac{1}{\alpha^2}\left(\alpha^2+1-\frac{(1+\alpha^2\rho^2)\ln(1+\alpha^2\rho^2)}{\alpha^2\rho^2}\right)$$

The Eqs.(5)-(11) we can used with a sufficiently good accuracy also for the transducer with the square diaphragm and the circular back plate. In this case we use the equivalent radius R= 0,45016 a, where a is the side of the square membrane .

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# Measurement of Permittivity of Gases

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The measurement of dielectric constant enables us to identify an important physical quantity that has a great influence on many physical and chemical phenomena. In order to measure the dielectric constant the optimal sensor structure and the measurement method have to be designed. This project deals with the design of sensor and the measurement method and instruments suitable to determine the dielectric constant of gases especially of the new ecological coolants. The goal of this project is to design the very accurate measurement system to make the extremely small dielectric constants exactly quantifiable.

Dielectric constant, also called permittivity, is the physical quantity that describes the influence of the material on the electric field properties inside this material. In order to exactly measure the dielectric constant it's necessary to design the optimal sensor firstly. As the direct method of permittivity measurement is not available, the conversion of measured quantity by means of capacitive sensor ids required. From the measured capacity of the sensor the permittivity can be found using mathematical description of electrical field between the electrodes of the sensor. The capacitance itself describes the ability of the material between the couple of electrodes to accumulate the electric charge with the defined electric potential between the electrodes.

Dielectric constant of gases is generally very small, it means very close to dielectric constant of vacuum, which is 1. Moreover the dielectric constants of various gases are very similar at the same temperature and pressure. Hence it's required to accurately measure very small differences of capacity in order to determine the dielectric constant of the tested gas exactly.

Whereas many methods to measure the capacity very precise were designed any method suitable to measure the extremely small capacities seems to be optimal to estimate the dielectric constant of gases.

The first part of the project is focused on the theoretical propose, design and construction of optimal sensor structure. Due to the extremely requirements, such as small differences of dielectric constant of different gases ($\Delta\varepsilon_r = \cdot 10^{-6}$), the optimal sensor construction has been sought. The required properties are granted by using the Thomson-Lampard theorem utilized for capacity etalon construction[1]. Well-known T-L theory mathematically describes the capacity of the couple of rectangular electrodes arranged co-cylindrically inside the tubular electrostatic shield.

Capacitance of capacitor designed this way depends only on the length of the active electrode and dielectric constant of inner material between the electrodes. Capacitance of electrode arrangement also depends on the angular dimensions of electrodes, but the thermal dilatation of material has the effect only on the length of electrode, not on their angular dimensions. Therefore the thermal dilatation affects only the length of the electrodes. This capacitor is also well immune against the outer physical disturbing quantities because of the surrounding tubular electrostatic shield.

In this project the T-L theory based capacitor was filled by the tested gas thus the precise capacitive sensor of dielectric constant of gases was created. Because the capacity of this sensor is very small, $C = 1.952\ pFm^{-1}$, the suitable measurement method has to be proposed.

The main requirement on the measurement system are following: sufficient sensitivity, and accuracy, immunity against the additional noise is the measured quantities, immunity against external electrostatic noise, elimination of the parasitic capacitances of leads, reduced thermal dependence, and time stability. Therefore the complete measurement system includes the high precision analog capacitance-to-voltage converter, the dual channel sine low frequency generator and the digital lock-in amplifier instrument. Because of very high impedance of sensor, the capacitance-to-voltage converter has to be based on ultra precision operation amplifier with input noise current less then 1 *pA* [2], [3]. The dual channel sine generator is in the system used to generate the exciting signals for the active sensor and also for the reference sensor. The reference sensor is filled by the referential gas, generally dry air. The differential measurement method allows us to improve the accuracy and the sensitivity of the complete measurement system. To achieve the requested properties of the system, especially the immunity against the additional noise in the measured signal, the lock-in amplifier is included in the capacitance-to-voltage converter. Then the complete system was connected to the PC computer through the GPIB interface in order to archive and present the results of measurement.

The complete system for measurement of dielectric constant of gases at normal temperature and atmospheric pressure was realized and its parameters were verified. The system is capable to measure very small differences of capacity, $\Delta C_{sensor} = \cdot 10^{-18} F$. The designed system is also sufficiently immune against the external electrostatic disturbance and stable in time. The measured values of capacity can be stored in the PC and later numerically processed. The results of the measurement demonstrate that the designed capacitive sensor and the measurement system are able to determine exactly the dielectric constant of requested tested gases.

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# 6th International Student Conference on Electrical Engineering POSTER 2002

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Student's research activity should be an inevitable part of the whole pedagogical process at all universities. Its main aim is to support an independent creative work of students and stimulate practical application of theoretical knowledge received during studies. We take for necessary and very useful to organize regularly student scientific conferences, namely because of comparison of contributions to solution of a certain research problem at different domestic and foreign institutions, establishing personal contact among young researchers, development of personal skills, and development of habits of research work and its presentation.

Students' scientific conferences POSTER organized by the Faculty of Electrical Engineering of the Czech Technical University in Prague began in 1995 as an internal meeting of students from all CTU faculties interested in the field of electrical engineering. In 1997, after two-year's experience, we decided to internationalize this event and invite both undergraduate and postgraduate students from neighbouring countries. Four following successful successors in 1998, 1999, 2000, and 2001 confirmed that this was a right choice.

The 6$^{th}$ international student conference on electrical engineering POSTER 2002 showed on further growing interest in this conference which was manifested by the 20 % increase of submitted contributions. The program committee selected for presentation 216 contributions of 32 undergraduate and 184 postgraduate students from a record-breaking number of 235 submitted abstracts. Criteria of acceptance were namely based on the scientific quality and originality of student's contribution. Majority of contributions came from FEE CTU (178), 6 from other CTU faculties, 11 from other Czech universities and 21 from foreign countries (Germany, France, Hungary, and Netherlands). The contributions were presented as posters in six specialized parallel sections :

| | |
|---|---|
| Electronics and Instrumentation | 45 posters |
| Communications | 30 posters |
| Informatics and Cybernetics | 56 posters |
| Power Engineering, Energetics and Material Science | 40 posters |
| Management | 17 posters |
| Natural Sciences | 28 posters |

Two page extended abstracts of individual contributions were published in the conference proceedings [1] that was passed to all participants at the desk of the conference. This year, the conference was enriched by the invited plenary lecture *"From university to a successful start-up company"* of Prof. Dr. Ing. Michael Heuken from Aixtron AG.

POSTER 2002 was sponsored by the CTU Grant Agenture, FEE CTU Prague, different companies (AIXTRON, Czech Airlines, Panasonic, Siemens, Spojprojekt, and T-Mobile) and scientific societies (the Czechoslovak section of IEEE and its Joint MTT/AP/ED Chapter) which provided organizers with numerous prizes ( flight tickets, financial awards, mobile telephones, scientific books and journal subscriptions, etc.) and conference bags.

Members of evaluating committees chose winners and further rewarded contributions in individual sections [2]. A total of 24 posters were awarded, 19 from FEE CTU Prague and 5 from abroad. Winners in sections advanced to the final selection where the program committee chosen six top posters awarded by special prizes :

| | |
|---|---|
| EI41 | Včelák Jan (K338) *„Opto-electronic gate with Intelligent features“*, |
| C21 | Oechterling Tobias, Walke Christoph (RWTH Aachen) *„Spectrum efficiency analysis of interference-limited MIMO radio systems“* |
| IC6 | Bárta Jaroslav (K333) *„Multi-agent approach to planning humanitarian relief operations“* |
| PE39 | Vyskočil Jiří (K314) *„Controlling slave drives in traction“* |
| M13 | Šucha Marek (K316) *„Requirements for transmission tariff system on liberalized electricity market“* |
| NS21 | Seidelmann Louis (K302) *„Discharge tube with virtual cathode“*. |

Six domestic student presentations, one in each section, received the IEEE Prize awarded by the committee of the Czechoslovakia section of IEEE.

In summary, we can conclude that The sixth international student conference POSTER 2002 was very successful. This is evidenced by record-breaking number of participants and increased quality of presented posters. The program committee decided to continue in organizing this conference in the year 2003. The 7$^{th}$ POSTER 2003 is scheduled for May 22, 2003.

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# Innovation of Courses on Programmable Integrated Circuit Design

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Programmable-logic devices are the fastest growing segment of the logic-device family for two fundamental reasons. Their ever-increasing logic gate count per device provides functions that might otherwise spread over a number of discrete-logic and memory chips, improving end-system size, power consumption, performance, reliability, and cost [1]. Equally important is the fact that in a matter of seconds or minutes you can configure and, in many cases, reconfigure these devices at your workstation or in the system-assembly line. This capability provides powerful flexibility to react to last-minute design changes, to prototype ideas before implementation, and to meet time-to-market deadlines driven by both customer need and competitive pressures. This also makes programmable integrated circuits the optimal platform for education of future electrical engineers in the field of integrated circuit design.

Layout and circuit-level activities are absent from programmable device design efforts because their physical structure is programmable but fixed. The best utilization of a device is typically achieved at the gate level using hardware description languages (HDLs) for design entry and synthesis. There are two sets of languages in common use. One set has evolved from the design of simple programmable logic devices (PALs and GALs). These languages (ABEL, CUPL, and PALASM) are simple, easy to learn, and require simple, usually free-of-charge software design tools. However, they are suitable only for the design of simple state machines and combinational logic (up to thousand equivalent gates). The other set of HDLs includes VHDL and Verilog, which are higher-level and more complex but are capable of describing complete up-to-date integrated circuits and systems with more than million gates. Time-to-market requirements, combined with the rapidly increasing complexity of programmable devices, are forcing a design methodology shift towards the use of Intellectual Property (IP) macrocells. IP macrocells provide the designer with a collection of predefined and already tested functions, such as microprocessors, DSP functional blocks, etc. The designer, therefore, need only to specify selected features and attributes and a synthesizer (design system) will generate a hardware description code or schematic for the resulting solution. In this way, complex designs can be realized in reasonable time.

The aim of the project was to innovate both the curricula and laboratory equipment of the courses on programmable logic design taught at the Department of Microelectronics, CTU in Prague - the undergraduate course “Programmable devices” and the course for postgraduate students “Programmable integrated circuit design” – to pursue the fast development in the field. Before realization of the project, the education was mainly limited by the available software design tools and corresponding hardware platforms: freeware design tools based on simple HDL languages which were suitable only for design of programmable circuits with a low gate density (below 10 000). For this reason, the innovation of the software and hardware design platform was a primarily task.

According our previous experience, we selected ISE (Integrated Software Environment) Foundation design package from Xilinx, Inc. as a basic design system. The ISE Foundation is the industry's most complete programmable logic design environment and includes the most advanced timing driven implementation tools available for programmable

logic design, along with design entry, synthesis and verification capabilities. It offers design entry in higher HDL language as VHDL and Verilog together with more than 200 IP cores, including PCI, DSP and other pre-designed and tested solutions. Ten PC based workstations were equipped with student's version of the software and completed with two workstations with the full professional version to allow education of postgraduates and realization of diploma works.

Three hardware platforms from Xilinx, Inc., the top producer of advanced programmable logic devices, were selected for design implementation and testing: the CoolRunner-II Complex Programmable Logic Device (CPLD) family, Spartan-IIE and Virtex-II Field Programmable Gate Arrays (FPGA). While the CoolRunner-II CPLD, which is the typical example of the CPLD with a classical architecture giving the best performance with the lowest possible power consumption, provides a platform to implement basic digital circuits of all kinds, from complex combinational devices to sequential machines and controllers, Spartan and Virtex FPGAs represent two distinct classes of high density FPGAs for implementation of integrated systems with the highest complexity. Spartan series devices represent the first FPGAs specifically optimized for the low-cost, rapidly changing consumer market. In contrast with it, the Virtex-II FPGAs, the highest density FPGA in the industry, deliver the system solution support, provide DSP solutions and a bridge between emerging high speed interface standards. The laboratory for PLD design was equipped with development boards for each type the device which are designed specifically to work with ISE CAD tools. The development boards are equipped with different peripherals, e.g. pushbuttons, keyboards, LEDs, LED and LCD displays, and connectors allowing communication with other boards or peripheral devices (PC mouse, PC keyboard, VGA monitor, etc.). In this way, a full-function calculator, a complete computer, a video game, as well as countless other circuits and systems can be designed and verified by students. The laboratory for PLD design was also equipped with a specialized library consisting of books dealing with the design of application specific integrated circuits, design entry and testing techniques using the VHDL and Verilog languages. This library is mainly intended for postgraduate students to deepen their knowledge in the field.

The inherent part of the project was the innovation of the curriculum of the subject "Programmable devices". The new software and hardware equipment of the labs enabled to introduce the education on highest worldwide standards. The VHDL language is now being used for design entry and test. Design implementation and verification is made on the CoolRunner CPLDs and Spartan FPGAs, while the Virtex devices are used for students research. High density of FPGA devices, 200 000 gates for Spartan and up to 1 million gates for Virtex gate arrays, allows realization of complex projects by students working in teams.

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# Accurate control of recombination centre introduction in silicon

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Controlled introduction of point defects by exposure of silicon material to MeV electron or ion beams is nowadays an essential tool to accurately set recombination properties in silicon electron devices. The irradiation induced point defects acts as effective centers for excess electron and hole recombination. A homogeneous concentration of these centers can be adjusted within the whole device by electron irradiation with energies higher than 1 MeV. Irradiation with high energy ions offers more degrees of freedom. In principle, nearly arbitrary axial and lateral distribution of defects can be precisely set by choosing the proper ion energy and masking the ion beam. For this reason, irradiation techniques replaced traditional methods of lifetime control based on noble metal (gold, platinum) introduction by high temperature diffusion. To create an arbitrary axial profile of recombination centers both the multiple implantation with ions of different energy and the combination of ion and electron irradiation have been proposed [1]. Although considerable achievements were already received in this field, more accurate control of defect zone shape and quality is still required. Therefore, this project looks for an optimum strategy for controlled and spatially defined introduction of recombination centers with a favourable position in the silicon bandgap. The main goal is an accurate and reliable control of axial defect distribution in the depth scale of hundreds of micrometers. The study is primarily focused on vacancy-related point defect and their complexes, hydrogen-related deep levels, hydrogen shallow donors – their electronic properties and distributions, and the control of the substitutional platinum distribution by co-introduction of vacancy related defects. Within the project, the EU LSF facility (FZ Rossendorf) is used for the accurate introduction of various types of radiation defects into the test structures whereas the laboratories of the Electron Device Group, Dept. of Microelectronics, CTU Prague provide diagnostic facilities to monitor and characterize the irradiation induced defect centers. The project is focused on the following topics:

**Accurate identification of radiation defect profiles resulting from MeV proton and alpha-particle irradiation**

In this part of the project, the special test structures suitable for non-destructive spatial characterization of radiation defects by High-Voltage Current Transient Spectroscopy (HVCTS) [2] were irradiated with hydrogen and helium ions in the energy range from 1 to 8 MeV and 3 to 15 MeV, respectively. The dose ranges were chosen in that way to fit the requirements for HVCTS studies ($10^9$ – $10^{10}$ $cm^{-2}$) and the levels useful for practical applications ($10^{10}$ – $10^{13}$ $cm^{-2}$). The distributions of resulting secondary defects (VO-pair, $C_iC_s$-pair, divacancy $V_2$, hydrogen-related defects – e.g. VO-H) are being measured and compared with simulated distributions of elastic energy deposition. The effects connected with primary defect diffusion and pairing are monitored in the wide depth scale. Some still unresolved problems, e.g., the origin of the point defects far beyond the end-of-range of incoming projectiles, are studied. It is expected that the samples will be further used for investigation of the annealing effects on defect reaction and distribution. The results are used for the calibration

of the models describing carrier recombination/generation in state-of-the art numerical codes used for simulation of irradiated silicon materials and devices (ATLAS, ISE).

**Stability of recombination centers subjected to various types of stress**
In this project, the power diodes irradiated into the anode region either with a single hydrogen or with hydrogen and helium are subjected to long term annealing at elevated temperatures ($125^0$C ) in combination with repeated stress caused by high forward current densities (up to 4 kA/cm$^2$). The stability of both the pure radiation defects and the hydrogen-related defects is monitored. Mutual reactions of these two types of defects are studied, as well.

**Modification of the recombination center structure and distribution**
Different temperature annealing schemes are applied on the test structures irradiated with protons and alphas to stimulate defect reactions and to test defect stability: 1) standard annealing conditions used for defect stabilization ( furnace anneal at 200 or $350^0$C for 1 hour); 2) long term annealing at elevated temperatures ($125^0$C ) combined with repeated stress; 3) isochronal annealing in the temperature range from 100 to $750^0$C to study defect reactions.

**Investigation of radiation defect reactions with intrinsic and extrinsic defects to optimize the recombination center distribution**

The project is devoted to the further extension of our investigations using the proximity gettering of platinum on radiation defects introduced by helium irradiation for accurate lifetime control in silicon where the helium irradiation is used to control the Pt in-diffusion [3]. In the contrast with our previous studies, the experiment is focused on low-doped N-type <100> float-zone silicon. The diffusion at different temperatures from the surface PtSi source is compared with that from an implanted Pt source.

The results of the project provide us with a detailed knowledge about basic processes in irradiated silicon during the post-irradiation period and allow us a complete understanding of the interaction between the ion beam induced point defects and impurities. The study also supports a detailed characterization and quantification of the process of radiation defect introduction and provides a platform for its further optimization.

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# Piezoelectric earphone for ANC with built-in microphone

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Electrodynamic acoustic transducer in headset/earphone with active noise control (ANC) system has some features which complicate design of ANC system. Its higher power demand challenges usage of power amplifier, its bigger group delay causes bigger geometry of the ANC system in respect to keep causality. Wide frequency transfer function of acoustic transducer brings on necessity to use an interpolation filter adding delay and makes ANC headset system larger. Piezoelectric transducer in newly designed earphone with built-in microphone was solution.

Piezoelectric earphone consists of earphone body, piezoelectric transducer, microphone, cover and two contact screw. Outline diameter is 37 mm and depth 27 mm. Both microphone and transducer have own capillary leading outside into adjacent points in entry to middle ear. Microphone is employed by ANC digital system.

Artificial middle ear was made for measurement purposes as the earphone acoustic loud. Inner volume with applied earphone is similar like human middle ear. Measurement microphone B&K can be applied instead infatuation. The infatuation has capillary lead outside. This capillary carries low frequencies below 360 Hz inside the artificial ear. Frequencies above 360 Hz are attenuated with steepness 40 dB/dec. The capillary can be closed by screw.
When the capillary is closed, the measured earphone transducer has transfer function flat from 0 Hz and sounds from background is not carried inside. When the capillary is open, the transfer function for frequencies lower then 400 Hz decreases and background sounds from outside penetrates inside.

Piezoelectric transducer in earphone has sharply limited bandwidth. Together with artificial ear it has bandwidth 0 to $f_u$ = 2.78 kHz. In the range the transfer function is flat – peek 7 dB is on the upper frequency 2.78 kHz. At frequencies above $f_u$ transfer function steeply descends (140dB/dec).
Piezoelectric transducer has electrical capacitance 41 nF. Can be feed directly by DAC – no necessity to involve power amplifier. Together with serial resistor 2200 ohm constitute 1st order lowpass reconstruction filter which has same upper frequency $f_u$. This reconstruction filter is suitable for sharp transducer frequency limit $f_u$ and allow to set sampling frequency for N=8 bit unipolar DAC

$$DR = 7.78 + 6{,}02.\log(N) \quad , \quad (\text{dB; -})$$

is dynamic range DR = 55 dB

$$f_s/2 \geq DR/140 + \log(2780) \quad , \quad (\text{Hz; dB})$$

and $f_s/2$ = 6870 Hz

Low order reconstruction filter has small group delay – at low frequencies near zero. That is desired asset – electrical signal path is quicker. Geometry of ANC is smaller because reference microphone may not be so far and better result in noise suppression is achieved.

Transfer function of earphone with artificial ear was analyticaly described and simulated in Maple software. Earphone with small anatomical change can be used for real ANC headset. The earphone helped with ANC system configuration and allowed to verify some design theories. Simplification of the ANC design is significant.

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# Colorimetry of the New Scanning and Display Systems

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The aim of here presented research was focused on the advanced colorimetry of the first and the last part of imaging systems – on the scanning and reproducing. Scanning is one of the dominant aspects, which destine the quality of colour image reproduction. One of today imaging systems is presented by television. In the TV camera, RGB scanning system for obtaining R, G, B signals, is used. These signals control display unit, e.g. Cathode Ray Tube (CRT). It means, that today scanning and on the additive mixing based reproducing systems are trichromatic. However, from trichromatic theory results that with three channel sensitivities, on the scanning side, and with three colour lights, on the reproducing side, are possible scan, but not reproduce the whole colour information. For correct scan the whole colour information about scene, a specific requirement on the three spectral sensitivities are asked. Spectral sensitivities of three colour channels of the scanning system must be a linear combinations of colour matching functions x, y, z.

In this paper studied scanning system is presented by colour splitting system, or so-called prism, which is used in professional TV cameras. In scanning system of today cameras, the RGB colorimetric system is still entirely used. The ideal spectral sensitivities of RGB prism result from the colour matching functions r, g, b. The cause of incorrect optical separation of the R, G, B partial pictures is the existence of negative parts of r, g, b colour matching functions. To put it simply, it is impossible to realize negative parts of the ideal spectral sensitivities of RGB prism in optical way. The reason for this is fundamental. There is no negative radiation intensity, there is no negative medium transparency and the photoeffect is also a response of the output quantity (charge, current, voltage) only to the radiation intensity. This causes, on the reproductive side, that even in case all-colours reproducing lights, only a RGB triangle (in term of CIExy chromaticity diagram) from area of all existing colours (horseshoe-area in CIExy chromaticity diagram) can be reproduced. Colour gamut of reproduction is primarily set by type of colour channel in scanning system of camera and further determined (limited) by primaries in display unit. The second problem with using RGB colorimetric system in scanning system of cameras is that the colouring filter is used for creating G partial picture in RGB prism. Such filter is losing. In addition, the light inputting in RGB prism and not being used for creating partial pictures R, G, B, is not absorbed in “waste” channel. These negatives lead to distortion of colour reproduction. The colour gamut of reproductive colours is reduced.

Solution of problem of insufficient scanning colour gamut is offered in an idea of scanning in preferable colorimetric system. Pioneer introducing the idea of scanning in XYZ colorimetric system, was V. Svoboda in the late 20$^{th}$ century [1]. The TV camera, which scans in colorimetric system of unreal lights X, Y, Z, is not predetermined by the colorimetric features of any display device. Theoretical spectral reflectances Ay, Bx and Cz of partial filters of XYZ prism correspond to the colour matching functions x, y, z, that are only positive. It is a decisive advantage. It solves a number of problems, which are known during

realization of conventional scanning system (RGB prism). The end effect is that the colour gamut of reproduction will not be reduced. Such XYZ colour splitting system was designed and now is already patented [2]. Design of the colour splitting system (XYZ prism) has three steps: Calculating of ideal spectral reflectances of partial XYZ prism filters, approximation these filters by real optical interference filters and establishing of the geometry of the XYZ prism. The spectral sensitivities of partial channels x', y', z' of the proposed scanning system are the colour matching functions x, z, y (CIE 1931, 2-deg), which are corrected for maximum efficiency of transmission of light flux through the colour splitting system, also for maximum transparency of the splitting system, and for the spectral sensitivities of CCD image sensor. The approximations of ideal spectral reflectances Ay, Bx and Cz by real optical interference filters were made using the Synopsys programme. The XYZ colour splitting system consists of four glass prisms (BK7 glass) and three reflective-interferential filters. Due to the transmissivity of the XYZ prism, and due to the summing curve of spectral sensitivities x', y', z', only a part of the incident light spectrum is used to obtain the trichromatic components X, Y, Z (partial images X, Y, Z). The unused light spectrum, mainly the section around wavelength 500nm, passes through filter Cz and leaves the XYZ prism. This light must be absorbed in the camera (e.g., absorption with velvet) to prevent it being reflected back into the prism. Otherwise this light would cause spurious artefacts in the picture during reproduction.

One of the problems at the end of TV (or more generally multimedia) chain is, that the colour gamut of contemporary display devices is not sufficient for true reproduction of colours. So is very needful to find the possibilities of reproduction by multiprimary colour display or, on the other hand, the possibilities of reproduction by laser primaries-based colour display. The aim of presented research was suggestion of two laser primaries based colour display device, which disposes with expanded range of reproducible colours [3]. Specific technical and scientific applications in which colour bears a substantial part of the information (cosmic development, medicine) demand high fidelity colour reproduction. The horseshoe-area of CIExy chromaticity diagram is contiguous and compact set. Then, there are two possibilities of configuration of two spectral primaries based display. First, one light must bee wavelength – tuneable and farther static light must lie wherever of CIExy chromaticity diagram. Advantageous position for static light is on red end of CIExy chromaticity diagram. In this case, the wavelength – tuneable light is sufficient to retune in range 420 – 550 nm, because out of this range, the border curve of CIExy chromaticity diagram is practically straight line. Second, both lights are wavelength – tuneable. In this case, there is multitude of possibilities of positions of spectral reproductive light. Advantage of this solution is exploitation of metamerism. There can be chosen energy – most economical positions of reproductive lights.

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# Measuring Optical Losses in Planar Waveguides

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Optical losses are one of the most important parameters which characterize the quality of optical waveguides. We would like to present simple measurement method that allows us to determine simply and nondestructively the propagation losses in various types of optical planar waveguides. This loss measurement technique in principle involves the measurement of transmitted and scattering light intensity as a function of propagation distance along the waveguide.

The scattered light measurement method which we used in our case to characterize planar waveguides fabricated on various glass and crystal substrates is based on the monitoring the intensity and distribution of light scattered by core inhomogeneities, imperfections and defects in the planar optical waveguides. The linearly polarized laser beam which goes through a system of mirrors, half-wave plate, and linear polarizer plate is focused into the optical planar waveguide by optical coupler prism. The half-wave plate and linear polarized plate is designed in order to create either TE or TM laser beam. The optical coupler prism and planar waveguide are mounted on a rotation stage. This stage allows to choose individual guided modes for measurement optical losses. This mode which is guided through optical planar waveguide can be then seen on the surface of the planar waveguide due to its scattering at inhomogeneities in optical waveguides. The light which is created this way on the top of the optical planar waveguides is detected by CCD video camera. The camera is connected with AD converter to computer. The CCD camera is situated above the optical planar waveguide and it is focused on the surface of the waveguide core. The intensity of the scattered optical light is regulated for better resolution and representation (the level of intensity is depicted from 0 to 255 levels). Then the image is stored and processed. The two-dimensional image of scattered light is reduced to one dimension by summing the pixels intensities in each column separately. The intensity of the light is a function of distance. The measurement profile of the optical scattered light is 5 mm long and was divided into 1288 columns in our cases. The number of the columns depends on the maximum resolution of the chip used in CCD video camera. In our case the maximum resolution of CCD chip is 1028 x 1288 pixels and 256 gray-level.

The scattered light decreases exponentially along the optical planar waveguides. The attenuation coefficient is obtained by fitting the measured light intensity to decreasing exponential function. The attenuation coefficient is recalculated at losses at dB/cm unit. This measurement method is independent on the uniformity of the losses along the waveguide length.

We can demonstrate this measurement method for measuring optical losses in planar waveguides which were fabricated by using $Ag^+ \leftrightarrow Na^+$ and $Li^+ \leftrightarrow Na^+$ ion exchange in special silica and bore-silica glass substrates, at temperatures 200 °C to 600 °C and at periods from 0.5 min to 100 min. The value of optical attenuation in planar waveguide which was fabricated by using $Ag^+ \leftrightarrow Na^+$ ion exchange was between 2.5 dB/cm and 4.9 dB/cm at wavelength 633 nm and between 3.8 dB/cm and 7 dB/cm at wavelength 532 nm. The total value of optical

losses in waveguides which were fabricated by $Li^+ \leftrightarrow Na^+$ ion exchange was about 1 dB/cm at wavelength 633 nm.

Our data show that the optical losses increase with decreasing of the wavelength. When we changed the wavelength from 633nm to 532nm the optical losses increase from 1.5 dB/cm to 3 dB/cm in average. The losses also increase with increasing mode number.

The smallest value of optical attenuation was 0.8 dB/cm at wavelength 633 nm in the planar waveguide which was fabricated by using $Li^+ \leftrightarrow Na^+$ ion exchange at substrate GIL49, temperature 600 °C and at time of diffusion 4 min. The minimal value of optical losses in planar waveguides which was fabricated by using $Ag^+ \leftrightarrow Na^+$ ion exchange were about 2.5 dB/cm at wavelength 633 nm and 3.8 dB/cm at wavelength 532 nm.

The scattered light measurement method described above can be used for measuring optical losses of various types of planar waveguides. This technique has the advantage of being nondestructive, rapid, accurate, readily automated, requires no special sample preparation, and is independent on the light coupling efficiency to the waveguide. This measurement method can evaluate optical losses in range from 1 dB/cm to 100 dB/cm approximately.

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# Modeling of Acoustic Waveguides

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The waveguides are very important parts of many acoustical and electroacoustical systems in solids and gases, the description of the systems being based on the Webster equation. In a waveguide with a uniform cross-section we can use the analogy with a homogenous electrical transmission line and consider the system as a T or π two-port network.

We demonstrate in [1], [2], [3] that similar analogue are possible for individual types of tapered waveguides of finite length. The analogy obtained is significant not only in conjunction with electromechanical transducers, but also in physiological acoustics for the modelling of the human external ear canal. In this contribution we shall discuss the family of Bessel waveguides having the cross-section function

$S(x) = \text{const}.x^{2m}$ (1), where for divergent waveguide $m \in R_0^+$.

The wave equation of the Bessel waveguides, by assuming the expression for the cross-section function *S(x)* (Eq. (1)) is

$$\xi'' + \frac{2m}{x}\xi' + k^2\xi = 0$$ (2), where $\boldsymbol{\xi}$ is the phasor of the displacement, $\boldsymbol{\xi}''$ and $\boldsymbol{\xi}'$ are its second and first *x*-derivatives respectively, and *k* is the wave number. The Eq. (2) is a special kind of the equation

$$\boldsymbol{u}'' + \frac{1-2\alpha}{z}\boldsymbol{u}' + (\beta^2 - \frac{\alpha^2-\nu^2}{z^2})\boldsymbol{u} = 0$$ (3), having the solution $z^{\alpha}Z_{\nu}(\beta z)$.

The Eq. (3) has the solution for $\alpha^2 - \nu^2 = 0$ and $\beta = k$, $x^{\nu}J_{\nu}(kx)$ and $x^{\nu}J_{-\nu}(kx)$. Let us write the solution in the form $\boldsymbol{\xi} = \boldsymbol{A}f(x) + \boldsymbol{B}g(x)$ (4)

where $\boldsymbol{A}$ and $\boldsymbol{B}$ are the integration constants and *f* and *g* are the linear combination of the solutions of the Eq. (2). The particle velocity is $\boldsymbol{v} = j\omega\boldsymbol{\xi}$ and the stress $\boldsymbol{T} = -E\boldsymbol{\xi}'$ (in the case of the extensional wave, *E* is the Young modulus).

Let us assume the divergent waveguide of the finite length $l = x_2 - x_1$, $x > 0$, $x \in \langle x_1, x_2 \rangle$ with the input/output velocities $\boldsymbol{v}_1 = \boldsymbol{A}j\omega f(x_1) + \boldsymbol{B}j\omega g(x_1)$ $\boldsymbol{v}_2 = \boldsymbol{A}j\omega f(x_2) + \boldsymbol{B}j\omega g(x_2)$.

The integration constants $\boldsymbol{A}$ and $\boldsymbol{B}$ are as follows

$$\boldsymbol{A} = \frac{\boldsymbol{v}_1 g_2 - \boldsymbol{v}_2 g_1}{j\omega\Delta}, \quad \boldsymbol{B} = \frac{\boldsymbol{v}_2 f_1 - \boldsymbol{v}_1 f_2}{j\omega\Delta}, \qquad \Delta = \begin{vmatrix} f_1 & g_1 \\ f_2 & g_2 \end{vmatrix},$$ (5)

where $g_2 = g(x_2)$, $g_1 = g(x_1)$.

The corresponding input/output stresses are

$$\boldsymbol{T}_1 = -\frac{E}{j\omega\Delta}\{\boldsymbol{v}_1 D_1 + \boldsymbol{v}_2 W_1\} \qquad \boldsymbol{T}_2 = -\frac{E}{j\omega\Delta}\{-\boldsymbol{v}_1 W_2 - \boldsymbol{v}_2 D_2\}$$ (6), (7)

where

$$D_1 = \begin{vmatrix} f_1' & g_1' \\ f_2 & g_2 \end{vmatrix}, \quad W_1 = \begin{vmatrix} f_1 & g_1 \\ f_1' & g_1' \end{vmatrix} \qquad W_2 = \begin{vmatrix} f_2 & g_2 \\ f_2' & g_2' \end{vmatrix}, \quad D_2 = \begin{vmatrix} f_2' & g_2' \\ f_1 & g_1 \end{vmatrix}.$$

The determinants $W_1$ and $W_2$ are the wronskians for $x = x_1$ and $x = x_2$ respectively. The Eqs. (6), (7) describe the waveguide of the finite length as a two-port network. For the input and output forces we obtain

$$\begin{bmatrix} \boldsymbol{F}_1 \\ \boldsymbol{F}_2 \end{bmatrix} = j\rho c \frac{S_1}{k\Delta} \begin{bmatrix} D_1 & W_1 \\ -W_2\left(\frac{P_2}{P_1}\right)^2 & -D_2\left(\frac{P_2}{P_1}\right)^2 \end{bmatrix} \begin{bmatrix} \boldsymbol{v}_1 \\ \boldsymbol{v}_2 \end{bmatrix} \qquad (8)$$

where $S_1$ is the input cross-section of the waveguide, $\left(\frac{P_2}{P_1}\right)^2 = \frac{S_2}{S_1} = \left(\frac{x_2}{x_1}\right)^{2m}$ and $S_2$ is the output cross-section. In an analogy with electrical circuits we shall assume that the above Eq. (8) describes a two-port network whose impedance matrix is

$$[\boldsymbol{Z}_m] = \begin{bmatrix} \boldsymbol{A}_0 + \boldsymbol{B}_0 & -\boldsymbol{B}_0\left(\frac{P_2}{P_1}\right) \\ \boldsymbol{B}_0\left(\frac{P_2}{P_1}\right) & -(\overline{\overline{\boldsymbol{A}_0}} + \boldsymbol{B}_0)\left(\frac{P_2}{P_1}\right)^2 \end{bmatrix} \qquad (9)$$

We see from Eq. (9) that the impedance matrix $[\boldsymbol{Z}_m]$ describes a circuit consisting of T-network and a transformer with transformation ratio $P_1 / P_2$.

If we compare the impedance matrix $[\boldsymbol{Z}_m]$ in Eq. (9) with the corresponding matrix in Eq. (8) we obtain the impedances $\boldsymbol{A}_0, \boldsymbol{B}_0$ and $\overline{\overline{\boldsymbol{A}_0}}$ as follows

$$\boldsymbol{B}_0 = -j\rho c S_1 \frac{P_1}{P_2}\frac{W_1}{k\Delta} \qquad \boldsymbol{A}_0 = j\rho c S_1 \frac{D_1 + \frac{P_1}{P_2}W_1}{k\Delta} \qquad \overline{\overline{\boldsymbol{A}_0}} = j\rho c S_1 \frac{D_2 + \frac{P_1}{P_2}W_1}{k\Delta}. \qquad (10), (11), (12)$$

We can easily expand these considerations to waveguides in a gaseous medium assuming the principle of the duality. It is therefore clear that the analog diagram of the waveguide in a gaseous medium will be topologically dual, when using the same type of analogy, i.e. as a π-network and a transformer.

In contribution the family of the Bessel waveguides was described. These results accompanied by the previous results published in [1], [2] and [3] for the hyperbolic and goniometric waveguides give a useful instrument for the description and the analysis of many systems in sonics, ultrasonics, electroacoustics, musical acoustics, and physiological acoustics [3].

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# An Upgrade of the Calibration Setups for the DAQ Systems

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We report about the newly upgraded calibration facilities that were prepared to tune up frequently used data acquisition systems for the variety of engineering measurements. Our department of Applied Physics has been involved in development of the diverse DAQ system for several past years. We have started with standard systems utilizing National Instruments cards and adequate LabView or BridgeView software products. Then a compact and mobile DAQ system has been developed utilizing widely used Advantec cards. The application programs used were prepared under the TestPoint software [1]. We are currently preparing a new data acquisition system – SCADA (Supervisory Control And Data Acquisition) that uses PVSS software via Canbus input/output interface.

Regardless of the applied software systems, one has to solve problems concerning the quality, stability and accuracy of the input/output interfaces (cards) and connected sensors during the measurements to achieve good measurement results.

We present our latest endeavor to solve some problems of calibrations of the pressure sensors and temperature sensors. Our effort in this area reflects experience from numerous employments of our DAQ systems in our Prague laboratory [2] or also from measurements performed at CERN during the last several years [3].

A versatile pressure calibration circuit has been designed and manufactured. It comprises of pressure vessel, multiple manifolds equipped with Swagelok and Legris connectors and valves, connecting pipes and precise reference pressure sensor (Hg "U"-tube for low pressures and a precise "Druck" pressure transducer for higher pressure values). Several pressure transducers were used for the calibration setup verification: differential pressure transducers „Honeywell" ranging from 0 to 35, 70, 100, and 200 kPa, two absolute pressure transducers Sensortechnics ranging from 0 to 500 kPa and from 0 to 700 kPa and transducer with temperature compensation - SenSym SCX 30DN with range up to 150 kPa.

A temperature calibration set up is based on the modified ASL Metal Block Calibrator. The model B140 was additionally equipped with computer-controlled card for its operation and originally "dry calibrator" was also adopted for fluoroinert liquid bath calibrations. A reference platinum thermometer Tinsley (Pt 25Ω) was read independently through Keithley 195A Digital Multimeter via GPIB interface. Variety of temperature sensors was used to verify basic functionality of the set up. The Pt100 and Pt1000 sensors with two, three or four wire mounting and two NTC type (bead and surface mounted) thermistors were used for verification by experiment.

We have also tested different input/output interface cards for sensor scanning during our experiments. Standard and sensor type oriented cards were employed both for temperature and pressure sensor calibrations for the initial measurements. Later, we have used the versatile cards with individual adaptors – Pigi modules for the connected sensors. This

approach minimizes the number of multiplexed channels and can significantly reduce a number of cards to be plugged into the DAQ system.

Results are presented in the form of Certificates of calibration for the sensors and overall performance of the set ups is also evaluated.

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# Fine Measurement of Dimensions Using Intelligent Opto-electronic Gate

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## Introduction

Measuring dimensions and position of moving objects is problem that we often have to solve in many industry branches. Some of contact-less methods should be the only way that satisfies our exigencies for price, precision, range and speed of measurement. This project deals with optical measuring of object position and dimensions. There are many ways how to contact-less measure object dimensions. One of the most accurate methods is optical measuring of object dimensions and position. The measuring set should be constructed as follows. The measured object is lightened by light source. Behind the object is placed light detector that evaluate dimension and position of shadow behind the object. Probably the simplest method is using only one light source and only one detector. This optical gate has only two-level output: Object is/isn't present. These simple sensors are very often used to control industry lines or are used as object counters. The main disadvantage of this method is, that we don't have any information about the position and dimensions of the object. Particular solution is using more light sources and detectors.

## Opto-electronic Gate with CCD Line Sensor

When we need high precision measurement, we can use array of fotodiodes integrated in *CCD* Line sensor. The opto-electronic gate with *CCD*-Line sensor uses the video-signal from *CCD* to determine the position and object dimensions from the shadow caused by the object. The electric construction of developed opto-electronic gate is very simple. The whole meter contains only three basic parts: RISC Microprocessor *AVR* AT90S8515, fast A/D converter AD9280 and *CCD* Line sensor ILX703. There are also special outputs to drive a set of light sources. These features provide this intelligent meter for industry use, thanks to low-costs and small dimensions (70x70mm). Integrated microprocessor is used not only for video-processing, but also for configuration and easy setup.

*CCD* Line sensor contains 2048 sensitive pixels. The size of each pixel is 14um x 14um. The output voltage for each pixel corresponds to its illumination. The developed opto-electronic gate processes video-signal from *CCD* Line sensor in two ways. For the first the video-signal is compared with voltage level in ***analog comparator*** which is built-in *AVR* microprocessor. This binaryzation of video-signal is used for very fast searching of optical edges. The other way of video-signal processing resides in ***digitalization*** using the fast A/D converter. The 256 values of digitalized video signal are stored in internal RAM memory and later are used for other computations. The main disadvantage of binaryzation is, that the recorded value depends on compare level. Therefore we compute the accurate position of optical edge from stored values using geometric interpolation of optical edge. The computed value doesn't depend on the compare level. The other way of processing of stored values is computing the center of a part of the video-signal.

**Main Features**

Intelligent opto-electronic gate is equipped with feature automatic regulation of integration time depending on the level of illumination. If the illumination is too small the exposition period must be increased. Meter allows adjustment of integration time in very wide range (from 125ns up to 32ms). The other advantage of intelligent opto-electronic gate is, that it allows automatic adjustment of compare level. The meter can directly control processes in stand-alone mode via two fully programmable optical isolated outputs . Dedicated PC software allows user fast and easy control all functions of opto-electronic gate. Developed Software is able to display glitter profile of whole ***CCD*** sensor or a detail of sensor's parts. Software allows user configure the gate for stand-alone measurement. Setup values are stored in EEPROM in ***AVR*** microprocessor. Meter can be used with or without lens for simple measuring.

**Thickness measurement**

When we measure thickness of the object we are sometimes not able to ensure constant distance between CCD sensor and measured object. In this case we have to use some method, where the measured value doesn't depend on the distance between object and sensor. One of these methods resides in illumination of the object with parallel beams. Developed source of parallel beams is constructed from light point source (laser diode SLD6505), which is located in the focus point of lens. These parallel beams illuminate the object and from the shadow on CCD we is computed accurate position and dimensions of the measured object. We have to assure that beams are really parallel, because if they aren't parallel the measured dimension would depend on the distance between the CCD and object.

The second method resides in illuminating of the object with two light point sources in turns. Two light sources are located above the object in the same distance from the CCD sensor. The distance between these two sources is known. In the first turn is switched on the first source and the position and dimension of the shadow is recorded. In the second turn is switched on the second light source and first source is switched off. The second dimension and position of the shadow is recorded. From these values and from conformable triangles is computed not only the dimensions (for example diameter) but also the distance between the object and CCD sensor.

**Position Measurement**

For measurement of the position in very wide range, I have implemented the triangulation method. This simple and very useful method is based on illumination of the object with a laser beam. This laser sign (on the object) is scanned with the intelligent opto-electronic gate with CCD in configuration with lens. The laser beam contains with optic axis of the lens angel $\alpha$. The position of the object is calculated from the position of the laser sign on CCD. On the angle $\alpha$ depend the precision and the range of measurement.

Opto-electronic gate is able to measure position in two normal directions using two punctual light sources, that was described before. The advantage of this method is the linearity of 150ppm from range. The disadvantage is, that the range is limited by the dimension of used CCD line sensor (for ILX703 it is about 24mm).

Developed gate should be used with convenience for precision industry measurement.

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# Signal processing in CNS systems

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Avionics systems of next generation are based on CNS (Communication, Navigation and Surveillance) systems. These highly integrated systems are fully digital and implement modern methods of signal processing.

Various modern radio communication services use the frequency spectrum very intensively. The main requirement on the new radio communication service or radio navigation service is ability to operate in this exposed environment. This means, that the service must not jam other services and the other signal do not have any affect on current service. The high level of communication and navigation service must be guaranteed in avionics CNS systems because of safety.

One of the fundamental functions of CNS system is generation of the digital modulated signal for communication and navigation purposes. The generation of the modulation signal in CNS systems is discussed in this contribution.

The band pass signal $s(t)$ can by represented by complex envelope $\tilde{s}(t)$ and frequency offset $\omega_c$

$$s(t) = \mathrm{Re}\left[\tilde{s}(t)e^{j\omega_c t}\right] \quad (1)$$

Easy and common implementation of generation of digital modulated signal is based on generation of the complex envelope. The complex envelope signal is generated in digital modulator as a pair of in-phase I and quadrature-phase Q signals.

**Analog Approach**

Complex envelope signal generated in modem is transformed to analog signal, which is applied to the quadrature modulator input. The digital modulated signal at intermediate frequency is at the output of the modulator. The important parameters of the quadrature modulator besides operating bandwidth are carrier rejection, sideband rejection, harmonic suppression, and conversion loss. These parameters are influenced by the non-linearity, amplitude and phase un-balance of the quadrature modulator parts.

**Digital approach**

Digital quadrature modulator, which is called Quadrature Digital Upconverter consists of interpolation filter, DDS (Direct Digital Synthesizer) and complex multiplier. The sine and cosine discrete signals are generated in the DDS. Cosine signal is multiplied by discrete I signal, sine signal is multiplied by discrete Q signal. Both output signals are then added together. This resultant signal is converted to analog signal in D/A converter. Discrete in time analog signal is passed to the low-pass or band-pass filter to be transformed to analogue continues time signal.

Quadrature Digital Upconverter can by theoretically used for generation of the signal with bandwidth equal to one half of the $f_{clk}$ DDS clock frequency.

Quadrature Digital Upconverter does not suffer from problems like analog quadrature modulator. For example, in analogue quadrature modulator there is problem with low carrier

rejection, amplitude and phase unbalance and harmonic suppression. In the case of Quadrature Digital Upconverer these parameters are significantly better.

Unlike in analog circuit, spurious emissions appear in the spectrum of the signal generated by Quadrature Digital Upconvertor. These spurious emissions are typical for DDS. Level of these emissions depends on the resolution of the build in arithmetic and on resolution and linearity of the D/A converter

**Test Application**

The Quadrature Digital Upconverter AD9857 was applied in the modem of the aviation Very high frequency Digital Link (VDL). This digital link is intended to replace existing aviation communication system. These links will be used for digital voice and data communication for both ATM (Air Traffic Management) and non-ATM applications like DGNSS (Differential Global Navigation Satellite System) correction broadcast.
VDL links operate with channel spacing 25 kHz. VDL mode 2 and 3 use Differential 8 state Phase Shift Keying modulation (D8PSK) with Raised Cosine Spectrum modulation pulse. Roll off factor is 0,6. Bit rate is 31,5 kbit/s.

Aviation standards allow very low adjacent channel emission because of payload of the VHF air band. For example, the amount of power from VDL airborne transmitter under all operating conditions when measured over the 25 channel bandwidth of the first adjacent channel shell not exceed 0 dBm. When 20 W transmitter power is considered, the power emission to the first adjacent channel shall be 43 dB below carrier. The attenuation of the second adjacent channel should be at least 68 dB.

**Experimental Results**

Experimental results confirm excellent carrier rejection of the Quadrature Digital Upconverter. No carrier residual is observed. The Harmonic suppression is excellent too. No harmonic components occur in spectrum of the modulated signal. The small phase and amplitude unbalance are guaranteed by principle of operation.

Some disadvantage of Quadrature Digital Upconverter is spurious emissions. These spurious emissions can be removed by band pass filter. In the case of wide band systems the spurious emissions cannot be generally removed.

The Quadrature Digital Upconverter is good choice for narrow band system where power consumption is not critical parameter. The progress in technology probably enables to reduce spurious emissions in the near future.

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# Lasers with Thin Strained InAs Layers in GaAs Electroluminescence and Photoabsorption at Elevated Temperatures

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Semiconductor high-performance lasers which are emitting light in the near infrared region 1.05–1.55 μm are strongly required for applications in $SiO_2$-based fiber optical communication systems. Nowadays, the development of quantum-size active structures and passive elements of lasers in technology based on InP substrate is relatively very expensive in comparison with the well-established GaAs-based technology. This cheaper and more advanced technology can use thin strained InAs layers or InAs quantum dots in the laser active region to extend the emission wavelength towards 1.3 μm. However, large fluctuation of InAs quantum dot size and shape makes it difficult to achieve this emission wavelength with a good efficiency and does not allow stable operation at elevated temperatures. The application of thin strained InAs layers as an active region in the GaAs waveguide seems to be more promising for preparation of highly efficient and reliable near infrared lasers.

Recently, we have shown that emission energy of the lasers with thin strained InAs layers can be varied by the configuration of the active region [1]. Three types of InAs/GaAs structures for laser active layer were investigated: single thin strained InAs layers with a different thickness, different number of identical thick InAs layers separated by the GaAs layer of the same thickness and seven identical 0.5 nm thin strained InAs layers separated by GaAs spacers of variable thickness. The lasers with active region formed as a series of seven identical 0.5 nm thin strained InAs layers, separated by 5.3 nm thick GaAs spacers exhibited the longest emission wavelength together with the lowest threshold current density ($J_{th}$) [2]. The long emission wavelength (~1100 nm), the low threshold current density (~0.5 $kAcm^{-2}$) and high breakdown voltage of the PN junction were reason while we focused our further research on these structures. Compared to our previous studies [1–3], we were interested in their electroluminescence (EL) and photoabsorption (PC) properties at elevated temperatures (above 25 °C).

Lasers with thin strained InAs layers in GaAs matrix surrounded by AlGaAs waveguide were prepared by Low Pressure Metal-Organic Vapor Phase Epitaxy (LP MOVPE) technique in the MOVPE laboratory at the Department of Semiconductors, Institute of Physics, AS CR. Growths were made in AIXTRON 200 MOVPE machine in horizontal low pressure reactor using TMGa (-10 °C), TMAl (+16 °C), TMIn (+16 °C), $CCl_4$ (-10 °C) precursors in standard bubblers, and DETe (99 ppm in Ar) and 100% $AsH_3$. Pd diffused $H_2$ was used as a carrier gas with the total flow of 8 slpm. The growth process was carried under the total reactor pressure of 70 mbar at temperatures 650 °C and 500 °C. Because of the Al containing passive layers, the growth temperature of 650 °C was used for $Al_{0.3}Ga_{0.7}As$ emitters as well as GaAs buffer and contact layers. For the growth of thin strained InAs and surrounding GaAs waveguide layers the growth temperature was decreased to 500 °C. (100) GaAs substrates doped with Te to $n=1–2\times10^{18}$ $cm^{-3}$ were used, as well as standard wet chemical etching before growth. After

growth, the substrate was ground down to 120 μm, and ohmic contacts Au/Ni/Ge and Cr/Au were evaporated and alloyed on the N-type substrate and P-type capping layer, respectively. Cleaved chips 400×250 $\mu m^2$ were soldered on coaxial holders using In-based solder.

PC and EL spectra and Watt-Ampere (W-A) characteristics of the lasers were measured in the temperature range from 25 °C to 105 °C in the Spectroscopy laboratory at the Department of Microelectronics, FEE CTU. Possible existence of quantum dots was checked by photoluminescence measurements on the etched samples. Photoluminescence signal corresponding to the emission from quantum dots was not observed. W-A characteristics were measured in the current range from 300 mA to 2800 mA. All light emitted from the front mirror was measured by optical power meter with Ge detector. The EL signal in the range of energies from 1.05 eV to 1.25 eV was analyzed by a grating monochromator in spectral range 1000–1200 nm (with resolution 0.2 nm) and detected by InGaAs detector. Both the EL and W-A characteristics were measured under the same pulsed current excitation. The pulse width of the excitation current was set to 200 ns and the pulse repetition rate to 10 kHz. The PC spectra were measured with different polarization of the incident light propagating parallel to the laser structure. The light in the wavelength range from 1.05 eV to 1.65 eV was provided by a tungsten lamp, dispersed by a grating monochromator in spectral range 750–1200 nm (with resolution 1 nm) and focused on the laser mirror. The resulting PC spectra were detected using conventional lock-in technique corrected with respect to the system response.

PC and EL spectroscopy was applied for the interpretation of electronic states in the active layer of prepared lasers. The results of the PC polarization dependent spectra show on two fundamental transitions between electron and heavy hole or light hole states at 1.16 eV and 1.24 eV at room temperature, respectively. According to W-A characteristics measured at 35 °C, the prepared InAs/GaAs lasers can be divided into two groups: the group A ($J_{th} < 0.5$ $kAcm^{-2}$) and B ($J_{th} > 1$ $kAcm^{-2}$). The peak of the stimulated EL of lasers from both groups switches to higher energy with increasing operating temperature and excitation current. This switching appears already at room temperature for lasers of group B while for group A the operating temperature must exceed 90 °C. The switching of the lasers emission wavelength is also accompanied with an appearance of several kinks on laser W-A characteristics. The difference (40 meV approx.) is lower than that corresponding to the difference between e-hh and e-lh transition (~80 meV) and the light emitted from the lasers exhibits only TE polarization (e-hh transition). This indicates that the observed wavelength switching is probably connected with a variation of the morphology of the laser active layer.

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# New ADC Transfer Ethalon

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***Abstract:*** *There is no reference digitizer or testing method with a significantly high precision for the evaluation of testing systems designed for dynamic testing of ADCs and AD modules, so only comparative measurement comes into consideration. Therefore, there was a portable high stable reference AD box designed, which is convenient for comparative measurements, and the first prototype was realized. The special interests of this design were high stability and minimization of internal disturbance. The improved model of the AD box is based on the first version. It allows acquiring much more samples; sampling rate is essentially higher and the real-time histograms could be counted. Some further innovations were also made. The new structure and functions are described bellow.*

To achieve greater flexibility and minimize internal disturbances, a modular solution was proposed. The designed device consists of two boxes: the ADC box with a high-quality AD converter, signal conditioning circuits in a separate module, and with control circuits for an ADC timing and a data transfer to a PC or a logic analyzer. The measured data could be transferred using a differential LVDS connection, standard high-speed RS-232 line or TTL drivers. The other box serves as a power supply with sophisticated battery recharges, which could even work while measuring. The device could be controlled from the front panel or from a PC using special software.

## Input module with an AD converter

To minimize all disturbances, there is the exchangeable module with an AD converter and signal conditioning circuits placed into a metal shielding case. It is also thermostated at an adjustable temperature, galvanic isolated and supplied from batteries to be protected from external influences.

An input circuit of a protective amplifier and active antialiasing filter is placed between the input BNC connector (galvanic isolated from the case) and the ADC. The high-quality commercial ADC with the successively approximating AD977A (16–bit/200 kSa/s) was used in the prototype for testing the functionality of the whole device.

## Control and data transfer part

Instead of many discrete logical circuits used in the prototype, the modern FPGA (Field Programmable Gate Array) was used. The main gain of this solution is in the reconfiguration of the device even when the PCB is already completed.

An internal crystal oscillator or external signal from the front panel could be used as a source of sampling clock. This reference frequency is divided at first by an adjustable ratio 1 – $2^{32}$. Since some ADCs require a certain width of the starting pulse, this function was also implemented. Rising or falling edge of the starting pulse and of the EOC signal (End Of Conversion) could be chosen as well.

To verify the data transmission from the control part, a test data generator was implemented. Measured data are sent to TTL or differential LVDS drivers or in case of histogram mode or RS-232 transfer (up to 115 kbit/s with hardware handshake) they are separately saved into a SRAM (up to 256 kSa).

The instrument could be controlled either from the keyboard and the display on the front panel or through the serial line from a PC. There is also shown an actual temperature of the ADC board on the display. A buzzer informs about some important events such switching on the device or start of measuring. All settings are stored in EEPROM and it is not necessary to set them up again after shutting the power down.

**Power Supply**

Circuits of the power supply part are designed as two separate modules – transformers, batteries and rechargers placed in the separate case and stabilizers placed in the case with the AD module and the control part. It brings maximal disturbance rejection on the power supply wires for the AD module.

6 LEDs on the front panel of main case indicate whether the 6 supply voltages are connected and high enough for the correct function of the device. The $7^{th}$ red LED informs when the heating of the AD module is on.

Batteries' recharging is driven by intelligent MAX712-713 circuits. They guard and follow the time and rightness of each recharge cycles and watch the temperature of accumulators. 5 LEDs are switched on during recharging of all 5 batteries. The recharge time is not more than 1.5 hour and the batteries could supply the instrument with power at least 3 hours. It is possible to work even during recharging, however, only the battery power supply (without recharging) should be used during precise measurement.

**CONCLUSION**

The designed device enables to compare results, which were achieved using different methods or different systems for testing of dynamic parameters of ADCs and AD modules. It is advantageous especially for tests using input signal with frequency above 20 kHz, when the quality of testing signal is usually not warranted for 16-bit AD modules.

Functionality of this instrument was proved with the first comparative measurements executed in two top laboratories. Thanks to universal and modular design of the device, other AD modules can be used to extend its frequency range. Results all test (which have been already executed) will be published.

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# Modeling of Acoustic Systems

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Modeling of acoustic and mechanical systems is based on the formal similarities between basic electrical and acoustical relations or between electrical and mechanical relations respectively. This method is useful for wide range of applications. In this contribution authors are presenting particular applications of this method for modeling of miniature silicon microphone as an example of acoustical sensors modeling, modeling of planar electrostatic speaker as an example of acoustical actuators modeling and modeling of outer human ear canal as an example of wave-guides with variable cross-section modeling.

**Acoustical Sensors**

First part of this work deals with modeling of miniature silicon microphone. Compared to conventional microphones those devices have potential advantages of small size, high reliability and reduced parasitic capacitance. Furthermore, signal-processing circuits can be integrated on one chip with a microphone.

A thin circular plate clamped at its center, a thin circular plate clamped at its circumference and a thin rectangular membrane have been used as a moving electrode. Equivalent mechanical circuits of the first two types have been derived from numerical analyzing of plates vibrating. Equivalent mechanical circuit of the third type has been found in [6]. Equivalent mechanical circuits of the further acoustic and mechanical elements of a microphone, i.e. an air-gap between moving electrode and back-electrode, an equalization slots in a moving electrode, holes in a back-electrode and a back-volume, have been found in [5] and [6]. With the equivalent circuits of all acoustic and mechanical elements, an equivalent circuit of whole microphone has been built up.

A simulation program, which has been made in Matlab, allows the calculating of the curve of a microphone sensitivity modulus. Changes of a sensitivity modulus can be easily analyzed by changing of geometric and physical parameters of a microphone.

**Acoustical Actuators**

Next part of this work is presenting the modeling of a planar electrostatic speaker. This electrostatic transducer is able to work in sonic and ultrasonic frequency domains.

Planar electrostatic speaker has a terfol diaphragm which is located between two fixed electrodes. The diaphragm and fixed electrodes are separated between each other by spacing foils. The spacing foil is perforated in the way that only perforated areas allow the moving of diaphragm. The fixed electrodes are uniformly perforated by a large number of small holes. In this part a theoretical equivalent model of this transducer is introduced. The real example of planar electrostatic speaker has been made and measured.

**Acoustical Wave-guides**

Third and last part of this work copes with the modeling of outer human ear canal. It is example of wave-guides with variable cross-section. It is assuming rotational symmetry wave-guides having straight axis and various type of cross-sectional function (conical, hyperbolic, goniometric) in gaseous or solid states.

Equivalent circuit of wave-guide with constant cross-section is symmetric T or Π-type network. In case of wave-guide with variable cross-section the equivalent circuit is

asymmetric T or Π-type network with an ideal transformer. Outer human ear canal can be expressed as a cascade of several wave-guides with various cross-sectional functions. The goal is to find an algorithm which would be able to build up such a cascade from a geometrical size of ear canal. This part of the project tries to solve it. Measurements on cadaverous specimens have been made in order to obtain the transfer function of ear canal.

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# Analysis and Verification of Leaky Waves on the Conductor - Backed Slotline

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This paper describes properties of the dominant and leaky waves on the conductor-backed slotline (CBSL). Leaky waves cause an undesired crosstalk in MIC but on the other hand they can be utilized for an antenna design. Leaky wave antennas have a low profile as do the patch antennas, but operate in a wider frequency band. That advantage appreciates designers of wideband communication systems. Leaky waves on the slotline have been widely discussed for more then thirty years. Dispersion characteristics of the leaky wave propagated as the parallel-plate mode on the CBSL are published in [1-4]. The method of the propagation constant calculation and visualization of the electric field distribution on the transmission line is presented. Identification and new interpretation of the dominant quasi-bound wave on the CBSL is included. My paper now summarizes new findings concerning the surface and the space leaky wave radiating from the CBSL.

The propagation constant is calculated by the method of moments modified as in the Galerkin testing procedure in the spectral domain. I assume unlimited line size in the longitudinal and transversal directions and infinite metalization conductivity. The method of moments, based on the Fourier transform, is applied in the spectral domain where the propagation constant is determined by solution of the system of the linear equations. The electric field distribution follows from the backward Fourier transform. The integration paths occurring in formulae specifying either propagation constant or field distribution must be chosen properly with respect to the investigated wave.

Verification of the dominant waves and the leaky waves on the CBSL were published in [4]. We designed the CBSL on an easily available plexiglass substrate with relative permitivity 2.6, substrate width 6 mm and variable width of slot. We applied active radiometry for the wave verification. A simple dipole, movable over the substrate fed by a noise diode in the middle, emits radiation. A radiometer receives the signal. We simultaneously used a second way for the measurement. The field is detected by a sliding monopole while a narrowband tunable generator feeds the line. The monopole can be movable over the substrate. In both ways we measure the field magnitude in the relative units, not the phase.

The paper presents of waves on the conductor-backed slotline. The dominant quasi-bound wave on the CBSL has been revealed and the leakage from this line is introduced. These waves have been partially identified by active radiometry. Radiation from the CBSL in the half space becomes an advantage for special antenna applications. The paper would stimulate discussion and better understanding of the field behavior on these uniplanar printed-circuits lines.

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# Fiber Optic Waveguide With Liquid Core

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Fiber optic waveguide with liquid core, typically consisting of small diameter tubes capable of guiding light through a liquid core by total internal reflection, are used in a variety of spectroscopic applications including fluorescence spectroscopy, Raman spectroscopy, optical absorption applications, luminiscence detection, evanescent wave spectroscopy and gas sensors. Liquid core optical fiber waveguides are capillaries that contain a liquid core – liquid sample for spectroscopic analysis. Most early work involved drawn borosilicate glass or fused silica capillares, which have excellent optical clarity and surface roughness, enabling them to guide light with very low loss (<0,01 dB/m) through transparent liquid cores [1]. The most significant drawback of silica based capillares is that their reflactive indices are higher than those of most common liquids. Since total internal reflection occurs only if the refractive index of the core is greater than that of the capillary tubing, conventional glass and fused silica waveguides are limited to use with high refractive index liquids such as aromatics, carbon disulfide, and various halogenated compounds [2]. This problem has been recognized, and a number of fiber optic liquid core waveguides capable of working with liquids of lower refractive index have been developed. Most of these fall into one of following three categories:

- glass or fused silica tubes coated with reflective metals
- tubes made of or coated internally or externally with low refractive index polymers
- bare glass or fused silica tubes that have been cleaned to enable light transmission through total internal at the outer (glass-air) interface

First category, metal coated or metal tubes are used routinely as waveguides for microwave and infrared radiation. In the ultraviolet and visible region they have high attenuation. For example 250 dB/m at 632 nm for 340 um i.d. and 520 um o.d. externally silvered tubes filled with water [3]. Glass tubes coated internally with silver [4] and externally with silver or aluminium have been evaluated for absorption applications.

Second category, plastic and plastic coated tubes have been investigated by several groups. Most of this work has involved low refractive index perfluorinated polymers such as poly(tetrafluoroethylene) (PTFE), poly(tetrafluoroethylene-co-hexafluoropropylene) (FEP), and poly(tetrafluoroethylene-co-perfluoropropylvinyl ether) (PFA). Typical refractive index values for these materials are 1,35; 1,34 and 1,35 for PTFE, FEP and PFA, respectively. Even more attractive than these materials are the amorphous copolymers of tetrafluoroethylene and 2,2-bistrifluoromethyl-4,5-difluoro-1,3-dioxole sold commercially as Teflon AF, which have lower refractive indices than water. Teflon AF 1600 have refractive index $n_D$=1,31 and Teflon AF 2400 $n_D$=1,29. The refractive index of Teflon AF 2400 is lower than that of virtually all standard temperature and preasure liquids, and it is near theoretical minimum for organic polymer predicted by Groh and Zimmerman. Tsunoda and co-workers archived losses as low as 0,57 dB/m at 632,8 nm using 900 um i.d. FEP tubes filled with 99,5% ethanol ($n_D$=1,36).

Third category is uncoated borosilicate glass or fused silica tubes in which light is guided by total internal reflection at the outer glass-air interface have been used in Raman, absorption and fluorescence applications. This type of waveguide have the advatages of high numerical aperture and the ability to guide light through any transparent liquid. In addition, they have been show to guide light through water with relatively low loss. For example Tsunoda

demonstrated loss 8 dB/m at 632,8 nm for 215 um i.d. and 360 um o.d. borosilicate glass tubes filled with water. Uncoated glass have a number of disadvatages. Since their loss charakteristics are determinated in large part by the condition of their outer surfaces, they must be cleaned prior to use, kept clean during use, and handled carefully to avoid scratching.

The fiber optic waveguides with liquid core are development at department of microelectronic, CTU in Prague. For long pathlength absorbance spectroscopy measurement the Teflon AF waveguide capillary cell for low refractive index liquids was designed. For ultraviolet and visible region this type of fiber optic waveguide with liquid core was designed. This liquid core waveguide can be used to extend the sensitivity of conventional absorbance spectroscopy by two or more orders of magnitude in chemical trace analysis.

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# Educational Program for Numerical Methods in Electromagnetic Field

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This paper describes the educational program that will be used in the course of Numerical Methods in the Electromagnetic Field. The program is applied to microwave technology. The objective of the program is to help students at both masters and PhD. Level to gain a deeper understanding and mastery of the subject.

We have created the interactive educational program in Borland Builder C++. The program has the form of a standard textbook and is divided into six logical units: Introduction, Method of Finite Differences – FD, Method of Finite Elements – FEM, Methods of Moments – MM, Tests, and Applications of the Methods in Microwave Technology.

The program is aimed at applications in microwave technology, namely at the analysis of microwave transmission lines, which are the main building blocks of all high frequency circuits. The program describes three methods: the method of finite differences, the method of finite elements and the method of moments. The method of finite differences has been chosen due to its simple principle and easy comprehensibility. It introduces the student to the subject simply and he or she is then able to master even the more complicated methods. The two other methods have been chosen as they are frequently used in the investigation of microwave circuits.

The most important part of the program is the educational part, which describes the particular methods. Texts with pictures and mathematical equations describing the methods are presented on the screen directly from the program, using the special editor. The testing part checks the student's knowledge. The tests consist of several questions testing the most important items studied in the course. Besides the educational part, eight presentation programs are appended, which analyze selected microwave transmission lines (microstrip line, coplanar waveguide, slotline, metallic rectangular waveguide) using the presented methods. Line characteristics, such as the propagation constant and the characteristic impedance, are calculated by these programs. The distribution of the electric field or of the potential in the transversal plane is carefully plotted. Some of these programs were presented in [1, 2].

The program is accessible via the www page, where basic information about the project is also presented. The program can be downloaded freely from this page to the reader's computer. The internet address is:

http://web.cvut.cz/fee/k317/projekty/frvs_nm/index.htm

This address is accessible from the main page of the Department of Electromagnetic Field of the Faculty of Electrical Engineering CTU:

http://web.cvut.cz/fee/k317/

It is necessary to click on "Ostatní projekty" – "Výukový program numerických metod". The program is compressed by the ZIP compressor and can run on a standard PC with the Windows 95/98 or higher operating system.

The program created under this project is a useful tool, which gives students a better understanding of these numerical methods. The methods have recently been gaining great

importance, not only in microwave technology, but also in many other technical fields. The subroutines included in the programs can be used not only for educational purposes, but also as a simple tool for analysis and design of the basic transmission lines used in microwave technology.

We aim to develop the program further in the future according to requirements raised and according to advances in technology. We propose to display even the source codes of the program for those who are interested in improving or modifying the codes by themselves.

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# Multichannel Receiver for Adaptive Antenna

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Design of multichannel receiver for adaptive antenna is described. The adaptive antenna systems belong to group of the phased antenna arrays. They are often used in order to form the antenna radiation pattern, to increase antenna gain and directivity, to electrically deflect the antenna pattern, etc. Adaptability of the systems enables automatic adjusting of the antenna patterns according to varying conditions.

Forming of the antenna radiation pattern can be realized by weighting of received signals. There are three possibilities: firstly by microwave attenuators, phase shifters and combiners between the antennas and the receiver; secondly by numerical weighting behind the digital receivers (one receiver per one antenna); and finally by combination of previous methods. The most important part of the second case of weighting is multichannel receiver with digital output of complex envelopes (I/Q components) of received signals. Numerical weighting of received signals allows parallel processing of several radiation patterns. Adaptability and parallel processing enables increasing of the capacity of base stations and gain of the antenna system. Thanks to these properties, a transmitted power of mobile phones and their energy consumption can be decreased. In addition, the influence of multipath propagation can be minimized.

This multichannel receiver consists of several single-channel double conversion superheterodyne receivers with common synthesized oscillators. The first synthesized oscillator is used for tuning of microwave part of the receiver and the second oscillator is fixed and used for the quadrature demodulation. There is a bandpass filter at the input of the receiver; witch determines its work band. The following parts are low noise amplifier, 1. mixer, IF filter, IF amplifier and finally quadrature demodulator. Quadrature outputs of the receiver will be converted to the digital signal by ADC and processed in the computer. Input frequency range of the receiver is minimally 1800 – 2000 MHz. The design of the input filters is also published in [2], [4]. The description of the multichannel receiver is in [1].

This multichannel receiver can be used for other purposes, for example in education of antennas and radio propagation, for my and college's doctor-thesis and for the new problematic of the multidimensional propagation (MIMO).

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# Project: INDECS,

# The Core

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The purpose of the core part of project INDECS is to create a flexible software basis for driving a neutron diffractometer. The software should operate somewhere within the range between hardware and directly above system level. It should be flexible enough to allow easy adaptation for various hardware of similar functionality and to many possible additional devices that may be of interest for the diffraction experiment (e.g. a cryogenic system). It should also be able to communicate with outer world over the local network and/or internet. This communication should involve transfer of measured data and driving commands for remote control as well.

Driving such experiment requires quite precise timing in many cases of interaction with hardware. To assure such timing the main part of the INDECS core runs under hard real-time operating system. Among hard real-time operating systems, RTLinux was chosen for its accent on speed, its compatibility with classic Linux operating system and thus great amount of available software and finally for its free availability.

The whole INDECS software consists of the following main parts: The *Core Server* which performs the necessary steps in directly driving the hardware devices of the diffractometer and obtaining measured data and which is the subject of this work. The *Control Server* which is responsible for further processing of measured data and controlling the Core Server. The *Application* (remote or local with respect to the Control Server) for interaction with user.

The base of the Core Server forms an ordinary Linux daemon process called *indecsd*. For better flexibility most executive parts of the Core Server are encapsulated in dynamically loadable modules either as shared libraries or as kernel modules (which applies mainly to the real-time processes). The idea of the RTLinux is to divide all of the real-time aware tasks into two parts. A small and simple one with hard real-time constraints running as a real-time process and a larger more sophisticated one running as a standard Linux process. So there is an effort to make the real-time part as small and as simple as possible. On the contrary, there is also an attempt to make the software time-stable and reliable. Thus the compromise has to be considered so that all time critical events (especially in matters related to the data collection and device control hardware) are handled by the real-time processes and the classic Linux processes take care of all the other stuff. There is however one exception and that is (in our case) the raw data received from the detectors ADCs. Because the rate of collecting the measured data can be pretty high, there may not be enough time for the basic preprocessing and analysis of the data in the non-real-time process (especially on slower computers), and so in this case it has to be moved to the real-time part to assure we get enough time to do the job.

PSD Acquisition Path (PSDAP) is in fact the most important part of the whole Core Server and perhaps even the whole INDECS project. It is a chain of hardware and software modules maintaining the data acquisition from the position sensitive detector (PSD). Input of the PSDAP is the data sampled by the analog-digital converters (ADCs) connected to the detector

output. To obtain the position information at least two ADCs are required no matter what method is used for position decoding (whether it is amplitude based, time based or any other). That's also the case of a linear PSD which is our main object of interest. For better precision and simplicity of comparison of sampled data we assume that the ADCs from one detector sample simultaneously. Output of a PSDAP is a histogram of collision events of measured particles with the PSD. There are three types of PSDAPs. The Indirect Software PSDAP (ISPSDAP) and Direct Software PSDAP (DSPSDAP) are used when the output of the detector is connected directly to the computer hardware (usually some data acquisition card with the ADCs). All the basic data preprocessing and analysis (peak analysis and position detection) is done in the computer by the modules in the appropriate PSDAP. The two approaches differ only in the (above mentioned) placement of the time-critical peak analyzer, which in DSPSDAP is placed in the non-real-time process, while in ISPSDAP it is located in the real-time process. Another approach represents the third one called the Hardware PSDAP (HPSDAP), which takes place when an external position detecting hardware is used, connected to the computer usually by some of the external data bus (i.e. IEEE-488 GPIB, USB or similar). The computer then only needs to read the histogram through this bus from the histogramming memory and so most of the work is done outside the computer. This approach is preferred when there is a larger amount of detectors connected to one computer, because each of the ISPSDAPs or DSPSDAPs requires a heavy data bus (usually PCI) load and computing power. On the other hand it allows collecting some additional statistics from the data.

Similar to the PSDAPs are the SSD Acquisition Paths (SSDAPs), they can also be considered a special case of the PSDAPs. The difference is that, they serve to collect data from the single side detector (SSD), which does not require position detection and thus require only one ADC per detector. Again there is a Direct and Indirect Software SSDAP (these are almost the same as in case of the PSDAP) and instead of the HPSDAP here is a Counter SSDAP (CSSDAP), which uses a simple hardware counter to count the collisions on the detector.

Core Server itself doesn't contain any code that would really drive the diffractometer step by step. It only includes a variety of preprogrammed steps that helps to do so and the ability to accept commands performing those steps. Furthermore it is of a modular conception and allows to extend itself to understand new devices if needed. The commands are sent to the Core Server from the Control Server. The processing of the received commands is performed by the Execution Engine (EE) module, which is the main part of the *indecsd* daemon process. It accepts the commands and either directly processes them or passes them further to the device drivers, acquisition paths and so on for processing. For easier driving EE can either process the commands directly as they come, or load the whole sequences of code and then execute it on its own without the need of an external connection. However direct commands can still be executed, so that for example the progress of the measurement can be monitored.

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# High Temperature Sensor Front-End for Space Facility

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The work is oriented to accuracy measurement high temperatures in furnace for special technological process. Exactly it is about measuring temperatures to about 1500°C with resolution perhaps 0.05°C. Measurement is performed with help measurement board: the first part is working with analog signal and the second part is working with digital signal.

Measurement process is executed with thermocouple and construction measurement board. The board is contained two amplifier links, a multifunction circuit with a thermal resistor, an analog filter, a voltage follower, an A/D converter, a reference of voltage, an operate amplifier, a voltage regulator of input voltage and stabilization and safety passive devices.

Two amplifier links are used for amplifier outputting voltage of thermocouple. The first is constructed of two preamplifiers and one differential amplifier and the second is created of one instrument amplifier. Application various amplifier links is done with jumpers.

On the board there is placed the multifunction circuit. This is used for power supply thermal resistor, which serves for measuring temperature of cold end. The part of multifunction circuit behaves emergency power supply. Constant current is flowing through thermal resistor, where creates voltage. This voltage gain is made in the other part of multifunction circuit.

On the board there is filter too with accuracy frequency knee. His function is lowing voltage noise on the input voltage signal.

Optimal run of amplifier links is ensured by the voltage followers too. These followers are between amplification stage and A/D converters. Because there are two amplifier links for two voltage signals, there must be two filters and two voltage followers too. This signal is going to the A/D converter.

Two 24-bit A/D converters are applied because of its proposed high accuracy of measurement. The first A/D converter is used for voltage signal from the thermocouple and the second A/D converter is applied for voltage signal from the thermal resistor. The accuracy measuring process is proposed only 17 bits from 24 bits.

On the circuit there are voltage references too. The firstly they are used here for setting voltage input of A/D converters. Secondly they are used for adding 0,5V potential to the ground on the input A/D converters. For this function it is necessary to use operate amplifier too. Operate amplifier is hooked a voltage divider.

Accuracy power supply of integrated devices is protected with the voltage regulator and the stabilized capacitor. The protection of A/D converter is created by connected diodes.

Digital signal from A/D converter is transported with help digital circuit to the PC.

Digital part of sensor is composed of two parts – hardware and software.

Hardware part of sensor represents the dividing line between analog and digital part of sensor. It secures galvanic separation of both part of sensor, the transfer of dates from A/D converter to the processor, transfer of control signals from processor to the A/D converter and converse of data into parallel form. Signals are carried to the A/D converter for control of

operating cycles of the A/D converters and clock pulses for reading data. From converters are carried data in serial from. Data are lead from serial form to parallel in the shift register HC299. Transfer is effected in three cycles, each of 8 bits. The 3 logical optical couples provide galvanic separation. (Data from A/D of thermocouple, data from A/D of sensor Pt100, control data for A/D).

Program for the digital part of sensor provide two fundamental functions. At first, control of the A/D converters and than processing of measured data.

Program monitors output of A/D converters and on the base of acquired data generates necessary regulating pulses and clock pulses. Clock signal is generated by the signal WRITE (Processor Intel KC196) and waiting period WAIT. WRITE is generated by record of data to the appropriate address, which lies out of address space of processor. Control signals are generated reason of initialization of A/D converters. Measured values from A/D are transmitted by means of program to shift registers. Data are read directly by external bus of processor from registers HC299.

Program contains algorithm of digital filter. This task is to suppress the disturbing components in measured data. This filter is designed like calculation of gleaning average from ten latest values. This enables first of all strong suppression of high frequency as well as frequency 50Hz. In spite of that data still represent measured voltage of thermocouple and resistance of sensor Pt100. From these funds are obtained the datum about temperature by means of conversion tables of thermocouple and sensor Pt100. Pack of information about the temperature is found by the method „look at table“. Search in the table is realized by „halving of intervals“. If the appropriate value isn't found, the linear interpolation is made. The output data of the program is the temperature of measured object.

Temperature is represented by the binary number in fixed point format. Real pack of information we got by „converse“ to the floating point format.

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# Methods of Partial Discharges Measurement

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Normally cavities or voids included in electrical insulation are filled with gases, which have lower breakdown strength than the surrounding insulation. Furthermore, the permittivity of the filling gas is often lower than that of solid or liquid insulation, which causes a stronger electric field in the cavity than in the surrounding insulation. Consequently, under the normal working conditions of the insulation system, the voltage across the cavity may exceed the breakdown value of the filling gas and cause a breakdown in the cavity. This phenomenon is called Partial Discharge (PD). Similarly, PD can develop on surfaces and in the vicinity of sharp electrodes.

Occurrence of PDs in electrical insulation is always associated with some signals: electrical, acoustical and light pulses emission or with products of chemical reactions. These signals are a means for detection and quantification of PDs occurrence in high voltage apparatures.

Partial Discharges originated by dielectrically defective parts of the high voltage insulation system result in its degradation, which may ultimately lead to a failure of high voltage apparatus. Therefore today's high voltage insulation technology requires modern diagnostic and testing. In this respect increasing attention is being paid to the development of predictive diagnostic tools. This has resulted in development of numerous PDs measuring techniques.

One of the most widespread applications of PD measurement is testing of rotating machines. Unfortunately there are some problems of partial discharges measurements on rotating machines, such as noise, attenuation of the PDs signals in stator winding impedance and calibration accuracy.

Partial discharges can be detected and localized by various electric or non-electric techniques. For example PD detection by radio frequency or acoustic emission during discharge and by the after-discharge chemical reactions product such as ozone in gas filled isolation systems. At present, techniques based on narrow and broadband detection are in use. These PD measurement techniques provide individual discharge events data or integral measurements of loss within the insulating system associated with PDs activity.

Our future research is focused on methods using basically detection of the voltage pulses. The coupling capacitor, is connected parallel to the test object. This capacitor shows high impedance for power frequency voltage but has low impedance for high frequency signals. Thus, the PDs pulses that have short rise times and include many high frequency harmonics pass through the coupling capacitance. These pulses are decoupled by measurement impedance connected in series with the coupling capacitor, and after amplification are measured.

Pre-processing steps would be applied because of PD pulses signal extremely wide frequency spectrum. Partial discharge voltage pulses in solid dielectric systems are short with approximately rise time 10 nanoseconds and exponential falling edge with 100 nanosecond time constant. These pulses are 10 times longer in liquid dielectric fluids (transformator oil).

The first step is electronic integration in fast charge sensitive amplifier/integrator with long discharge constant (50 microseconds). The second step is signal amplifying and shaping from step pulses to relative short but not sharp bipolar or unipolar narrow band pulses. This

shaping circuit is based on band pass filter with one derivation stage and one or two integration stages, which produced unipolar (after first integration) and bipolar (after second integration) pulses approximately 10 times longer than integration and derivation time constants. At the beginning we chose time constant as one microsecond. Therefore, pre-processed pulses are about 10 microseconds long. Finally these narrow band preprocessed pulses are recorded by peak detector and digitized or shown on oscilloscope. The peak detector is zeroed by the controlling processor. The peak detector zeroing is synchronized by the voltage on the diagnosed machine power terminal, where the coupling impedance also is connected. Result of this measurement is PDs pulses histogram or PDs waveform in time domain (one AC period not integrated in histogram).

The second our research focus is direct digitalization of the step pulses with high speed ADC and fast digital processing by Field Programmable Gate Array (FPGA). In FPGA there would be included shaping circuits, peak detector and storage memory for PD time distribution figures.

For this type processing the shaping techniques as described above are not suitable, because of heavy computing amount is needed for them (a lot of multipliers-dividers and summators). Shaping circuits are realized as digital delay lines and substractors which produce sharp digital pulses. The pulses are accumulated for increasing signal to noise ratio and processed to the histogram, or to the time waveforms as described above. The digitally shaped pulses are sharp and short. In case of 40 MHz ADC clock and the pulses eight or four ADC clocks long and output pulses are 200 or 100 nanosecond long (for our example). By the digital method increasing of time resolution is reached, because "dead time" of the aparature is as short as time resolution. This digital technique also has possibilities of good pile-up pulses rejection. The technique looks be perspective, because its next important advantages: small count of analog circuits and high EMI immunity.

Used coupling technique is non-invasive and is suitable for new or installed machines on-line predictive diagnostic. If the measurement equipment is synchronized with proper AC line sources of PDs can be localized in tested power machines.

Our research is focused on the study of both described measuring methods, the PD on-line measurement equipment calibrating and coupling impedance elements.

# Implementation of Digital Switching Arrays in FPGA Circuit for Education Purposes

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Digital switching arrays became the basic element of telecommunication devices based on the time multiplexing of voice and data channels TDM. Designer of such a device has a few possibilities for realization of digital switching array. The easiest way is to use some of the integrated circuits available on the market (single chip digital switching array produced by Zarlink semiconductors for switching 2048 x 2048 channels). Next way of realization of digital switching array is to use programmable devices, which are usually used for realization of other functions in the design (control logic, framers etc.). Using of programmable devices enables the optimization of the digital switching array (size and interface) for concrete application and consequently reduces occupied board space and cost of the device.

As if was mentioned in [1], the PCI FPGA DEVELOPMENT KIT (PCI or ISA card for PC) was developed for purposes of education of designing with FPGA programmable devices in subject Construction of telecommunication devices. PCI FPGA DEVELOPMENT KIT is based on FPGA programmable circuit SPARTAN II. Firmware for the FPGA has a modular architecture, which was chosen specially for education. Students meet basic principles of designing of complex projects, when one man couldn't finish entire project but the cooperation is needed. Firmware for the FPGA is divided into four modules with specified interfaces. Module of control logic (PCI or ISA bus controller), module of synchronization (control signals for serial telecommunication bus used for communication between modules) and module of test streams generator (two streams 2.048 Mbit/s, 32 8-bit channels each, constant data in each channel controlled by control registers) are prepared. The task, which students will solve within their project, is to program the module of digital switching array S (space) and T (time) type. Each step of the development will be accompanied by simulation before implementation into FPGA with simulation tools, which are included in the development software, and verification after implementation into FPGA with logic analyzer.

The first step of implementation of digital switching array type S into FPGA SPARTAN II is to use the simple combinatorial logic (*case* and *if* clauses in VHDL). After the implementation of the digital switching array into FPGA there will be shown disadvantages of the solution with simple combinatorial logic for arrays with more input streams then the number of input signals for block of combinatorial logic in FPGA. The second step of implementation of digital switching array type S into FPGA SPARTAN II is to use the tri state logic (0, 1, high impedance) and elucidates advantages of that solution.

Within the implementation of digital switching array type T into FPGA SPARTAN II students meets fundamentals of synchronous design and using internal block dual port SRAM memories in FPGAs for purposes of connection memory.

Project Implementation of digital switching arrays in FPGA shows basic features of FPGA programmable devices, possibilities of their using and programming via VHDL. This is the first project with FPGA programmable devices in the Department of Telecommunication

Engineering. We suppose that the experiences with it will be used in education of other subjects for example demonstration of scrambling or Reed-Solomon coding.

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# The Measuring Methods for Analog Front End of xDSL Systems

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**Annotation**

This article describes a new testing system that will be used for experimental verifying purposes, namely to verify quality of particular parts of ADSL modems and to check on the quality of measuring methods used for testing analog interfaces of ADSL modems.

**Introduction**

ADLS systems standards describe both general principles of theirs function and general testing methods for the systems measuring. The aim of the bellow described project is to elaborate theoretical and especially practical usage of the ADLS systems principles and their testing methods with regard to measuring equipment and resources available at the Department of Telecommunication Engineering at CTU FEE.

**Problems of ADSL modems synthesis and measurement**

A simplified block diagram of an ADSL modem consists of digital interface, digital signal processing block and analog interface. The diagram is applicable for both ATU-C and ATU-R modems.

For the time being the aforementioned parts of the project have been narrowed down to the problems of the analog interface Analog Front End (AFE) [1, 3] circuits analyses and synthesis. To check on the practical functions and qualities of such circuits a development kit with selected circuit AFE1302 (TI) is being developed. The AFE1302 circuit includes a digital interface for a DSP processor, interpolation and decimation filters, 16-bit DAC and ADC, LP filters, an attenuator and a buffer, a programmable gain amplifier and an oscillator and PLL circuits. The kit will also contain some auxiliary circuits. Namely a line driver (TI: THS6052, THS6042, TI/BB: OPA3691), a receiving amplifier (TI: THS3001, THS4001, AD: AD812, AD8132, AD8138), input and output filters, a hybrid and an separating transformer. The style of the kit will be modular to make possible a realization of both analog interfaces ATU-C and ATU-R along with an option to replace circuits in order to check on their parameters.

An AFE is necessary to test in both digital and analog fields. The tests are aimed at the quality of internal D/A and A/D processes as well as the quality of an analog signal internal processing. Hence, next tasks to be solved are the generating of measuring signals suitable for an analog interface testing along with finding a way of the signals analysis and evaluation. An individual solution for each type of an AFE circuit is needed due to the fact that there is no standard for an interface between a block of digital signal processing and analog interface.

The possible utilization of signal processors TMS320C62x and TMS320C67x for the digital signals generating and analysis have been tested. Due to their insufficient performances a possible usage of signal processors with better computations speed TMS320C64x is now being taken into consideration. Next option, also being intensively investigated, could be an utilization of the kit 'FPGA PCI DEVELOPMENT KIT' originally created for teaching and development purposes at our department.

**Measuring set**

Measuring devices for analog signals measuring and data storing are controlled over HP-IB bus. To allow the devices controlling and data analysis an program in system Lab-View has been developed. The program controls a function generator Agilent 33250A and a spectrum and circuit analyzer HP 3589A in the process of low total harmonic distortion, intermodulation distortion and noise measuring through spectral analyses. Measuring of symmetrical interfaces with measuring devices equipped non-symmetrical interfaces only make possible special active differential N/S and S/N probes developed at our department.

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# Equipment for Determination of Dependence of GPS Signal Parameters on Environment Quality

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One of the modern trend in satellite navigation is Assisted GPS (AGPS). The primary purpose of AGPS is location of mobile users in wireless network. It is obvious, that the knowledge of spatial distribution of mobile users will help with planning, design and operation wireless network. The rescue teams will be able to quickly an precise locate people who are injured and the mobile users will gain the ability to get local traffic information, direction to gas stations, restaurants and other services.

AGPS system consists of wireless handset with incorporated GPS receiver, AGPS server with reference GPS receiver and wireless network. AGPS infrastructure (server and network) can predict and deliver GPS signal parameters so the sensitivity of receiver and Time to First Fix (TTFF) can be greatly improve. This assistance enables navigation in difficult environments, such as buildings, urban canyons, areas under dense foliage, where traditional GPS receiver is unreliable or cannot work correct.

AGPS receiver is not simple combination of wireless handset (phone) and traditional GPS receiver because of mode operation. Navigation is provided on demand for better performance. At the request, the server sends the information about the satellites in view at the wireless handset approximate location. The GPS receiver snaps the GPS RF signal segment (few hundreds of milliseconds) in handset memory and then the DSP processes the data and returns the measured pseudoranges to the AGPS server. The position of mobile user is thus computed in the server. This solution saves the handset DSP load and thus battery consumption.

For verification, the AGPS signal processing and obtaining the signal parameters the experimental system for recording part of signal in L1 band was assembled at the Department of Radioelectronics at CTU FEE. This system can load the signal in computer memory. The size of record is limited (in this stage of implementation) by the size of computer memory.

The following equipment characteristics was required:

- sufficient data rate correspond with needed sample frequency for L1 band (with C/A code)
- suitable length of record (minimum several hundreds of milliseconds)
- portability of whole system – cooperation with the common PC interface available on most notebooks
- simplicity of implementation

The system consist of the Magellan GPS receiver, data-logger equipment (FIFO) and PC (notebook). The Magellan MeridianXL is especially suitable because of robust RF part, which enables output of I (inphase) and Q (quadrature) one-bit quantized samples of GPS L1 signal. The main purpose of data-logger is transforming the continuous data flow from GPS receiver to the batch data flow needed for PC. The data-logger consists of large FIFO (64 kB) and other support circuits. The connection between the data logger and PC uses parallel port interface. The EPP (Enhanced Parallel Port) mode is used to guarantee sufficient data flow.

The software for PC was prepared. The purpose of this software is capture data from parallel port interface and store them to file. Current software implementation has a very simple solution, the process runs under "user mode" and zero static priority (normal process). The other standard solutions of this problem use kernel module and then the application can use system call, which runs under "kernel mode" because of reliability and operability. Of course, the nonzero static priority value, used for real-time applications, will increase performance too.

The some basic tests were performed to ensure correct function and reliability both the data-logger equipment alone and whole system. The whole system was tested with L1 carrier signal, L1 signal with PRN C/A code from GPS simulator and with real GPS L1 signal obtained from antenna with clear view of sky. These tests are very important because structure of equipment (data-logger) can by prone to errors: repetitive bits, repetitive or missing bytes and missing continual block of bytes. The cause of repetitive bits in record is a spurious activity signal on the clock wire, the cause of repetitive (missing) bytes is a spurious signal on the write (read) input of FIFO. Overfull of FIFO cause of lost block of bytes. All of these possible problems were tested and few incorrectly behaviours were eliminated.

The effective algorithms for detection and processing measured signals are developed now. The Matlab is used for algorithm design and verification. Effective processing of signal will be implemented using the C language. Then we will be able to measured and determinate GPS signal parameters in the various environments (indoor, outdoor, mobile). This will help us to create mathematical models of signals in these environments and obtain the abilities for signal processing needed for AGPS.

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# IN-based Measurements of Voice Transmission Quality inMobile Networks

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Speech transmission quality measurements as described in P.86x of ITU-T or in other standards like PAMS and TOSQA enables to compare and benchmark different transmission technologies or codecs from the point of view that is rather close to that of end-user. Moreover, some transmission technologies and their chains that appear in today's converging telecom networks are difficult to compare by means of any other method (e.g. circuit-based and packet-based transmissions).

The basic scheme is almost identical for all the above mentioned standards: special dedicated test call is established and suitable speech sample is transmitted between calling and called station over the tested network. Received version of speech sample is (digitally) recorded and (automatically) compared with original speech sample (after level and time correlations/adjustments). This comparison is performed by suitable algorithm that should precisely comprise all known features of human's ear and brain related to speech listening.

Despite the fact that intrusive measurement as described above provides higher accuracy (means better correlation with subjective listening test results) than non-intrusive approaches there are some drawbacks and weak points:

-Uncertainty about radio interface influence. Current systems use connection between two mobiles that means that each direction has to pass the air interface twice. This generates doubts about the origin of potential source of radio interface problems. To resolve this problem, it is necessary to use other data from the network (like signalling information on the Abis interface between BSC and BTS). This requires additional HW and SW and also the assistance of the network operator is required.

-Special active test calls has to be established. Unless the measurement is performed by network operator itself, those calls are billed as usual and the costs for long-term measurements can be enormous (especially for performing international calls).

-At least two measuring stations (transmitting / receiving) of the system have to be active for each test case.

The new approach is based on using the Intelligent Network (IN) part of the mobile network. In particular, voice mail (VM) equipment and some kinds of prepaid card services (charging the card by phone, on-line voice credit verification etc.) are suitable to replace the "far-end" of the testing system.

The basic principle of measurement is then as follows:

-Reference sample acquisition. This has to be done during low traffic time when no significant distortion is expected (2. a.m. etc.). The voice response of the selected IN service ( like "Welcome to pre-paid charging system of ... company. Press ONE for charging you mobile phone, press TWO for ...") is acquired as the reference speech sample. It can be additionally cleaned by common DSP procedures as available e.g. in CoolEdit (R) speech processing software. It is also possible to aquire this speech sample more times and then clean it by

averaging process (after proper time correlation). In our experiments, we have combined both ways.

-Measurement period. The identical speech sample is acquired periodically and the intrusive algorithm (like P.862 – PESQ) is applied to the sample, having the previously recorded reference sample as the one on the "transmitter side" and the actually recorded as the "receiver side". Observing the algorithm result (Mean Opinion Score – MOS) continuously, it is possible to evaluate reliably the network voice transmission quality of service.

For real mobile networks measurements, a special measuring system that has been developed at the department has been used. It enables to perform both intrusive and non-intrusive measurements in standard ways (without IN exploatation) and also the special IN-based measurements. The system is based on PC with mobile terminal attached by means of serial line and audio bi-directional connections. The basic measurement is an intrusive measurement with presence of original speech sample. The connection between two (local and remote) stations of measuring system is established and the predefined speech sample is transmitted and evaluated. The evaluation is performed by remote station (called party) and only results are transmitted back to the laboratory. This procedure can be repeated for more GSM operators (by changing the SIM modules of GSM terminal) and for more speech samples for each operator. The results are statistically processed.

The system allows to enter input speech sample, to establish the connection between two station of the system, to transmit the sample and acquire its received version. Finally, the transmitted and received versions are compared according to current speech quality standard (P.862). The standards are implemented in Matlab that enables the user to experiment easily with internal algorithm settings. To correctly interpret results, also additional parameters like overall transmission delay in speech channel and parameters of radio channel that are usually considered as the weakest part of the communication chain - RxLev (electromagnetic field intensity) and RxQual (Bit Error Ratio for digitally modulated signals used e.g. in GSM or DECT) - are acquired. This enables to find easily the reason of quality decrease when it appears. Three different mobile networks have been evaluated by means of above described IN-based procedure, and by standard instrusive approach in parallel. It was confirmed that the measured results can compete easily with results obtained by standard approach.

Using the measured results, it is easy to evaluate e.g. the network suitability for special applications with high requirements of reliability and QoS like emergency service communication, emergency systems for people with disabilities etc. Some basic parameters like busy hours, mean network availability, mean successful call setup probability etc. can be evaluated – such parameters are easily available to network operator but belong to the strategical information that is not published.

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# Analysis of Sounds Produced by Small Species

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In the world of animals sound is one of the main means of communication between individuals of the same or different kinds. Although most invertebrates communicate by means of chemical signals there are exceptions e.g. locusts, cicadas and even some spiders are able to produce sounds. Since these sounds are in the environment by human ear hardly audible, not much attention has been paid to them so far, but there are many in spider family which can produce sounds. The sound is produced in three ways: stridulation, percussion and vibrations. Most species use stridulation, i.e. rubbing sclerosed projections against grooved plates. These can be placed at various body parts, e.g. legs, prosoma, etc. According to this placement four stridulation types are distinguished.

One of spider families being able to stridulate are Palpimanidae. Majority of species live in Africa and South America, only four can be found in Europe, namely in the Mediterranean, in Greece, Turkey, Cyprus, Spain, Portugal and Italy.

Palpimanus family, individuals of which we studied, are very rare, which is the reason why there is no extensive study on them and first attempts to record their sounds are only recent.

The function of stridulation is not yet known, but there are several hypotheses, all of them waiting for verification. Stridulation can provide protection from predators, it can also attract prey or even serve as means of communication between individuals of the same kind.

The aim of this study was to record and analyze stridulation of both sexes of two kinds, Palpimanus orientalis and Palpimanus gibbulus. The problem is interesting also from the point of view of electroacoustics because the signal acquisition in various types of environment has to be solved. Spiders can be monitored not only in laboratory environment (the work described is the case) but also in the wild and/or with the presence of other individuals of the same/another kind to investigate changes in sounds produced under various conditions. The sounds produced by spiders propagate not only through the air but also through the material spiders stand on, i.e. web, plants etc. Sound can be monitored using appropriate type of transducers. In this article analysis of sounds acquired in the laboratory from males and females of two kinds is presented.

Five individuals were used for signal acquisition. One male and one female of P. orientalis and three females of P. gibbulus. Individuals of P. orientalis were collected on Corfu while P. gibbulus in the region around Evora, Portugal. Shortly before signal acquisition were spiders attached to a soft support by means of miniature attachment clip.

The measurements have been performed in the acoustically improved room using Bruel and Kjaer measuring chain. Measured signals were recorded on SONY R-DAT 60ES and then processed using CoolEditPro (1.2) software. Because of low effective signal levels (around –50 dB SPL at 1 cm from the spider) high amplification was needed which brought about the presence of high low level noise in the signal. This was fortunately below the frequency range of the effective signal (above 800 Hz) so simple filtration was ample for extracting it from the noise.

So that the individuals produce sounds they were excited with tweezers on their bodies. After such excitation stridulation was the strongest. The excitation was repeated when the signal weakened.

The signal consists of trains of signal bursts having the length of approximately 150 μs which repeat after 200 μs. The signal can last dozens of seconds, depending on stimuli. The frequency analysis was carried out from signal parts where significant frequency maxima were found. In all cases the main frequency maximum was in the region of 3,7 kHz. Other frequency maxima lay around frequencies 9 kHz, 12 kHz and even 18 kHz. No significant changes in frequency contents of sounds produced by various individuals of both sexes were found. In some cases the major maximum was observed in the region of 8 – 9 kHz and one more local maximum around 1,6 kHz. The difference between Palpimanus orientalis and Palpimanus gibbulus was in intensity, the latter produced lower signal levels.

Stridulation of Palpimanidae spiders has wide frequency spectrum, ranging from 700 Hz up to 20 kHz. Our results differ from those obtained by Uhl and Schmitt in the position of the main frequency maximum, theirs being around 1 kHz, ours around 3,7 kHz. The research in future will be aimed at acquiring stridulation signals from other species and under various conditions as described above.

This research is carried out in cooperation with the Department of Zoology and Ecology, Faculty of Natural Sciences, Masaryk University in Brno.

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# Universal Processor Module for Intelligent Mobile Sensor System for Monitoring of Physical Quantities in Environment

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Environment and its qualities become to be increasingly important for life. Thus monitoring of different parameters of environment is actual and vital field today. The number of monitoring system applications rises up very quickly and the flexibility, scalability and possibility of easy changes in system configuration become increasingly important.

Nevertheless, most of currently available monitoring systems are halfway the same – they usually depend on power supply and communication networks, that are often not available on preferred monitoring sites. Our monitoring system provides a wide range of measured quantities and allows user to focus just on a monitoring task - not on the system technical knowledge. It is designed with focus on user-friendly use and configuration; no special skills are needed to configure all the parts of the system. Most of the configuration operations and set-up functions are fully automated.

Our monitoring system consists of a number of fully autonomous measuring stations, which are controlled time-to-time or on operator's request by the central station, which can be represented by a middle-performance standard PC. Each station can be connected directly using GSM or PSTN modems or using other wireless connection with especially designed transceivers. A station consists of several eight-module parts connected together with the central unit via two-wire serial bus. Each part can be occupied by processor and sensor modules. Each processor module has communication sensitive automatic power-on capability. An especial serial bus for special controlling functions of the whole system is implemented to ensure the maximal system safety. The whole system can be fully and automatically configured using its hot-swap and plug&play functions and capabilities. The central unit manages all the modules of the monitoring station and communicates with the central station through a modem (mostly a GSM modem).

This paper presents developed universal processor module. The processor module is designed as fully universal, including universal two-plane printed circuit board. It means that the same board can be used for more functional version of the module. It saves production and assembling costs.

The module can work as a universal processor module or as a CAN processor module (with the main function of a communication bridge or interface) in dependence of a concrete assemblage of the board.

The first version of the module with CAN interface uses T89C51CC02 microcontroller from ATMEL Corporation. As the CAN transceiver, PCA82C252T from Philips Semiconductor is used, it means, that the CAN interface is primarily designed in accordance with ISO11519 - Low Speed CAN. The high-speed CAN was not implemented due to its

lower reliability (physical layer safety capabilities) and poor power management capability. The CAN transceiver is galvanically isolated up to 1 kV using DC/DC converter and optocouplers. This voltage converter and the entire CAN interface part can be powered up/down on software demand. The entire module draws in peak about 45mA (including DC/DC converter and CAN transceiver, 19mA by the microcontroller only). In the power down mode (sleep mode), the module draws only about 350 uA. The microcontroller offers ’51 compatible instruction set, but all the instructions can be executed two times faster (in this mode, called ”X2 mode”, the core needs only 6 clock period per machine cycle).

The second version of the module is designed as full processor module with full connection to a sensor module capability. The board is based on T89C51AC2 microcontroller from ATMEL Corporation and supports automatic sensor module and its capabilities identification. The entire module draws about 11mA and about 300uA in the power down mode only. The microcontroller offers ’51 compatible instruction set, but all the instructions can be executed two times faster (the same ”X2 mode”).

The above mentioned versions were successfully implemented and tested. In the hardware area, the modules are fully ready to use. The future work consists chiefly in software area.

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# Monitoring Station Main Unit of Intelligent Mobile Sensor System for Monitoring of Physical Quantities in Environment

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Environment and its qualities become to be increasingly important for life. Thus monitoring of different parameters of environment is actual and vital field today. The number of monitoring system applications rises up very quickly and the flexibility, scalability and possibility of easy changes in system configuration become increasingly important.

Nevertheless, most of currently available monitoring systems are halfway the same - they usually depend on power supply and communication networks, that are often not available on preferred monitoring sites. Our monitoring system provides a wide range of measured quantities and allows user to focus just on a monitoring task - not on the system technical knowledge. It is designed with focus on user-friendly use and configuration; no special skills are needed to configure all the parts of the system. Most of the configuration operations and set-up functions are fully automated.

Our monitoring system consists of a number of fully autonomous measuring stations, which are controlled time-to-time or on operator's request by the central station, which can be represented by a middle-performance standard PC. Each station can be connected directly using GSM or PSTN modems or using other wireless connection with especially designed transceivers. A station consists of several eight-module parts connected together with the central unit via two-wire serial bus. Each part can be occupied by processor and sensor modules. Each processor module has communication sensitive automatic power-on capability. An especial serial bus for special controlling functions of the whole system is implemented to ensure the maximal system safety. The whole system can be fully and automatically configured using its hot-swap and plug&play functions and capabilities. The central unit manages all the modules of the monitoring station and communicates with the central station through a modem (mostly a GSM modem).

This paper presents the heart of every autonomous measuring station – the main unit of the station (called as central unit in the local meaning). The main function of the unit is to manage the entire local system, including power management, measuring tasks initialization and measured data storing, plug&play functions and communication with the outside world (central station) via (GSM) modem, etc.

The station is based on DS89C420 microprocessor (CPU), produced by DALLAS (now MAXIM) company. This microprocessor offers the best peak computational performance as well as low power consumption during low utilization of the unit or during sleep mode of the whole system. The processor has its own 16KB of flash memory with self-programming capability and small SRAM memory for all the important system functions and management. An external zero-power SRAM up to 512KB with built-in real-time clock with

alarm function is used to store all the measured data and large system databases. The memory is produced by MAXIM Corporation and the system and board of the module is designed to be capable to use more types of the memory in dependence of concrete system requirements, costs or chip availability. The internal software system uses multi-process software techniques to ensure all the functions.

As written, the state of the unit can be the full mode or the sleep mode. In the full mode, the power requirements of the whole system can be managed by the CPU using appropriate software methods (especially the process execution management) and/or by using software controlled power management of all the internal peripherals. In the second mode (sleep mode), the CPU (including all its internal peripherals) is powered off. In this state, the unit can be powered up using the following methods. The first method is an interrupt generation by the communication over modem serial line. This means that the central unit can be powered up by ringing of the (GSM) modem at the start of the communication with a base (central) station. The second method is an interrupt, generated by the communication over service serial line. This means that the central unit can be powered up by connection with a service computer automatically. The third, the most used and very useful method is an interrupt generation from the on-board real-time counter. The interrupt can be generated at the specified time (hours, minutes, seconds and day) or after specified time quantum (in ranges from second till minutes). These features generate very flexible system (chiefly) in power management as well as in the computational area. For example, in time of periodical, e.g. temperature, measuring and storing, the entire system is in sleep mode and has very low power consumption (in mW) during waiting for an interrupt from the built-in real-time clock. Its power consumption rises up only for a very short time only during the data processing and/or storing or more complicated measurements or communication.

The developed main unit was successfully implemented and tested, including GSM communication using GSM modem from Siemens company. Thanks to the described operational modes, the power consumption of the unit can be fully managed. The power requirements of the unit are from ca. milliwatts in the sleep mode up to a half of watt in the full mode. Our future work will be in the software area chiefly.

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# Acoustic Digital – to – Analogue Conversion

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Transducers, both sensors and actuators, were the last elements in the electroacoustic chain which did not work in the digital mode, i.e. their inputs and outputs were only analogue. Signal processing, recoding, and transmission are to the large extent digitized, their analogue versions are used mostly for some special purposes. Transducers remained analogue until recent time. The analogue-to-digital conversion (A/D) performed by a microphone has been also described and some companies offer digital microphones where the A/D converson is performed imediatelly by the microphone capsule, usually using sigma-delta modulators.

Digital-to-analogue (D/A) conversion in the electroacoustic chain can be applied at several levels. The most common is converting the signal before its amplification and then feeding it into the "analogue" transducer. The other possibility is supplying the digital signal to the transducer where the conversion is performed in the transducer on its mechanical side by adding forces acting on the mebrane, these forces are proportional to the bit stream and corresponding bit weight. The "purest" acoustic digital-to-analogue conversion is performed in the gas medium in which acoustic signals – "digital waveformas" corresponding to bit streams add and create the "analogue" waveform. These "digital waveforms" can be created in two ways. Either by a transducer with membranes, the number of which corresponds to the number of bits the signal consists of and the size of which is weighted by the bit weight (A-type), or by a field of transducers, where the n-th bit from the bit signal drives n transducers (the most significant bit is the highest) - (B-type). The problem arising from the first solution is the variety of sizes of membrane surfaces, the second solution brings about a very high number of transducers needed to be employed (65535 for the 16-bit transducer), hence directivity problems.

The reason why the research goes in this direction is the attempt to improve the weakest part of the electroacoustical chain, the loudspeaker, which has had the same construction for many years, materials of membranes and magnets being the only parts that improved most. All other parts, which are digitized, could have quality parametres which are superior to parametres of the human ear, so attention paid to this domain is logical. The advantage of this system might be lower demands on the power supply, because the need for power amplifiers is limited when properly designed. The most-wished quality is the foreseen low distortion.

Such type of transducer was theoretically described in the beginning of the 80s, but the applications have been appearing only recently. When it comes to the design of a digital transducer the first question that arises is that concerning the choice of the transducer type so analysis of the applicability of respective types comes into focus.

Transducers with the magnetic field are suitable especially for the A-type digital transducer. The electrodynamic transducer can be designed with several voice-coil sections, each of them having the number of turns proportional to the weight of the driving bit signal. The voice coil can be either in the ordinary 3-D form or printed on the membrane. The problem to be solved here is the magnetic circuit since the form of the coil, especially in the latter case can be rather complicated. The electromagnetic transducer can also be employed, using the

driving coils with various turns. The D/A conversion is effected in the magnetic circuit by adding magnetic flux. Usage of electromagnetic and electrodynamic transducers as the digital loudspeaker is limited because of slim chances for their miniaturization and difficulties in fabrication of complex parts of magnetic circuits. Nevertheless some prototypes have been introduced.

Transducers with the electric field offer much more promising future concerning their application. Unlike transducers with the magnetic field the transducers with the electric field can be used especially in the B-type arrangement of the digital loudspeaker. The main reason for this is the favourable possibility of miniaturization. The microtechnology has been attempting to make the miniature electostatic transducer for many years and it seems that the mass production of these is the question of near future. It is certain that the field of digital loudspeakers will make use of these very quickly. The size of the membrane inferior to 1 $mm^2$ offers the possibility of favourable spacial alignment and at the same time limits problems with the phase.

Before that is made possible, the piezoelectric type of transducers will be one of favourites for the construction of the digital loudspeaker. Several constructions have been announced, some of those introducing new forms of piezoelectric transducers, all of them using transducer arrays. Piezoelectric transducers offer large flexibility of their shapes and sizes, their sensitivity is also favourable. Piezoelectric transducers can also be miniturized and fabricated on a silicon wafer which contributes to their versatility.

Transducers with magnetic or electric fields are the principal transducer types but there are more of them so surveying those is a must. Piezoplastic transducer is a variety of the piezoelectric transducer. The spiral arrangement, where a number of piezoplastic film turns are used, is suitable for the assembly of the A-type digital loudspeaker. The drawback might be an extremely high demand for manufacturing precision. Another type is the thermoacoustic transducer, but the possibility of making these transducers small may not outweigh very low sensitivity of these transducers. Optoacoustical transducers, especially in their miniature form, again, on a silicon wafer could interfere into the world of the digital loudspeaker.

The future of the digital loudspeaker, that is audio digital-to-analogue conversion, will be made possible especially with the broad availability of miniature transducers fabricated on a silicon chip.

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# Methods of Subjective Evaluation of Sound Codecs

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From the beginning of the audio technology evolution engineers were striving to enhance parametres of the electroacoustic chain. The quality of audio equipment was usually expressed by measured values of electric parametres hence proving it from the point of electric measurement. With the onset of the digital technology, measured electric parametres of audio devices began to surpass those of the human ear. The relatively high amount of data needed for conveying the recorded audio information led to the question whether we need all of it to get the same impression as in the case of the original recording, i.e. how much information we can leave out without the loss of quality that could be percievable. Using knowledge of human ear characteristics, e.g. equal loudness curves, sumultaneous, backward, and forward masking etc. many sound coding methods were developed, from which the mp3 format attained the widest range of usage. Some methods for subjective quality evaluation have been proposed but variety of sound codecs, variety of sound recording and variety of listeners´ needs calls for further investigation in theis field, that is developing methods for assessment of the sound codec quality. The first problem to be addressed is that concerning principles of subjective measurement, choice of listeners, choice of testing signals and their sequencing, listening conditions, data collection and evaluation. Arrangement of each subjective measurement must take into account its objective, i.e. whether we test systems for general purpose or expert systems, whether we want to grade systems under test or only state whether they provide sufficient quality or not etc. These aspects are discussed.

The basic question in selection of listeners is the one concerning the experience, whether we want to have data from the “common” listener or from an expert, trained and experienced in discovering deficiencies in sounds. Those in favour of the “common” listener substantiate their choice by the statement that most systems of commercial technology is used by such type of listeners and hence they should have their say. Nevertheless even in this case the listeners should be tested for their hearing abilities . In case of professional systems testing or in case of testing limits of sound systems (could be the case of sound codecs assessment) experienced listeners should be used. Those should have unimpaired hearing systems and be under 35 but older experienced listeners could also supply valuable data.

There is a huge variety of signal types from the point of view of temporal evolution or frequency contents. This is also the reason why sound codec testing is very time demanding because different codecs could be used for different signal types. The attempt to choose musical signals with various and distinguishable attributes, such as frequency contents, dynamics, temporal evolution is natural, so several signals, such as striking the triangel, chime, piano, saxophone, human voice, chamber music were chosen for basic tests. The question arises whether listeners should be familiar with the music used for tests since differences in rendition could affect the final judgement although it is not the subject of the test. Unknown pieces of music with familiar motives is a suitable solution.

Listening environment affects the judgement not only with its acoustics but also with its psychological impact. Comfortable seating of subjects along with suitable light conditions ensure that subjects will not be biased because of their discomfort. If the acoustics of the listening room are not favourable (recommendations have been proposed) the usage of headphones provide uniform conditions for all subjects limiting the outside noise at the same time.

Presentation of test signals also affects validity of subjective measurement. The total length of a test should not exceed 30 to 45 minutes since after that the tiredness of a subject can distort the results, he or she can excert less effort for individual judgement and therefore come to invalid conclusions. The lenth of individual signal presentations should not exceed 30 seconds which was determined having in mind subjects need to remember as many details as possible for their judgement and the short-time memory is limited. If the test signal is a well-known piece the length can be greater. The sequencing of test signals depends on the purpose of the measurement. In some cases we want grade signals on a certain pre-defined scale which is explained to subjects at the beginning of the measurement, in other cases we want to compare certain signals with a reference (being the case in sound codec evaluation). We can test subjects for reliability of judgements by repeating the same testing sequence several times and find out whether the judgements of subjects are coherent.

The most common way of data collection is the usage of questionnaires. According to the task we can opt for co-ordinating items to mutually exclusive groups or scaling items on a pre-defined scale with or without determined metrics. In all cases training should take place so that the subjects have an a-priori idea about classification. In some cases the subject can adjust the parameter to be tested to the level he/she regards as best. This is also the way for determining the “still acceptable deteoration”, i.e. just noticeable difference in respect to various parametres.

In the process of data evaluation the decision concerning the data selection has to be made. In some cases some data from some subjects can be left out, which is made following the data pre-processing. Usage of statistics also affects final results, the most natural option is that for non-weighted average and dispersion. These results can be related to a reference for easier interpretations of results.

In evaluation of sound codec quality the task is to determine whether the perception of the signal treated with a codec is the same, slightly different or very different from the original. Listeners with some experience should be used. Compressed signals are intended for broad public and expert listeners could declassify codecs which would be acceptable for target users. At present the collection of variety of sound codecs is on the way and their subseqent evaluation will use principles outlined above.

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# Microscope Scanning System

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## Introduction

Nowadays there have been widely used electronic devices with CCD elements for image scanning. Their most important features are possibility of fast image control, high scanning speed, easy data storage and image processing. Also process costs are low. In pedagogical process is very interesting the possibility of projecting observed object on the television screen. It is very favorable in team work such are laboratory exercises. The improvement in the system performance is possible equipping digital camera to the microscope . The relatively low price of the digital cameras allow their wide application. Thanks to FRVS grant we have equipped our metallography microscope Neophot 30 with a digital camera. This system is used for surface and thin films study and for teaching some laboratory exercises.

## Camera selection

At present there are three main groups of digital cameras on the market. Firstly that are compact systems equipped with inseparable lens. Secondly there are reflex cameras, classical designed with film replaced with CCD chip. These devices are more expensive than first group. Their advantage is removable lens so it is possible to attach another components. Third group are cameras, designed directly for micrography. They have cooling of the sensing element to increase sensitivity and different computer interface.

For our purpose is clearly most suitable the last group. However, the prices are very high, about three times higher than other ones. We have made some tests and found out that we can obtain similar results with cheaper camera. The optical adapter is necessary in order to compensate lens. We have decided for Nikon Coolpix 5000. Another possibility with similar parameters was a camera by Olympus but price of the equipment was substantially higher.

## System parameters

Coolpix 5000 is a compact digital camera with five million pixel CCD chip. Lens is a Nikon Nikkor with 3x zoom and focal length from 7 to 21 millimeters. The device also contains adjustable 2” LCD display. Shutter speed is within interval 1/4000 – 8s. The camera electronics allow fully automatic as well as manual scanning. We have recognized that most of all our object we can photo in automatic mode, only in some special cases it is necessary to focus and set scanning time manually. The only problem we had with automatic color balance because it changed the image appearance in bad way.

The camera is connected to the microscope with mechanical and optical adapter. The optical adapter compensate the lens because the microscope output was designed to direct projecting onto the sensing plates. There is also a TV connected through video output of the Coolpix. It is used for focusing and overview of the image.

The camera is connected to the PC through the built in USB port. One disadvantage is, that it is impossible to scan when the camera is connected so it must be disconnected after image transfer. The freeware GIMP is used for image processing. This software is comparable with well known Adobe Photoshop which is quite expensive. It is easy to change contrast, sharpening the image or measuring distances.

Camera utilization

We have used the system for several purpose this year. For teaching it helped us with laboratory exercise from "Surface and Coatings" and "Plasma Technology", subject intended for last year students of the Material Science Engineering. The camera is also used for research mainly for tribological tests evaluation.

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# Comparison of Microwave Structures Modeling Using Frequency Domain and Time Domain Analysis

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For the development of any antenna structure it is necessary to create and analyse a proper model. Due to increasing capacity of memory and speed of personal computers different electromagnetic field simulators are used. These methods are generally divided into two domains: frequency domain and time domain. Methods FDTD (finite-difference time domain) and TLM (transmission line matrix) fall into the time domain and methods FEM (finite element method), FDM (finite different method), and MOM (moment method) fall into frequency domain.

Two software tools are used in this paper. The first one is IE3D, which calculates antenna at frequency domain by current distribution using MOM. The other one is FIDELITY that calculates antenna at time domain by FDTD method.

The comparison is shown using three microwave structures. The first structure is the double ridged horn antenna. The second is a transition from coaxial to double ridged waveguide that was used in horn antenna. And the last one is a slotline leaky wave antenna. The designed structures are solved by means of IE3D as well as FIDELITY programmes. Then the structures are measured and are compared with calculated data. Further, the results using IE3D and FIDELITY are summarized and compared: Model setup, Grid, Time of calculation, Accuracy of calculation, and RAM requirement.

At first there is described basic comparison between solution in time domain and frequency domain. FDTD is easy to implement. Its basic principle is to use finite difference to represent the differential in Maxwell`s equations. The final algebraic equations for FDTD are in the time-marching style. FDTD does not create large matrix equations which are common in MOM and FEM. FDTD`s memory requirement is proportional to N compared to $N^2$ for FEM and $N^2$ for MOM. FDTD`s time requirement is also proportional to N compared to $N^2$ for FEM and $N^2$ to $N^3$ for MOM. Although the basic computational requirement for FDTD is normally much higher than that for MOM (for modeling small and medium size structures), FDTD may require much less computational resources than MOM for large structures. On the other hand, FDTD normally require less computational resources compared to FEM except for strong curved structure. FDTD`s simulation normally is a wide-band result. One simulation can yield a wide-band frequency response. MOM and FEM normally require sweeping frequency. FDTD simulators can handle complicated dielectric structures much easier than MOM and FEM.

For the design of double ridged horn was used MathCAD and the designed structure was simulated by means of IE3D as well as FIDELITY programmes. The time of calculation by IE3D is only for one frequency. Maximal possible grid by using IE3D is 5000 then the memory is over RAM (768 MB). This structure is not possible to simulate by means of IE3D because the maximal possible solved frequency is 8 GHz. Further, the layout neglects real thickness of conductors. FIDELITY is better tool for this structure analysis (structure is possible to simulate at all frequencies and with real thickness of conductors).

The transition WRD-750/SMA from the coaxial cable to the double ridged waveguide is presented. The operating bandwidth of the transition is from 8 GHz to 18 GHz. This

structure was used for the design of double ridged horn antenna. The FIDELITY results are more accurate then IE3D results. Further, the FIDELITY simulations are faster and need less memory then IE3D.

Slotline leaky wave antenna is a planar structure. The center of operating bandwidth is about 2.67 GHz. In this case, the IE3D results are more accurate then the FIDELITY results, and corresponds well with the measured data. Further, the solution of this structure by IE3D is faster.

From previous comparison ensue:

- FDTD is better for the design of 3D structures or complicated dielectric structures then MOM.
- MOM is accurate and faster for the design of 2D or 2.5D structures such as planar antennas structures.
- FDTD simulation is a wide-band result
- MOM requires sweeping frequency.

It is important to note, that ideas given in this paper arise from one of the many possible points of view. In order to obtain a complex comparison of these two methods, additional experiments should be performed.

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# Delivery System with Hollow Waveguide for Ophthalmology Treatment

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In most surgery laser systems where continuous radiation is delivered, a fiber is used for a radiation delivery to an interaction place. In the case of high-powered nanosecond or picosecond pulses or in a case of mid- and far-infrared radiation delivery, no reliable long lifetime fiber has been available so far.

For the purpose of the ophthalmology treatment a special hollow waveguide based delivery instrument was developed. It consists of a 2 m long cyclic olefin polymer coated silver hollow glass waveguide (inner diameter 700 μm) and a special cap allowing the contact of the waveguide with a wet eye tissue. In our experiment the characterization of this delivery system was made at first for the mid-infrared Er:YAG laser radiation ($\lambda$ = 2.94 μm) and then the pre-clinical interaction experiments of this radiation with the eye tissues (cornea, lens, and sclera) were performed with above mentioned delivery instrument. A comparison of two types of interactions – the action of Er:YAG free running pulses (with length 40 μs) and giant pulses (450 ns FWHM) were investigated.

From the transmission measurement follows that the radiation energy losses are acceptable. Changes in temporal profile of the laser pulse during delivery were not also significant.

For interaction experiments the human eye tissues (in vitro) were cut in half and the samples (a cornea, lens vitreous, and sclera) were immediately (in wet state) irradiated by laser radiation with the energy of 7 mJ (the corresponding spot size diameter was equal ~ 700 μm). The Er:YAG laser fluence used in this experiment was 1.8 J/cm$^2$. For the analysis, all samples were photographed after the laser treatment. Nicon SMZ-2T microscope and the Mitsubishi CCD colour video camera (CCD-100), and PC computer were used for the notation of the interaction changes. After the treatment the samples were stored in formaldehyde solution and examined by Scanning Electron Microscope – JEOL (JSM 6400). The applicability of the particular treatment was determined.

From the results measured there follows an essential difference between the free-running and giant pulse treatment of the eye tissue. It is recognizable if the microscope and SEM results are compared. These differences follow from the interaction power radiation influence and they are diverse for particular eye tissues.

The giant pulse ablates the cornea tissue in some hundreds of nanoseconds. The cornea molecules are decomposed after being exposed by high intense laser irradiation (4 MW/cm$^2$); direct breaking of molecular bonds follows together with very clean ablation. In the case of free-running pulse interaction a thermal decomposition takes place. Water molecules present inside the cornea tissue absorb the energy. This process is followed by the increase of pressure

and therefore water molecules try to expand in volume which leads to localized micro explosions resulting in thermo-mechanical effect leading to vaporization of tissue. The action of the free-running pulse (irradiation 45 kW/cm$^2$) is by two orders longer than that of the giant pulse, and therefore in the case of the free-running long pulse the heat is dissipated into the surrounding tissue and the surface of the cornea is significantly corrugated, much more than in the case of the giant pulse influence.

For the case of the lens mass, the tissue was grinded by the Er:YAG radiation with short (Q-switched) or long (free-running) pulses. It will be the task of our following investigation to compare the velocity of both treatments.

From the sclera investigation it follows that for the perforation of this tissue the longer pulses are more convenient than the shorter ones. This could arise mainly from the fact that the radiation must overcome the reflection of this white tissue. By supplying the heat into the sclera tissue during the microsecond pulse, the reflection of the tissue is changed and the rest of the same pulse can cause the ablation.

The optimum correlation between the energy dose and the number of pulses for the eye tissue treatment is still to be found. There are two main requirements for thus. At first, the minimum number of laser pulses is preferable because the natural movement of the human eye globe could be eliminated and also the velocity of the whole operation event is shorter; at second, the radiation dose has to be as low as possible to guarantee that the value of the temperature damage threshold energy for the particular tissue is not reached.

As conclusion is can be summarized that the giant pulses are more efficient in the ablation of cornea, they are comparable with the free-running long pulses in the case of grinding of lens and less functioning for perforation of sclera. As concern the delivery of the radiation it has been proved that the energy delivered by the waveguide was sufficient and suitable. The sealed waveguide was not damaged during the treatment. It showed its very good applicability for the transportation of the energy into the wet tissue.

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# Solid state photon counters based on GaAs and GaP material

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The all solid state photon counters with high timing resolution are of interest of numerous techniques: laser range finding, optical time domain reflectometry, distributed temperature sensors, time resolved spectroscopy, quantum cryptography, optical transillumination and others. At present, the most promising technique to detect single photons by use of a solid state detector is an avalanche photodiode (APD) operated in the Geiger mode. Our previous research and development in the field of single photon avalanche diodes resulted in a large aperture silicon and germanium photon counters with an active quenching circuit well adopted for applications listed above[1,2]. For further development of high timing resolution solid state photon counter we are focusing for materials with the higher carrier velocity, the III-V semiconductors are one of the candidates. The gallium based III-V semiconductor material also seems to be promising candidate for detectors operating in the x-ray region. The availability of an all-solid state individual photon counting system with the high timing resolution sensitive in x-ray is strongly demanded as crystalline silicon based detectors degrade when they are exposed to x-ray flux. The higher atomic mass of gallium should provide higher detector stability and lifetime. In general, the GaP semiconductor material seems to be the most promising candidate for the detectors operating in the x-ray region. That is why we have carried out the experiments to test the capability of the GaP photon counters to respond to the x-rays.

The first experimental samples of the photon counting detectors on the basis of GaAs, GaAsP and GaP semiconductor material have been developed and operated in our labs in last years[3,4]. The first experimental results with x-ray detection have been reached[5].

The structure manufactured on GaAs and GaP has been tested. The active area of both diode types is of octagonal shape with the diagonal of 350 μm; GaP diodes are reach-through orientated. The individual diode samples have been selected according to their reverse bias characteristics. The breakdown voltage of the samples was 40 Volts for GaAs and 24-58 Volts for GaP. In all the experiments, all GaAs and GaP diodes have been operated in an active quenching and gating mode, using a circuit developed for silicon photon-counting detectors[2].

The time-correlated photon counting scheme has been used for timing resolution tests. Experiment repetition rate was 10 kHz. The laser pulser provided optical pulses 32 picoseconds long at 0.757 μm. In general, the timing resolution of GaAs detectors is significantly lower in comparison to the silicon ones. The best value of the resolution obtained 230 ps is 4 times worse in comparison to the value obtained for the silicon-based detectors. The timing resolution of the GaP detector has been tested on the same wavelength, the measurements have been carried out relying on the residual sensitivity of the order of 0.01%. Although this value is low, the time-correlated photon counting experiment can be accomplished. The timing resolution FWHM reaches 102 psec, deconvoluting the contribution of the laser pulse length and the timing electronics involved, the timing resolution of the detector itself is better than 100 psec. The data distribution is highly symmetrical. The relative sensitivity and signal to noise ratio (SNR) of the GaP based photon counter versus the bias

above the breakdown voltage has been measured. The optimum bias voltage was found at 0.7 V.

The response of the GaP detector to the x-ray has been tested using the continuous wave source and gated operation of the detector in an active quenched operating mode. The selected GaP structures have been biased in range up to 2.0 Volts above their breakdown voltage in this experiment. The x-ray source, the tube providing 10 mW radiated into an entire hemisphere at 0.15 nm band has been used. The photon counter active area has been mounted at a distance of 300 mm from the source. Measuring the photon flux, the mean time between the detector activation and the first following detection event has been measured and averaged. The inverse value of this interval corresponds to an effective count rate. The measurement repetition rate was 100 Hz, 500 independent readings have been averaged to evaluate one count rate value.

Taking into account the radiated power, energy of a single quantum and the geometry of an experiment, the flux on the detector input has been calculated. Detection quantum efficiency has been calculated as a ratio of a difference of effective count rates (with and without x-ray quanta) and calculated flux. Resulting efficiency was 14 +/- 3% for selected diode sample. Linearity of x-ray quanta detection has been measured attenuating x-ray source power and successfully verified up to photon flow 40 photons per second and square micrometer.

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# Research of Selective Structures for Mobile Communication

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## Introduction

Comb-line filters are commonly used in a number of applications, e.g. GSM multiplexers. Design of such filters is mostly based on the work of Cristal ([2]), who investigated cylindrical rods. This analysis neglects some effects, so that one must resource to a number of tuning screws. Designs with more than 50 of those are not an exception, resulting in tuning times over five hours a piece. Since 1964, advance in computer technology has made more detailed analysis possible, enabling savings in tuning times. The results are reported here.

The components that comb-line filters are made of are coupled transmission lines. In order to be able to analyze these filters one needs to know the parameters of the transmission lines, i.e. capacity per unit length as well as mutual capacities between the lines and the same for inductivities. If the dielectric material of the line is homogenous, all the inductivities can be directly and easily obtained from the capacities.

We focused on the computation of the capacities. The moment method described in [1] was enhanced and the result was compared to a structure, for which the precise analytic solution could be found. The method was found to be very precise and fast.

Finally, the results from [2] were recomputed and corrected.

A more detailed description of the computation method as well as more results can be found in [3].

## Comparison to the results from [2]

In [2] a common basic component of a filter is investigated. Capacities of parallel circular cylindrical rods between two parallel ground planes are presented. The rods are also parallel to the planes, their axes lie in the center between the planes and their diameter is $d$. The distance between the planes is normalized to unity, the spacing of the rods is $s$ (the distance between their surfaces, not between the axes).

We recalculated some result from [2], in the concrete the odd mode capacities and found a good agreement (1%) only for non-extremal spatial configurations: If some parts of the electrodes get closer to each other than the other parts (it becomes when $d$ is 0.7 or higher or for small $s$), the disagreement with our results is significant and can be even higher than 10% . Our opinion is that the deviation is due to the computation of the indicated integrals (9) in [2] – in other words we think that a more simple method was used.

The assumption that the direct influence beyond the neighboring rods is negligible is correct unless the shielding of the ground planes vanishes, i.e. unless the planes are relatively far from the rods ($d$ as well as $s$ is small). In the structure with three rods we computed the "trans-mutual" capacity for $d = \frac{1}{2}s = 0.05$ and found it to be as high as 20% of the rod self capacity. But for higher $d$ and $s$ it decreases rapidly and for $d = \frac{1}{2}s = 0.2$ or higher the ratio was less than 0.5%.

Further we verified how the capacities depend on the number of the rods and on the position of a rod in the structure. Significant dependence of the self-capacity was observed for small $d$ and $s$ again. And even if $d$ and $\frac{1}{2}s$ were as high as $0.2$, there was still a difference between the self-capacity of an outer rod and a surrounded rod (50%) despite that the dependence on more exact position of the rod vanished (<0.3%). The mutual capacity variation for $d = \frac{1}{2}s = 0.2$ or higher was small regardless we computed it between two border rods or rods deeper in the structure (<0.5%). (We computed that for 2-5 rods.) This justifies the computations in [2], which were done for simplification for a periodic structure, with an infinite number of rods. The problem with significant self-capacity deviation of the outer rod could be apparently solved by a closing wall, perpendicular to the ground planes and parallel to the rods with $\frac{1}{2}s$ distance from the border rod. The wall would act as a mirror, and thus the border rod would be influenced as if other rods surrounded them. The self-capacity of the border rod would then be approximately the sum of the self-capacity of an inner rod and twice the mutual capacity. This was also verified by computations and it holds, as long as the "trans-mutual" capacities are small, of course, (if e.g. $d = \frac{1}{2}s > 0.2$, the deviation is <0.8%). The dependence of the mutual capacities on the number of the rods, however, increased about three times in the closed structure.

**Conclusion**

The design method of the filter can be found in the literature (e.g. in [2]). The precision of filter analysis depends on the input data, which are primary parameters of coupled transmission lines that the filters are made of. The parameters are obtained from static capacities between the line conductors.

The method for computation of the capacities is fast and seems to be very precise. The results in [2] – capacities of periodic, circular cylindrical rods located between parallel ground planes – were verified and corrected. Our computations seem to be more precise even for spacing, for which a problem could arise, e.g. electrodes close to each other. Further, if the mutual capacities beyond directly neighboring electrodes are not negligible, we can compute them as well. Moreover the method is not confined only to cylindrical rods.

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# Crosstalk Analysis in CMOS Integrated Circuits

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The ICs in LSI technology require multilayer connecting-lead systems employing large leads density, diminishing the physical distance between individual leads. The small lead-to-lead separation results in increased crosstalk effects inside the integrated circuits. A method was designed to facilitate the forecast of crosstalks in integrated circuits using simple passive LCR circuit models of connecting lines [1]. It appears as possible, given a well defined standard interconnecting technology, to forecast the maximum value of crosstalk in a digital system regardless of the physical length of the mutually interfering leads. This presents a major design advantage since the maximum crosstalk value can be determined using simple equations without any need to perform circuit simulations of digital systems including the influence of parasitic couplings. The application of these limit cases can speed up considerably the design of electromagnetically compatible electronic systems.

The advent of novel sub-micron technologies of IC fabrication led to such a decrease in lead-to-lead separation that it is not possible any more to neglect the influence of these leads on the reliability of the system operation. Both the small lead separation and the application of multilayer interconnecting systems cause parasitic electromagnetic couplings [2]; in the case of a unipolar CMOS technology, the capacitive coupling is the dominant effect. Recent digital IC design systems try to include the interconnecting lead effects in the simulation procedures. There appear to be two popular approaches: either an inclusion in the digital simulations that try to describe real delays in the interconnections or analog simulations extracting the parasitic parameters of connecting leads from the IC layout. Analog simulations of the whole digital integrated circuit including all parasitic effects are extremely time-consuming. Consequently, more often than not only partial simulations are performed for the close environment of critical leads.

For optimum operation of digital systems composed of logic gates it is necessary that the state variations of their active components are as fast as possible. The quick voltage variations as well as the related current variations create time-variable electric and magnetic fields around the components, especially around connecting leads. These fields can cause error states in the digital system. Similar, though a bit different behavior appears in systems working with analog or mixed signals.

In order to simplify the simulation of electronic systems in integrated circuits, a method was devised [1] for estimation of crosstalks with the aid of simple circuit models of crosstalk-creating lines. These line models can be incorporated into system simulation schemes and so they make possible to investigate the crosstalk effects in a given digital system.

A complete equivalent circuit of a twin-lead line close to a grounded plane was designed as a symmetrical PI-network including mutual magnetic coupling. The parameters of

the line equivalent circuit are: capacitances CC (mutual lead-to-lead capacitance) and CS (the lead-to-ground plane capacitance), inductances LL (self-inductance of the lead), M (mutual inductance of the leads) RL (lead resistance).

Capacitive coupling is the dominant effect in high-impedance circuits like unipolar digital ICs in CMOS technology. The influence of inductive coupling can be neglected in these circuits and thereby the equivalent circuit simplified to a circuit of twin leads with parasitic capacitive coupling only.

The lead dimensions correspond to the design rules for this technology (2.4 μm Mietec CMOS). Further there are indicated the leads parasitic capacitances: $C_C$ – the mutual capacitance between the A and B a twin line leads, and $C_S$ – the lead-substrate capacitance, all according to the simplified equivalent circuit.

The actual magnitude of crosstalk between leads inside an integrated circuit depends on the geometric parameters of the line and on the electrical parameters of gates connected to the line. Most of the geometric parameters of the line are usually predetermined by the design rules of the particular technology. The electrical parameters of the gates are bound to the standard digital cell libraries and the designer can only select from a limited assortment of available digital cells.

In general, it can be expected that the crosstalk magnitude will rise with increasing length of mutually influencing leads. A non-active line in an interference-free situation is assumed to be in the state of logical zero. The interfering impulses are transferred by parasitic capacitive coupling. The interference source was a CMOS gate-driven line, with the gate operating off a $U_{CC}$ = 5V power supply, generating a rectangular waveform signal.

In order to be able to derive the maximum crosstalk amplitude regardless of the line length it is necessary to adjust the simplified IC twin-lead line equivalent circuit into a form permitting to set up the crosstalk transfer function. This equivalent circuit adjusted for AC crosstalk analysis contains capacitances $C_V$ and $C_S$, the capacitance $C_S$ must also include input capacitances of the gates connected to the line. The driving CMOS gates connected to the line were transformed to resistors with a value R, representing the actual resistance of the MOS transistor in the "on" state. The interference source is represented by the driving gate connected to the active line, in this case a $U_Z$ voltage source while the interference receiver is a gate connected to the far end of the non-active line, in this case the interference is represented by the $U_P$ voltage.

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# Support of Tutorial by Up-to-date Methods of Electromagnetic Wave Propagation Prediction

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Indoor wireless communications is one of the most rapidly developing fields. There is an increasing demand for efficient and accurate signal propagation models and design tools. There are two conventional approaches to the indoor signal propagation modelling:

- Empirical models are based on very simple and straightforward formulas [2]. The are very fast, only simple input is needed and the formulas are very easy to apply. On the other hand they provide a poor site-specific accuracy and incapability to predict wide band parameters of communication channel.
- Deterministic models try to follow physical principles of electromagnetic wave propagation. The most popular are ray tracing and ray launching. They are based on geometrical optics principles. These models are very accurate, site-specific and they can predict wide band parameters as well. However, in the same time, they are slow or they are fast but need some pre-processing and simplifications. In addition, they need very precise input database of obstacles including the electrical parameters of used materials, which are often unavailable.

New semi-deterministic approach was introduced [1] to combine advantages of empirical and deterministic approaches: wide-band results, high site-specific accuracy, fast computation time and easy to obtain input data. The main idea is based on a ray launching technique, Monte Carlo method and statistics. Without complicated electromagnetic calculations of reflection and diffraction all the effects including diffuse scattering are taken into account in the prediction using a new “motif-concept”.

The Motif model based on this approach was developed, implemented and tested. Signal strength as well as wide-band parameters such as impulse response and angle of arrival can be modelled. The calculation of common scenarios takes a few seconds on an ordinary PC Pentium. The measurement campaigns at the frequencies of 900 and 1900 MHz were undertaken to evaluate the model. All the evaluations show good agreement of prediction results with measurements. The standard deviations were usually smaller then 5 dB. The model is being implemented into a CAD software tool for complex design of indoor wireless cellular systems. This model could be also adapted for outdoor scenarios.

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# Measurement of Thermophysical Properities of Fluids by Thermistor

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In an industrial branch we often meet with a thermophysical parameters. The knowledge of these parameters is decisive factor for optimal implementation of physical processes. A lot of disturbing phenomena have affect on result of measurement of the thermophysical parameters. An elimination of disturbing phenomena leads to a various principle of measurement. The principle of each method is based on appropriate generation of thermal field. It is based on solving of partial differential equation of heat conduction for a particular initial and boundary condition. Practically each laboratory develops its own methods of generally known principle of measurement. The existing methods of measurement of thermophysical parameters could by divided as stationary and nonstationary.

The goal of this work is measure thermophysical properties of fluids by subminiature bead thermistor. Particularly the thermal conductivity of gases is measured by nonstationary method. The method is a variant of known "Hot Wire Method". These methods are based on generating thermal field in gas and measurement of time dependence of temperature. Commonly for the hot wire methods platinum wire is used like a source of heat and at the same time like a temperature sensor. The platinum wire is heated by a current and a temperature response of the thermistor is measured. The new method, developped in this work, substitutes wire by thermistor. The thermistor has a different shape then wire and so the new solution of partial differential equation must by performed. From the point of view of the solution of partial differential equation the question of the initial value problem. It could by expressed by means of fundamental solution of equation of heat conduction. The total solution is derived bt the convolution of density of heat source and the fundamental solution.

The thermal conductivity is found from the time record of small changes of resistance of the thermistor. The time change of temperature after applying the heating current is proportional to the change of resistance. The thermistor is connected to a source of current and the change of thermistor resistance is measured directly by Ohm's law. Plotting the time change of temperature on the graph with square root time axis gives straight line with the slope inversely proportional to the measured thermal conductivity. The time change of temperature is affected by free convection of surrounded gas, heat capacity of thermistor, heat dissipation of lead wire and temperature differences between the thermistor and boundary of cell. The new generation of bead thermistor has small diameter (0.15mm) and reach metrological properties comparable to platinum temperature sensors. Small size and more then one order large temperature coefficient of resistance then this of platinum temperature sensors suppress these disturbances.

Some experiment was performed for verification theory of measurement thermal conductivity. The thermal conductivity was verified experimentally by miniature bead thermistor by measurement of air. Used measurement system was composed from measured plug-in PC card AD14DSP with 14bit A/D converter. Triggering of converter and current was performed by digital output of card. Algorithm of measurement was programmed in development environment Lab Windows/CVI in language C. Measured data was stored in file and calculated in Matlab.

Measurement was performed for current in the range from 1 to 100 μA. A disturbing voltage appears for a 1μA current thus data filtering must be used. Result for measurement current of 100 μA are without significant disturbace and can be used easily for computing of thermal conductivity.

The measureming equipment was expanded the new type of intelligent measurement circuit Data Acquisition Microcontroller XE88LC05 fabricated by XEMICS. Significant benefit was analog-digital converter with voltage zooming. The converter substitute complex bridge circuit for measurement of thermal conductivity by simply method of direct measurement of resistance. The converter simply take off initial value of measurement voltage. Differential voltage is amplified and measure with 16bit resolution.

The feedback control of heating current maintaining constant dissipated power during the transient process is required. These is realized by the circuitry based on monitoring voltage and current through thermistor and using them for calculation of instantaneous power dissipated in thermistor. For these purpose is used special microprocessor with zooming analog-digital converter.

Measuring of coefficient of heat conductivity by subminiature bead thermistor is useful in many applications. On the base of measurement of coefficient of heat conductivity is possible measure ofbladder wall permeability.

The measurement of the thermal conductivity of gases is important in sensors based on heat transfer and dissipation. On the base of heat transfer are working the sensors of flow, calorimeters, chromatographs and many others sensors. All of them measure thermal conductivity by thermistor and must by calibrated for particular environment. If we are able measure the thermal conductivity the calibration is not necessary.

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# Contactless Current Measurement with the Anisotropic Magnetoresistors

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The classical way of the current measurement, using the shunt resistor, can be complicated or impossible in some cases (e. g. by very high current measurements that is dangerous and requires very precise shunt resistor with a high power dissipation). Being suitable for high-voltage applications, the magneto-optical current sensors are under intensive development. However, their errors are higher than 1 % even when the temperature influence is compensated [1].

The basic requirement to a contactless current sensor is that it should be geometrically selective, i.e. insensitive to the magnetic fields acting in other directions than is the sensitive axis. Therefore many contactless current measurement devices employ magnetic circuit formed by a ferromagnetic ring (yoke), in whose air gap the sensor is placed. Increasing the sensitivity, this configuration is usual when Hall sensors are used for the current measurement. Such current measurement is suitable especially for the currents higher than 10 A, yielding the accuracy of 0.5 to 1 %. In this conception, the problems may be caused due to the magnetic leakage in the air gap and saturating of the ferromagnetic material of the yoke.

Novel current measurement device based on the magnetoresistive sensors has been developed in our laboratory. Our device employs four (or eight) sensors with anisotropic magnetoresistors (AMR) positioned symmetrically around the hole for the measured wire. Each sensor contains two pairs of complementar magnetoresistors connected to the full Wheatstone bridge. This configuration is more feasible for the further processing than to use single magnetoresistor. Current supply of the Wheatstone bridge reduces the temperature dependence of the sensor sensitivity. Precise instrumentation amplifiers process the signal from all the sensors individually at first to provide the impedance matching, and then the signals are summed all together. This configuration considerably reduces the influence of the unsymmetrical wire position in the hole. Moreover, the undesirable changes of the output signal due to the ambient magnetic fields (e.g. geomagnetic field) are also suppressed, because these signals are added to the signal of some sensors positivelly and to some of them negativelly.

Philips KMZ 51 anisotropic magnetoresistors are used in our device. We utilized the result of our previous research on KMZ 51 sensors in the development of the electronic processing chain for our measurement device [2]. To reduce the hysteresis, prevent the fall of the sensitivity due to the large fields, and obtain the convenient alternating output signal, the flipping technique is used [2]. This method is based on the periodical saturating of the material of the sensor by means of very high and short current pulses, creating the field in the integrated flipping coil [3]. A synchronous detector processes then the summed alternating signal from all sensors. The timing for flipping as well as for the synchronous detection is controlled by a microprocessor. A special timing concept is used, ignoring the unstable behavior of the output signal, which occurs in short time areas immediately after the flip. That can make undesirable oscillation of the output signal.

Feedback compensation significantly reduces the linearity error and suppresses the temperature influence of the sensor output. The producer supports the feedback operation

mode integrating the compensation coil on chip. By means of this compensation coil the current flowing through generates the magnetic field of the same value but the opposite direction to the measured one. Thus the sensor always operates near the zero point of the characteristics (i.e. sensor works as a zero indicator). Consequently, the compensation current is proportional to the measured magnetic field.

In our previous research, we built the simple AMR magnetometer [2], which possesses the total error better than 0.03 % of the full scale in the recommended measurement range of the sensor (± 200 A/m). The contactless current measurement device, using the same processing techniques, has the linearity error of 0.4 % in the current range of ± 2.5 A, but we think the parameters could be still improved. This is one of the goals of our further development. The distance between the middle of the hole and the sensitive axis of the sensor is one half of the inch, i.e. 12.27 mm. As the resolution of the AMR magnetometer is better than 10 nT, we suppose that the current measurement device enables to measure the current with the resolution better then 700 μA up to the current of 15 A. However, linearity error matters in these considerations. Our next research will be focused on the suppressing of the offset, improving the linearity and reducing the overall noise of the measurement device.

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# Portable Calibration Standard for Satellite Laser Ranging

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The factors contributing to the laser ranging precision and accuracy have been investigated in detail. The contributions of the ranging machine, Earth atmosphere and other possible sources have been taken into account. The accuracy of the satellite laser ranging may be estimated on the basis of analysis of all the individual contributors to the ranging error budget. All the error budget contributors have their random (precision) and systematic (bias) components. It means, that the correct understanding and interpretation of the ranging precision is the precondition of the ranging accuracy statement.

The Portable Calibration Standard is a powerful tool for the satellite laser ranging machine diagnostics and performance check, it has been developed by our group within the last years [1,2]. Its main components are the Portable-Pico Event Timer (P-PET), time and frequency reference, atmospheric monitoring devices, computer control and data processing packages. To meet the growing demands of the world community, the Pico Event Timer has been upgraded in 2002. The main objectives of the upgrade were to decrease the timing jitter and to enable the operation of the Portable Calibration Standard based on an upgraded P-PET at the stations equipped with the multi kHz lasers. The new input board has been constructed, providing the advanced gating and arming options. This upgrade, together with the built in software modifications, gives the Portable Calibration Standard a possibility to cooperate with the high repetition rate laser ranging systems. The repetition rate of the laser system under test may be as high as 2 MHz, the measurements are sampled with the rate of 100 measurements per second. The timing linearity self test option has been included into the system[3]. Within the last years, the Portable Calibration Standard missions have been completed on seven satellite laser ranging sites[4].

The contribution of the Earth atmosphere to the laser ranging error budget has been investigated. The motivation of this research was the discrepancy between the ground and space target precision achieved. The best existing ground based ranging systems are capable to reach millimeter ranging precision when ranging to short distance terrestrial targets. However, ranging to Earth orbiting satellites the best precision obtained is typically 3 times worse. As this value is obtained even for satellite targets not spreading the echo signal, there is a speculation, that the remaining contribution to the random error budget is contributed from the atmosphere. We have used the available atmospheric modeling code GLAD to simulate the propagation of the optical signal in the laser ranging experiment. The propagation the 35 picoseconds long laser pulse in the atmosphere has been simulated, the diffraction, atmospheric fluctuations and standard atmospheric constitution has been taken into account. Both the horizontal path and the slant path to space and vice versa have been modeled. The beam propagation direction and signal delay have been evaluated for a large number of simulated laser shots. All possible atmospheric conditions have been simulated: seeing in the range 1 – 10 arcseconds, elevation angles 20 – 90 degrees, and different atmospheric constitution models. The differences of a picosecond pulse's optical path, caused by atmospheric turbulence have been evaluated to be below 10 micrometers peak to peak in all the cases. It means that the atmospheric turbulence cannot be responsible for the satellite laser ranging jitter increase[5].

As a conclusion of our error source analysis, there exists an error in Satellite Laser Ranging, both random and systematic, this has not been identified till now[6]. This contribution is not detectable by a existing Portable Calibration Standard. According existing atmospheric propagation models it is not caused by an atmosphere. According to the satellite retrorefletor response function ground tests, this error is not caused b the retroreflector array, as well. The random component of this error is on a millimeter level, its systematic component may be estimated once it will be identified and characterized. The identification of this error source is a big challenge for the near future of the Satellite Laser Ranging research groups.

Our activity and the acquired results in the field of the Portable Calibration Standard led to the decision of an European consortium EUROLAS to accept the Portable calibration Standard as a world wide reference for the satellite laser ranging systems on its meeting held in Herstmonceux, UK, March 2002. The European countries nominated the joint project as an Integrated Project to the 6th Framework Program of European Community for the period 2003-2008 [7]

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# Optical Processors

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Optical information processing (OIP) utilizes the physical properties of light beam spreading for time consuming calculations. These techniques are characterized by massively parallel and very fast calculations.

Two different approaches in OIP as in the general electronics are used. One group is so called analog and the second one represents the digital group. Analogue methods are usually based on the simple implementation of Fourier transform and complex multiplication. While the digital methods utilize the similar configurations for interconnection and logical operations only. In the second case the effective computational power rapidly decreases.

The total calculation time can be divided into two main parts. The first one represents the spatial light modulator (SLM) incl. detector response time due to the fact, that incoming and outgoing data as well as the storages for data coefficients are so far realized in the electrical domain. Although the fast progress during last years was achieved, this part causes the most delay limiting in final performance and calculation speed. The second part of calculation speed depends on time needed for light passing across the optical setup. This time usually represents the pure calculation time. The real value is marginal in comparison with the response time mentioned in the first part. As a logical step is therefore the implementation of iterative algorithms, where only the input and final output need to be converted to the electrical domain. Due to the huge difference of both parts affecting calculation speed, there is a good opportunity to speed-up whole calculation process.

Although OIP over past twenty years has presented very promising results, the pure implementation of classical general algorithms like matrix-matrix multiplier are not practically suitable because calculations exploiting the analogue OIP are affected by a relatively high level of noise, so that the real number of levels resolved is relatively small. In the real situation the uniformity of the light source beam, aberrations of optical systems used, uniformity of SLMs and detectors together causing in result the time invariant calculation error. An analogue OIP uses mostly coherent light, where speckle, scattering and other coupled effects corresponds to additive and multiplicative noise in the result. The result of calculation includes both influences. However in particular case the determination of all influences is very complex. The final result is substantially affected; therefore the class of suitable algorithms for implementation is so far very limited.

The adaptive and robust algorithms, where the imperfectness of calculation in each individual equation can be overcome by the number of redundant interconnections, can be find. Typical example represents artificial Neural Networks (NN). Adaptation performs correction of time invariant errors and the redundancy removes the noise. In case of iterative algorithms such us NN learning process or fractal compression, which are very effective in OIP as mentioned above, the situation is more critical due to errors accumulation.

The stability of recurrent algorithms under real level of noise and errors was studied. A simple model of perceptron field was created by OIP. Adaptive dynamics were defined as classical perceptron learning rule. However a complete training cycle was calculated in parallel as one calculation step. For better utilization of SLM the normalization of weights was performed. The simple perceptron field was qualified by known convergence rule, discovered by

Rosenblatt, the perceptron inventor. The calculation steps were repeated until vector of weights does not changed for ten consecutive steps. Learning process was sufficiently stable. During initial learning the noise changes generated weights. Presented level of noise had a positive impact to the learning process and improved generalization of the NN.

Although the experimental results shows that OIP can be used for iterative calculations, the iterative function system (IFS) should be carefully selected. On the other hand the fuzzy environment of OIP is closer to the real biologic NN than computer simulated NN.

By the noise level control in the optical set-up the stochastic Hopfield NN known as Bolzmann machine or Cauchy machine can effectively be used. This class of NN requires complicated and time-consuming adaptive dynamics using simulated annealing. Implementation with OIP gives an advantage in comparison with computer simulation.

The other class of algorithms suitable for analogue OIP is a calculation of the 2-D correlation for object identification and localization. In those cases the result of calculations is not usually of exact value, but the presence/absence of correlation peak and as much as correctly defining its position. In last time the role of 2-D correlation increased due to 2-D wavelet transform. It represents an integral transform from 2-D space to the 4-D space, where first 2 correspond to the 2-D correlation with the core - mother wavelet and the rest determines different scale factors. Correlation and wavelet transform are very useful techniques in fractal compression. In all those cases is the calculation speed critical, while the correlated fields remain large.

Implementation of 2-D correlation by OIP can easily be provided in the space domain using systolic algorithms. Acustooptical modulator inherently realizes such algorithm. A pair of AO modulators can perform 2-D correlation. The disadvantage is the limited calculation speed and the dimension of both modulators. As it was mentioned above analogue OIPs perform simply Fourier Transform, so the correlation can be easily calculated in the spectral domain as a complex multiplication. Joint Transform Correlator (JTC) technique is based on a replacement of complex multiplication by applying complex non-linear function to joint spectra. The wanted term is selected by the space separation of final terms.

The JTC technique was experimentally demonstrated for letter identification in simple two-step set-up. Used configuration enables to work in quasi-real time with the TV rate. In the first step the FT and square function were performed. In the second steps the inverse FT was calculated. Results were simulated in MATLAB and than experimentally verified.

Influence of LCD nonlinear transfer function to the final terms, dependence of used optical elements to the total scale of terms and influence of additive Gaussian noise were studied.

Very good coincidence of simulated results with experimental result was observed.

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# Optimized Education of Electronic Circuits and Functional Blocks

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The aim of this project is to prepare working environment for seminars of Electronic circuits in bachelor degree courses and related seminars in master degree courses with respect to required knowledge depth and profesional skills of graduates and throughput of this demanding part of electrical engineering study. First partial goal is general redesign and rework of student laboratory, including sets of measuring equipment and special study documentation sets and laboratory modules.

Requirements for the student measurement laboratory are given by the set of subjects teached in this laboratory. These requirements influence selection of basic measurement instruments, possibility to add individual special measurement instruments, and selection of gradually added development kits and laboratory modules. Besides the regular use during the study term, the laboratory should also be used for individual project assignments (design, simulation, construction) at different study levels (study term projects, bachelor projects, diploma projects).

Subject Electronic Circuits is the main subject teached in the laboratory. It is one of the basic subjects of study branch Electronics and Communications. The laboratory will also be partially used in subjects Fundamentals of Electronic Circuits, Analysis of Electronic Circuits, Architectures and Using of Programmable Circuits I and II, Digital Filters, Implementation of DSP algorithms, Design of Electronic Circuits, Electronic Systems Labs, and Experimental Work in Labs.

Main parts of the project was:

- design of standard measurement equipment set for every workplace, including one PC per workplace
- choice and placement of workplace equipment, including placement on laboratory tables
- spatial arrangement of 12 workplaces
- design of AC power lines arrangement in the classroom and in the laboratory tables
- system of gradual innovation of equipment
- innovation of laboratory tool sets for Electronic Circuits – document sets for circuit simulation and laboratory measurements

Main results of the project:

- Reconstruction of AC power lines and room lighting. Special original arrangement of PC power lines ensures trouble-free room power startup.
- Delivery of custom ergonomic laboratory tables designed exactly according to our needs.

- Construction of AC power network and data network in laboratory tables, interconnects and tests of all laboratory equipment.
- Allocated grant money were used to buy laboratory DC power sources HAMEG. According to our tests these DC sources are able to meet stringent requirements of analog and digital functional blocks used in the laboratory.
- Allocated grant money were also used to buy three generators GOODWILL; these generators are now being evaluated.
- Other financial sources were used to buy new oscilloscopes and personal computers.
- Equipment sets fully satisfied our requirements during four-week long intensive use.
- Circuit simulation software system WINSPICE was installed besides the PSPICE system used so far. Study documentation and related files can be found at Internet web server [3].
- Document sets to be used for laboratory work and operational amplifier parameters identification can be found at Internet web server [4].

All these changes allow optimal combination of different types of students' work - laboratory measurement including diagnostic of circuit being worked on, seminar work, and individual project assignments (design, simulation, construction) - and different study levels. We expect that laboratory arrangement will be able to meet requirements of dynamic evolution in this field for at least ten years.

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# Microsystem Design for RF Power Measurement

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This paper discusses the thermo mechanical simulations performed in the aim of optimising the temperature distribution of the Micromechanical Thermal Converter designed for Microwave Power Sensor Microsystem. The conception of absorbed power measurement is based on thermal conversion, where absorbed RF power is transformed into thermal power, inside a thermally isolated system. By means of thermal simulations, we propose Micromechanical Thermal Converter design, layout and placement of the active heater, and temperature sensor integrated within MTC. Spatial temperature dependences, thermal time constant power to temperature characteristics, misses' stresses and displacements caused as a result of temperature changes in the structure are calculated from the heat distribution and thermo-mechanical simulations. The 3D thermal and thermo-mechanical simulations of the sensor structures were performed, using the Coventor Ware simulator.

Transmitted radio frequency power (RF) measurements are of great interest in the field of microwave equipment. The conventional method to transmitted power measurement is based on the measurement of absorbed power waves that requires complex power meter structures and need complicated calibration of the measured data. Preferable approach of the absorbed power measurement is based on thermal conversion principle where, absorbed RF power is transformed into thermal power inside of a thermally isolated system.

Thermo-mechanical numerical modelling has a substantial impact on the optimal MTC topology design. The main characteristics which we use to optimise these devices are the temperature distribution over the sensing area, time response, sensitivity analysis and evaluation of the mechanical stresses in the MTC structure.

The most significant advantages of GaAs based MEMS are some intrinsic properties of the material, lower thermal conductivity, high temperature performance, heterostructure quantum effects, etc. The technology of high electron mobility transistors (HEMT) is also developed for the GaAs based structures e.g. GaAs-InGaAs or GaAs-InGaP GaAs-based Integrated Circuits can also be integrated within the bridge sensor microstructure.

GaAs multilayer MTC creates optimal conditions for both the monolithic integration of GaAs based Heterostructure Field Effect Transistors (HFETs) and thermal isolation of the microwave sensor elements.

For Cowentor Ware simulation tools 3D models of GaAs MTC has been designed. First model represents two symmetrical cantilever beams structure fixed by polyimide layer in rigid GaAs substrate which has been designed 10μm thick for the purpose of the thermal and thermo-mechanical simulations. Second structure is GaAs island floating in polyimide layer that mechanically fix MTC structure. Both MTC devices consists of a heater (the MBE-grown MESA isolated type of AlGaAs/InGaAs/GaAs pHEMT transistor monolithically integrated on the micromechanical structure) and temperature sensor. The temperature changes induced in the cantilever beam by electrical power dissipated in the HFET are sensed using the temperature sensor. The MTC GaAs MEMS structure (1μm) is completed by Ti (50nm)/ Au

(150nm) metallization, which enable to connect the heater and temperature sensor. Free micromechanical structure is fixed by 1μm polyimide layer.

Fabrication of the MEMS device is provided by front-side surface processing of HFET structures and surface micromachining which are combined with a back-side bulk GaAs micromachining of a cavity.

The temperature distribution over the sensing area and device mechanical stresses were optimized by studying different MTC formations, and layouts of the heater and temperature sensor. We have investigated three basic adjustments to compare their thermal and mechanical behavior:

- *Fixed Cantilever Beam MEMS devices*
- *Fixed Island MEMS device*
- *Fixed bridge*

Main characteristics to optimize for such devices are the temperature distribution over the sensing area caused by power dissipation in a heater, thermal time response as a result of power changes, evaluation of the mechanical stresses, displacement and deformation in the MTC structure.

The thermo-mechanical modules MemTherm and MemMech ware used to simulate the thermal and mechanical behaviour of micromechanical thermal converter.

The input power dissipation in the heater was defined as heat flux through the gate area patch of HEMT.

Finally, the power to temperature (P-T) conversion characteristics of the MTC structures, were investigated by simulation and were compared with the real micro-machined devices. High electro-thermal conversion efficiency defined by extracted thermal resistance values ($R_{th}$) 11 K/mW (experimental measurement) and 11.5 K/mW (CoventorWare simulation), respectively, was achieved for fixed bridge structure and 24 for island K/mW MTC. When compared with the experiment, the thermal resistance values are congruent.

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# IGBT Lifetime Killing Process Design Using Simulation Tools

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The proton [1] and helium irradiation [2, 3] is frequently used for lifetime reduction in Insulated Gate Bipolar Transistor (IGBT) in order to shorten substantially the turn-off time and turn-off losses. Compared to the electron irradiation, the ion irradiation techniques give superior trade-off curves of the ON-state voltage drop versus turn-off time for any voltage class. In this project, we concentrated our effort on 600V vertical Punch Through (PT) IGBT.

For the ion irradiation of the PT IGBT with N-epitaxial layer, two basic approaches were reported, namely the ion irradiation from the frontside (through the MOS structure) and backside (through the collector region) [2]. The former results in the threshold voltage shift [1] and always leads to the modification of the lifetime in the N-epitaxial region [2] thus bringing undesirable increase of the forward voltage drop. The latter enables one to avoid both the modification of the MOS structure and N-epitaxial region at an undesirable area (far from the $N^+$-buffer), but scattering of the substrate thickness precludes from the precise positioning of the ion range. Moreover, in the case of IGBTs with low breakdown voltages, that possess a thick $P^+$-collector layer (400 - 500 μm thick), high irradiation energy is necessary for the backside approach. Depending on available irradiation facility, this can exclude usage of helium irradiation thus providing the proton irradiation as the only alternative. In spite of the problems summarized above, the backside irradiation was chosen for this study thanks to more attractive features for practical application over that of the frontside approach.

The device under study was 600V vertical PT IGBT with an active area of about 25mm$^2$ designed by CNM Barcelona and IMT Bucharest. The device was processed in CNM using 8 mask process on 4 inch wafers cut in <100> plane. The starting substrate thickness was 525 μm. As the ion irradiation was performed through the relatively thick $P^+$ substrate (backside approach), the substrate had to be thinned prior to processing of the backside contact including subsequent special anti-stress procedure. The resulting total device thickness was 450 μm including both the buffer and epitaxial layers. This allowed for application of the proton irradiation with energy of 7.35 MeV resulting in the proton range far enough from the MOS driving structure. To achieve several proton ranges in the IGBT volume, up to three aluminum foils with thickness of 15 μm were inserted into the beamline during the irradiation process. This enabled us to study the influence of the ion range inside all the three regions of the IGBT, namely in the N-epilayer, $N^+$-buffer, and $P^+$-substrate. The irradiation dose was chosen in the range $3x10^{10} – 3x10^{12}$ cm$^{-2}$.

The design of the irradiation procedure was supported by the device simulation using ATLAS. For the simulation of irradiated devices, the multilevel Shockley-Read-Hall (SRH) model with full trap dynamics was applied. The model parameters were chosen intuitively using the experience with

calibration of power devices. After irradiation, the SRH model parameters of individual centers were precisely calibrated to get a close match between the measured and simulated collector current turn-off waveforms to avoid the problems with accounting for the contact resistance resulting from the measurements at the probe station. For the unirradiated device, a single level with uniform spatial concentration distribution was accounted for the background lifetime. The parameters of other physical models of the unirradiated device were calibrated with reference to the threshold and breakdown voltages using the static I-V curves. The resulting magnitudes were also used for the irradiated devices. For the proton irradiated device, the two most relevant deep levels corresponding to the single acceptor level of divacancy and vacancy-oxygen pair were added. The proton irradiation defect profiles were recalculated from the distribution of primary vacancies received from Monte-Carlo simulation. The influence of the hydrogen shallow thermal donors was also accounted for, although the background doping of the N-epitaxial layer is quite high ($10^{14}$ $cm^{-3}$) to affect the results. Models and parameters of various scattering mechanisms (mobility), Auger recombination, band-gap narrowing, and impact ionization were the silicon default settings of the ATLAS simulator.

To avoid the influence of the changing device thickness, the thickness of individual devices was measured an the ion range introduced into the simulation was adjusted accordingly for every device. The influence of the dopant type was considered together with that of the doping density using a lower defect introduction rate for the $P^+$ substrate region compared to that of the $N^+$ buffer and N epitaxial layer. Finally, for the irradiation doses in the order of $10^{12}$ $cm^{-2}$, the saturation of the radiation defect density with increasing irradiation dose was taken into account. The agreement achieved between the simulated and measured waveforms is very good.

The experiments have showed that the best trade-off is that of the IGBT with the defect peak placed into the boundary between the $P^+$-substrate - N-buffer layer provided that a relatively high irradiation dose is used [4]. This was found in a good agreement with the simulated trade-off even without calibration of the recombination model. At present, measurements at high voltages close to that of a real application are being performed. The experience obtained with 600 V IGBTs will be used in the forthcoming project dealing with 6.5 kV IGBTs.

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# Multi-frequency Laser for Millimeter Satellite Ranging

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To range Satellites / Moon one has to consider several "contributors" to the overall accuracy of the Satellite Laser Ranging SLR: the station itself, satellite retroreflector array and the atmosphere, as well. Current SLR technology aims toward millimeter accuracy.

From the point of view of the SLR station, rms the laser pulse duration, Start and Stop detectors rms and the Event Timer jitter are involved. Due to different satellite retroreflector array geometries, to understand the ultimate limit, the best choice is perhaps the European Remote Sensing ERS satellite array and the optical spherical retroreflector, Luneberg lens, on the board of the Meteor 3M satellite.

Related to the atmospheric dispersion, the existing models are not yet explaining the contribution at millimeter accuracy level. The SLR at different frequencies might help to understand the atmospheric mapping function down to millimeter / submillimeter level. In fact, multi-frequency SLR is an unique method for overall optical path dispersion model direct verification.

Assuming the atmospheric dispersion, to find the right laser for multiple wavelength millimeter SLR, one can consider the Nd:YAG / SHG / THG, Nd:YAG / SHG / Raman First Stokes / First antiStokes in Hydrogen, Nd:YAG / SHG / Raman First Stokes in Methane and the Titanium Sapphire Fundamental / SHG, all of them at different repetition rates. The selection of the laser transmitter concept is influenced by the required reliability in the routine field operation. Considering that the 6 picoseconds round trip time corresponds to one millimeter range, therefore to reach the millimeter goal, the acceptable laser pulse width within the range of 10 to 50 picoseconds is desirable. The experiment energy budget requires the energy in one pulse in order of several tens of millijoules. Considering the principle SLR scheme, just the fundamental $TEM_{00}$ laser transmitter mode contributes to the energy budget. The selection of the right wavelength pair is determined by the atmospheric dispersion mentioned above, by atmosphere transparency, and by the availability of high effective frequency shifters. In principle it is difficult to use to independent lasers due to the required picosecond synchronization.

The available detectors have to be considered either. Our laboratory has long term experience in the field of picosecond temporal resolution solid state detectors. For the visible range we did examine mainly Silicon based Single Photon Avalanche Detectors SPADs, for the eyesafe SLR Germanium based SPADs. The Silicon one can be operated at Peltiere cooling temperature, but its detection quantum efficiency in eyesafe region, close 1.54 μm, is not acceptable. The Germanium based detector is suitable for these wavelengths, however it has to be cooled by liquid Nitrogen. Using the Quantel YG580 Laser 30 mJ / 1,06 μm, 35 ps, different Raman tubes filled by Hydrogen at different pressure, different focusing lens, we were

getting 8 mJ / 0.68 μm, 1 mJ / 0.45 μm. Considering the eyesafe SLR using Raman shift in Methane we were getting 3 mJ / 1.54 μm.

Using Raman, one has to be cautious at higher pumping levels. Either to monitor the far field beam structure using intensity profile detector or to monitor temporal pulse structure using streak camera might be a proper diagnostics. As a far field beam structure detector we were using CCD in visible region and the $LiNbO_3$ converter / CCD for 1.54 μm region.

The multiple frequency laser transmitter based on Nd:YAG picosecond laser generating the second harmonic frequency and the Raman Stokes and anti Stokes frequencies is dedicated for the new Shanghai SLR station, the part of Western Pacific Laser Ranging Network.

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Section 5

# MATERIALS ENGINEERING

# Computational Simulations of Pulsed Laser Induced Phase-Change Processes in CdTe and CdZnTe

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Many II-VI semiconductors, such as HgCdTe or CdZnTe, can be considered as pseudobinary alloys in a certain temperature and concentration range. Therefore, in modeling transport phenomena in this class of semiconductors basic treatments commonly employed for binary systems can be utilized.

In this paper, we employ some basic ideas of modeling binary alloy melting and solidification induced by pulsed lasers that were formulated by Černý and Přikryl in [1], [2] and apply them to selected II-VI semiconductors, namely CdTe and CdZnTe.

We consider a binary alloy consisting of components A, B that is irradiated by a laser pulse. We suppose that the dimensions and symmetry of the sample allow us to treat it in one space dimension. Initially, the sample is in the solid state and occupies the one-dimensional domain (interval) [0,D], where D is the thickness of the sample. Due to the laser irradiation the sample begins to melt and we suppose that the solid phase occupies the interval [Z(t),D], whereas the interval [0,Z(t)] corresponds to the liquid phase.

We suppose that no chemical reactions occur in the system, and regarding to the large temperature gradients induced by pulsed laser irradiation, we neglect the convection in the melt. Similarly as with the classical Stefan problem, we also neglect the density change due to melting and solidification. Therefore, it is sufficient to employ the balance equations of internal energy of the system and the balance equations of mass of the component A in both the phases. In formulating the corresponding balance equations at the solid/liquid interface Z(t), we employ the theory of discontinuity surfaces. Besides the balance conditions, two additional conditions at the solid/liquid interface have to be formulated, namely the liquidus and solidus curves of the phase diagram, and the Wilson-Frenkel interface response function. The practical implementation of the nonequilibrium phase diagram is performed using the nonequilibrium segregation coefficient in our model.

In solving the problem formulated above with the appropriate initial and boundary conditions, we employ first the Landau transformation to map both the liquid and the solid domain onto a fixed space interval [0,1]. To solve the fixed-domain initial-boundary value problem obtained we employ the Galerkin finite element method. The iteration algorithm used to solve the nonlinear problem under consideration is based on the successive approximation approach with underrelaxation. Its final purpose is to find the temperature and concentration fields in the sample and the position and velocity of the phase interface such that the interface response condition is satisfied within a specified accuracy in each time step.

In our numerical experiments, we used the model to simulate Nd:YAG laser (6 ns FWHM, 353 nm) induced melting and solidification of CdTe and CdZnTe. The initial content of zinc in the CdZnTe pseudo-binary was assumed to be 4% in all calculations. The energy density of the laser pulse varied from 0.01 $Jcm^{-2}$ to 0.10 $Jcm^{-2}$. The shape of the laser pulse employed in the computations was obtained by experimental measurements. The thermodynamic parameters of CdTe and CdZnTe were taken from [3], the optical parameters from [4].

The results of computer simulations performed for CdTe show that surface temperatures increase very fast with the laser energy density. This is a consequence of two basic factors, namely the relatively short duration of laser pulse, and relatively low thermal conductivity of CdTe (1-7 W/mK depending on temperature). For the energy density of 0.10 $Jcm^{-2}$, the surface temperature is higher than 3000 K, so that it is approaching the boiling temperature. The melt depth vs. time curves exhibit typical features as in the other cases of laser-induced phase change processes in semiconductors, but there is some important difference for instance to similar cases with Si or Ge, namely that the maximum molten layer thickness is relatively low, about 100 nm for the case when surface temperature is higher than 3000 K. This is apparently due to the low thermal conductivity of CdTe. Other consequences of the relatively low thermal conductivity of CdTe are that the melt front velocities achieve 20-25 m/s in the melting phase and 5 m/s in the solidification phase, the overheating is up to 150-250 K, the undercooling 50 K.

The calculations performed for CdZnTe show a similar view for the above parameters. For instance, the maximum surface temperature of CdTe is by about 1% higher than that of CdZnTe, the surface melt duration of CdTe by about 4% higher compared to CdZnTe. This is a consequence of the fact that the zinc content in CdZnTe is relatively low, so that the results should be very close to that obtained for CdTe. Concerning the other characteristic parameters of the process, the peaks on the incident laser reflectivity vs. time function are apparently a consequence of the appearance and disappearance of the liquid phase. The curve corresponding to 0.02 $Jcm^{-2}$ shows the change of reflectivity of the solid phase due to the temperature changes. The final concentration of ZnTe after pulsed laser irradiation changes compared to the initial ZnTe concentration in not a very high extent, which is a consequence of high melting and solidification velocities, resulting in the values of nonequilibrium segregation coefficients close to 1.

On the basis of the computational simulations performed it can be concluded that some features of the process, which may be interesting for an experimentalist, were identified. The most important of them is probably the fact that the laser energy window for the applications, which is demarked by the melting and vaporization thresholds, is significantly narrower than that in the case of basic semiconductors, typically from 0.04 $Jcm^{-2}$ up to 0.10 $Jcm^{-2}$. It may lead to the necessity to improve some of the current experimental setups towards a higher accuracy of laser energy adjustments.

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# Polycrystalline Silicon Thin Film Solar Cells Produced by Pulsed Laser Processing: Computational Optimization of the Production Process

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Recently, low cost crystalline silicon thin film solar cells on a glass substrate find growing interest as an alternative to amorphous silicon solar cells. The highest effort has been devoted to micromorphous and to quasicrystalline cells. For both an efficiency of up to 10% has been demonstrated. For micromorphous cells a fine grained silicon layer is deposited by choosing appropriate deposition conditions. For quasicrystalline cells a thin single crystalline sheet is removed from a wafer and pasted onto the glass substrate. A further method for preparing crystalline silicon layers on glass is to deposit amorphous silicon followed by laser induced crystallization. In this paper a computer simulation study is presented devoted to the evaluation of optimal layer as well as optimal laser parameters.

The proposed technology for the preparation of crystalline silicon thin film solar cells on glass in as follows. In the first step, a seed layer is produced by depositing 200-800 nm of amorphous silicon (a-Si) on the glass substrate and converting it into large grain polycrystalline silicon (pc-Si) with crystallite sizes of about 100 μm by scanning an Ar- or frequency doubled Nd:YAG cw laser beam. This seed layer contains impurities incorporated from the glass substrate because it has to be completely melted during the laser processing, which leads to partial melting of the substrate as well.

In the second step, the absorber layer of the cell itself is prepared by sequentially depositing further a-Si layers (typical thickness 20-100 nm) and crystallizing them by periodical short pulsed excimer laser irradiation. The conversion of the newly deposited a-Si layers into large grain pc-Si layers can be achieved if each laser pulse melts completely the a-Si layer and partially also the pc-Si layer below so that after the pulse, epitaxial crystallization of the molten layer can be initiated. Depositing further and further a-Si layers and converting them into pc-Si (the total thickness of the absorber is supposed to be about 4 μm), the properties of the absorber layer as a whole may change in a significant way, concerning the absorption and redistribution of the laser energy. The main reason are the big differences in thermal conductivity of the a-Si layer, pc-Si layer and the substrate, and also considerable differences in their optical properties.

The question arises how important are the thickness of the seed layer, the thickness of the a-Si deposited between the excimer laser pulses and the fluence of the pulses. In order to keep the process simple and economical, the number of excimer laser pulses should be kept as low as possible and the fluence should be kept constant during the deposition process. Computational optimization is probably the fastest and cheapest way how to find the proper parameters of the chosen technology.

The first necessary step in the computational optimization process is to formulate exactly the conditions for this optimization. From the purely technological point of view, it is not desirable to change the laser energy density or the thickness of the deposited a-Si layers during the process of the preparation of the absorber because it imposes unnecessary

requirements to the technology. Thus, the first optimization condition is the constant energy density of the laser and constant thickness of the deposited a-Si layers.

As it was mentioned before, the laser energy density should be high enough to melt through the whole newly deposited a-Si layer and a part of underlying pc-Si layer. This lower limit for the laser energy density presents the second optimization condition. We should note in this respect that the lower limit of energy density depends on the thickness of the newly deposited layer and also on the thickness of the seed layer.

There is also an upper limit for the energy density. The energy should not be so high that the glass substrate would be melted again in the second phase of the technological process because additional impurities from the substrate would be incorporated into the absorber besides those already presented in the seed layer. This upper limit is the third and final optimization condition, and it also depends on the thickness of the seed layer, and in some extent also on the thickness of the first newly deposited a-Si layer.

There is naturally one more condition, a general one but in fact the most important because it decides about the possibility to perform realistic computational optimization of any process. This is a proper choice of the physical and mathematical model describing the process under investigation. From this viewpoint, the model of pulsed laser induced melting, solidification, evaporation and explosive crystallization of multi-layered a-Si and pc-Si systems developed by Černý and Přikryl [1] can be considered as very suitable for our purposes because in the previous applications, it exhibited a very good agreement with available experimental results. Therefore, we employed it for the calculations in this paper.

We performed a series of calculations of pulsed laser induced (KrF excimer laser, 248 nm, 30 ns FWHM) phase change processes in three-layer systems consisting of an a-Si layer, an underlying pc-Si layer and the glass substrate. The thickness of the a-Si layer varied from 20 nm to 100 nm, the thickness of the pc-Si layer from 200 nm to 4 μm. The laser energy density was supposed to vary between 0.40 J/cm$^2$ and 0.75 J/cm$^2$.

The results have shown that at a laser fluence of 0.55 J/cm$^2$ as used in experiments, the laser pulses melts not only 20 nm of newly deposited a-Si but also several more 10 nm of the underlying pc-Si layer so that the silicon layers are molten repeatedly for several times making the process inefficient. Moreover it has been demonstrated that during the deposition process the individual melt depth reached at each pulse reduces.

For further experiments we draw the conclusion that at a fluence of 0.55 to 0.60 J/cm$^2$ the amount of a-Si deposited between the pulses may be increased to 50 to 80 nm. Under these conditions the a-Si layer and a small amount of pc-Si below can be molten. In order to get a stable process during which the melt depth remains constant the thickness of the starting seed layer should amount to 700 nm.

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# Moisture Transport and Storage Properties of AAC, Ceramic Brick and Calcium Silicate in the Hygroscopic Range

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Three common building materials, namely autoclaved aerated concrete (AAC), ceramic brick (BR), calcium silicate plate (CS), were tested to receive an overall characterization of each material from the moisture perspective. In the first part a material characterization was carried out by means of capillary uptake and dry and wet cup transmission tests. The second part dealed with adsorption and desorption isotherms.

The water absorption coefficient and the apparent moisture diffusivity were got from one-dimensional free imbibitions experiment. After being dried in an oven, the specimens (10x10x5 $cm^3$) were water and vapour-proof insulated on four edges and the free face side of each was put on a water-saturated sponge lying in a tank. The whole system was placed into a climatic chamber at 98% RH and 23±1 °C. The known water flux into the specimen during the suction process was found out from samples weighing on an automatic balance. The water absorption coefficient A [kg $m^{-2}$ $s^{-1/2}$] is defined as the slope of the first stage of the cumulative inflow curve as a function of square root of time. For calculating the value of apparent moisture diffusivity, there was employed the basic approximate relation between the saturated moisture content $w_c$ [kg $m^{-3}$] and the absorption coefficient [1].

The dry and wet cup vapour transmission was determined in accordance to prEN ISO 12572 [2]. The measurement was carried out in steady state under isothermal conditions. It is based on establishing one-dimensional water vapour diffusion and measuring the diffusion water vapour flux through the specimen and the partial water vapour pressure in the air under and above specific specimen surface. Water vapour transmission properties of the particular materials were found by placing a specimen of the material on the top of a cup and sealing it. The cup contained sorption material (in this case $CaCl_2$ (RH 0%), $Na_2Cr_2O_7$ (RH 52%), KCl (RH 86%), $KNO_3$ (RH 94%)). The sealed cup was placed in a controlled climate chamber at 24±1°C and weighed periodically. The steady states values of weight gain or lost were utilized for the determination of the water vapour diffusion permeability. In the practical calculations of water vapour transport in porous building materials, the diffusion coefficient of water vapour D, water vapour diffusion permeability $\delta$, and the vapour resistance number $\mu$ were used.

The water vapor adsorption and desorption in a porous material are based on a mutual force between the surface of the porous matrix and water vapour molecules [3]. The dry material weight increases after a contact with moist air because of gradual bonding of water molecules from the air to the pore walls in the case of adsorption. Desorption is reversed physical phenomenon, the initial state is fully saturated sample. At the moment of achieving the equilibrium state between the water vapour pressure in the moist material and in the surrounding air, this process is stopped. The measurements of adsorption and desorption isotherms were done in constant laboratory conditions, at 24 ± 1°C. For each relative humidity both in adsorption and desorption, 10 test specimens of each material with overall dimensions (l x w x h) of 30x30x10 $mm^3$ were prepared. For the determination of the isothermal

adsorption curve initially oven dried samples were used while for the measurement of the desorption isotherm initially capillary saturated specimen. The samples were placed into the desiccators with different solutions (LiCl, $MgCl_2.6H_2O$, $NaNO_2$, $NH_4Cl$, $KNO_3$, $K_2Cr_2O_7$) to simulate different values of relative humidity. The experiment was performed parallel in all desiccators in a common way. The mass of samples was measured in specified periods of time until steady state value of mass was achieved. Then, the moisture content by volume was calculated.

Table 1 Hygric properties of tested materials.

| | Capillary uptake | | Cup transmission tests μ [-] | | | Sorption and desorption isotherms u [kg/kg] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A [kg m$^{-2}$ s$^{-1/2}$] | κ [m$^2$ s$^{-1}$] | Wet cup RH% | | Dry cup RH% | 12% | 33% | 65% | 79.5% | 94% | 97% |
| | | | 52/86 | 86/94 | 0/52 | | | | | | |
| AAC | 0.085 | **1.6E-08** | 8.44 | 8.03 | 9.73 | 0.0125 | 0.0164 | 0.0229 | 0.0298 | 0.0375 | 0.0934 |
| CB | 0.115 | **2.5E-07** | 4.05 | 3.83 | 5.91 | - | 0.0002 | - | 0.0003 | 0.0011 | - |
| CS | 0.384 | **2.5E-07** | 3.54 | 1.63 | 2.81 | 0.004 | 0.008 | 0.021 | 0.030 | 0.107 | 0.247 |

Table 1 shows the results of measurements of hygric parameters of the three building materials. Calcium silicate was found to be a very capillary active material and in the range of higher relative humidities it was also very hygroscopic. Ceramic brick was also highly capillary active but not hygroscopic. Autoclaved aerated concrete exhibited a lower capillary activity compared to the other two materials, and its hygroscopicity was between CS and CB.

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# Measurement of Water Retention Curves of Building Materials

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Moisture storage parameters for porous building materials are usually divided into two groups. In the hygroscopic moisture range, where the transport of water vapor is the dominant mode of moisture transfer, the moisture storage function is called the sorption isotherm. It expresses the dependence of moisture content in the material on relative humidity. In the overhygroscopic moisture range, where liquid water transport is the dominant mode of moisture transfer, the moisture storage function is called the water retention curve. It expresses the dependence of moisture content on capillary pressure. The sorption isotherm and the water retention curve for the same material can be unified into a general moisture storage function using the Kelvin relation.

The principle of determination of water retention curve used in most classical methods is the same (see e.g. [1]). A specimen of a porous material is placed on a semi-permeable plate or membrane and exposed to either underpressure under the plate or overpressure above the plate. Due to the pressure difference between the interior of the porous body and the surroundings, the porous plate either draws in water from the specimen or transfers water to it, until pressure equilibrium is achieved. At that moment, the pressure in the porous space (i.e. the capillary pressure) is equal to the pressure in the measuring device, which can be easily determined. The moisture content is measured by the gravimetric method, i.e. by weighing the specimen before and after the process, or by measuring the volume of the drained or supplied water.

Overpressure devices are more common for measuring water retention curves of building materials, these are used for higher values of capillary pressure than underpressure devices, above 100 kPa. Either pressure plate or pressure membrane devices can be used [2]. These devices consist of an overpressure chamber with a semi-permeable plate or membrane. There are two basic types of overpressure device. The first has a ceramic plate, which may have a rubber cloth on its lower side. A metallic net between the membrane and the cloth forms a space with an outlet outside the chamber for retaining the drained water. The second type of overpressure device works with a cellulose acetate membrane. The membrane is placed on a metallic net, which makes space for the drained water, and the outlet is in the bottom of the overpressure chamber under the membrane. To press the specimens to the membrane, a rubber diaphragm may be used with a slightly higher pressure above it than the pressure in the space where the specimens are placed. The overpressure chambers of all devices are closed by massive covers with large screws. The overpressure is achieved using a compressor unit or by pressure vessels with compressed air, and it is controlled by regulation valves and manometers. The amount of water drained or supplied is measured by burettes connected to the outlets by polyethylene tubes.

In the practical measurements in this paper, we employed a pressure plate device. Experiments took place in air-conditioned laboratory at 25±1 ºC and 44-46 % relative humidity. There were measured twelve capillary saturated specimens of each of three analyzed materials, which were autoclaved aerated concrete (AAC), ceramic brick (CB), and calcium

silicate (CS). Sample sizes were 35-40x35-40x10-15 mm$^3$. Pressures of 0.16; 0.32; 1.06; 3.16 and 10.0 bar were applied in the extractor.

Capillary saturated specimens were placed on airproof and water saturated ceramic plate covered by fine kaolin layer and fine meshed cloth into the pressure plate extractor. The extractor was closed, a chosen value of pressure in the application range of the particular pressure plate was applied and the outflow of drained water into the burette was observed. After the equilibrium state was achieved, the applied pressure was released, the specimens were weighed and moisture was determined by the gravimetric method according to equation

$$u = \frac{m_w - m_0}{m_0} \text{ [kg/kg]}, \tag{1}$$

where $m_w$ is the mass of wet sample in steady state conditions, $m_0$ is the mass of sample in dry state [kg]. The experiment then continued at a higher-pressure level, and again, after achieving equilibrium state, the moisture content was determined by the gravimetric method. Finally, water retention curve was obtained as a point-wise pressure vs. moisture content function.

Tab.1 Moisture content in kg/kg for different pressures in the pressure plate device.

| Pressure [bar] | AAC | CB | CS |
|---|---|---|---|
| 0.16 | 0.651 | 0.117 | 3.201 |
| 0.32 | 0.644 | 0.110 | 3.199 |
| 1.06 | 0.629 | 0.015 | 3.193 |
| 3.16 | 0.602 | 0.010 | 2.258 |
| 10.00 | 0.498 | 0.007 | 0.373 |

The experimental data obtained from water retention measurements are presented in Tab.1. The differences in water retention curves of different materials are related to the differences in their porous structure. The sudden change of moisture content with increasing pressure observed for all three materials roughly corresponds to the value of median pore radius in each particular case.

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# The Role of Exact Knowledge of Properties of Fiber Reinforced Cement Composites for Their Technical Applications

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Cement-based materials are characterized by very good properties in compression but their brittle manner of failure under tensile or impact load was a limiting factor for their applicability range from the very beginnings. Fiber reinforcement is a traditional and effective method how to improve the toughness and durability of cement based products. The steel rod reinforcement became very popular during the whole last century and remains the most frequently used type of concrete reinforcement until now. However, in the second half of the 20th century, an application of uniformly dispersed short fibers strengthening the brittle cementitious matrices appeared with an increasing frequency. In the current practice, steel, glass, carbon and various polymeric fibers such as polyethylene, polypropylene, nylon, polyester, polyurethane, cellulose, etc., are commonly used in cement-based materials.

Glass-fiber reinforced cement composites (GFRCC) are produced by incorporating a small amount of alkali-resistant glass fiber in cement mortar to overcome the traditional weakness of inorganic cements, namely poor tensile strength and brittleness. The length and content of the glass fiber reinforcement can be chosen to meet the strength and toughness requirements of the product. Also, the type of aggregates can be varied in order to control thermal properties.

GFRCC have found their place as versatile and commercially viable materials for use in construction industry in the beginning of 1970s [1]. Currently, they are frequently applied in wall systems, utilized in form work, pipework, used for surface bonding and rendering, etc. They can also replace asbestos cement products as fire protection materials.

Carbon fiber reinforcement has found its application first in polymeric matrices for automotive and aircraft industry. It partially replaced previously used glass fibers in such situations where superior strength properties, very low tensile strains and mass savings were necessary. The initial phases of utilization of carbon fibers in the production of composite materials were affected by their high price. Carbon fibers are produced by the controlled oxidation, carbonization and graphitization of carbon-rich organic precursors, which are already in fiber form. In the beginnings of carbon fiber production the most often used precursor was PAN (polyacrylonitrile) that gave superior carbon fiber properties but was quite expensive. The appearance of low cost pitch based carbon fibers in 1980s has led to a significant increase of various applications of carbon fibers. In the construction industry it resulted in an increasing use of carbon fiber reinforced cement composites. A comprehensive survey both of properties and processing of carbon fibers and of the various types of carbon fiber reinforced composites (CFRCC) can be found in [2].

The applications of FRCC in different technical areas require specific design principles to be employed. However, one condition is common for all applications. A designer should be provided by an exact knowledge of mechanical, thermal and hygric properties of

the particular FRCC. Otherwise, the assessment of mechanical and hygrothermal performance of FRCC in the particular application cannot be done in a serious way.

Among the properties of FRCC, the mechanical properties are of primary concern in all their applications because the use of fiber reinforcement was always motivated mainly by the improvement of tensile and flexural behavior of cement based materials. Therefore, the role of mechanical properties is often overestimated in the building practice and mechanical properties are the only parameters being determined.

However, knowledge of solely mechanical properties is not sufficient for a designer working with FRCC. There are several sound reasons for this statement. First, lightweight FRCC can be used as thermal insulation materials. Then, thermal properties should be known in sufficient temperature and moisture ranges. Second, FRCC can be used as fire protection materials. Here, the high temperature thermal properties such as thermal conductivity, specific heat, linear thermal expansion coefficient are supposed to be measured to assess the fire protection function of an envelope in an appropriate way. Third, for FRCC used in any wall systems both hygric and thermal properties have to be determined in sufficient temperature and moisture ranges because without this knowledge the hygrothermal performance of the wall cannot be assessed. Finally, FRCC are often employed in severe conditions. They can be exposed for instance to high temperatures, high mechanical loads and their combination. In this case, thermal and hygric properties should be determined as functions of thermal and mechanical load and their combinations.

As follows from the above mentioned, the role of knowledge of thermal and hygric parameters is in a variety of applications of FRCC very significant and these parameters should be measured with the same frequency as the mechanical parameters. Therefore, a comprehensive set of measurements of thermal and hygric properties of various types of GFRCC and CFRCC was done during the solution of the research project of GA CR 103/00/0021 "Analysis of Properties of Fiber Composites in The Conditions of Elevated and High Temperatures, High Moistures and Mechanical Load" (see e.g. [3], [4] for a survey of measurements). Linear thermal expansion coefficient and thermal diffusivity were measured in the high temperature range to $1000^0$C. Moisture diffusivity, water vapor permeability, high temperature thermal diffusivity, room temperature thermal conductivity and specific heat capacity of fiber reinforced cement composite materials were measured on specimens thermally loaded by subjecting to a temperature up to $1000^0$C, tensile stress up to 70% of ultimate load and their combination prior to the measurement.

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# Thermal Diffusivity of Carbon-Fiber Reinforced Cement Composites in High-Temperature Range

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For a long time, thermal properties of building materials were considered in the form of single room-temperature values. Later, also their dependence on temperature within the range corresponding to their supposed application was taken into account. However, some weakly studied areas remained until now. One of them is the influence of high temperatures on the thermal properties of materials which is an interesting topic for instance in fire engineering. In this paper, the thermal diffusivity of three carbon fiber reinforced cement composites is studied in high temperature range.

The measurements of thermal diffusivity were conducted on the carbon fiber cement composites, denoted as CF I, CF II and CF III by its producer VÚSH Brno. The samples CF I and CF II were plate materials with Portland cement matrix, which was reinforced by carbon fiber, and contained wollastonite, microdorsilite and microsilica. The samples CF III were plate materials with alumina cement matrix, which was reinforced by carbon fiber, and contained wollastonite and microdorsilite.The basic composition is shown in Table 1.

Table 1 Composition of the carbon fiber reinforced cement composites CF I-III (in % of dry substances)

| composition | CF I | CF II | CF III |
|---|---|---|---|
| cement CEM I 52.5 | 39.71 | 39.71 | - |
| alumina Alcoa CA-14M | - | - | 40 |
| microdorsilite | 16.5 | 11.5 | 28.4 |
| wollastonite | 39.6 | 39.6 | 29.5 |
| microsilica | 1.96 | 6.96 | - |
| metylcelullose | 0.11 | 0.11 | 0.1 |
| superplasticizer | 0.98 | 0.98 | - |
| plasticizer | - | - | 0.8 |
| carbon fiber based on resin | 0.98 | - | 1 |
| carbon fiber PAN | - | 0.98 | - |
| defoamer | 0.16 | 0.16 | 0.2 |
| water | 0.8 wt. cem. | 0.9 wt. cem. | 0.73 wt. cem. |

The determination of thermal diffusivity was done in the high temperature range up to $1000^0$C by CF I and CF II and up to 1200°C by CF III using the double integration method [1]. The basic ideas of the method can be summarized as follows. We have the one-dimensional heat conduction equation in the form

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial x}(a\frac{\partial T}{\partial x}), \tag{1}$$

where $a$ is the thermal diffusivity. We suppose $T(t)$ and $T(x)$ to be monotonous functions and choose a constant value of temperature, $\tau = T(x,t)$. Then, there must exist one-to-one parametrizations $x = x_o(\tau, t)$, $t = t_o(\tau, x)$, where $x_o$ and $t_o$ are monotonous functions.

Considering this fact, an integration of heat conduction equation (1) by $x$ and $t$ can be done,

$$\int_{t_1}^{t_2}\int_{0}^{x_0(\tau,t)} \frac{\partial T}{\partial t}(x,t)\,dx\,dt = a(\tau)\int_{t1}^{t2}\frac{\partial T}{\partial x}(x_0(\tau,t),t)\,dt + \int_{t_1}^{t_2}\frac{q(0,t)}{\rho(\tau)c(\tau)}dt\,. \qquad (2)$$

After some algebraic modifications (see [1], for details), we arrive at the relation for calculating the thermal diffusivity $a(\tau)$ in the form:

$$a(\tau) = \frac{1}{\int_{t_1}^{t_2}\frac{\partial T}{\partial x}(x_0(\tau,t))dt}\Big(\int_{0}^{x_0(\tau,t_2)} T(x,t_2)dx - \int_{0}^{x_0(\tau,t_1)} T(x,t_1)dx -$$

$$-\tau[x_0(\tau,t_2) - x_0(\tau,t_1)] - \int_0^l [T(x,t_2) - T(x,t_1)]dx\Big)\,. \qquad (3)$$

The thermal diffusivity is then determined using the results of experimental measurements of temperature fields in the sample at one-sided heating in the solution of the inverse heat conduction problem (3).

The measuring procedure consisted in the following. The measured samples were cubic, 71 x 71 x 71 mm. One-side heating of a specimen with thermally insulated later faces was realized using a muffle furnace where a constant temperature is kept. Along the longitudinal axis of the sample, a set of temperature sensors was positioned, which made it possible to record the temperature field through a measuring unit by PC. From the measured $T(x,t)$ curves, a set of 8-10 curves was chosen, and these curves were used in the computational treatment.

The measured results show that the character of $a(\tau)$ curves of all three materials was very similar. First there was a fast increase in $a$ until approximately $350^0$C so that the values of thermal diffusivity were here almost two times higher compared to $100^0$C, and then the thermal diffusivity began to decrease - the values at $800^0$C were comparable to those obtained at $100^0$C. The changes of thermal diffusivity with temperature were for CF III significantly slower compared to the other two materials. This is an apparent consequence of using alumina cement in CF III that exhibits much better thermal resistance than Portland cement.

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# Effect of Gravity on Moisture Transport in Building Materials

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Gravity plays an important role in describing water transport in soils but for most building materials its effect is usually lower. Nevertheless, it cannot be generally neglected and it is necessary to assess its real influence case by case. In this paper, we analyzed the effect of gravity on liquid moisture transport in three typical building materials, namely ceramic brick, calcium silicate and autoclaved aerated concrete (AAC).

Liquid moisture transport is mostly characterized by moisture diffusivity $\kappa$ (see e.g. [1]). Therefore, we have chosen moisture diffusivity as the main parameter for the assessment of the role of gravity on moisture transport. The moisture diffusivity was determined using the measured moisture profiles in a solution of the inverse problem to the diffusion equation describing liquid moisture transport.

We performed a typical experiment for the determination of moisture profiles that simulated one-dimensional moisture transport. The specimen having a rod shape was water and vapor proof insulated on all its edges, one of the faces was exposed to water, the other one to the air of the same relative humidity as in the pores of the specimen in the beginning of the experiment. The moisture profiles were measured using capacitance method [2]. The electrodes of the capacitance moisture meter had the dimensions 20 x 40 mm, the measuring frequency was 250 – 350 kHz. The calibration was done by the standard gravimetric technique separately for each specimen. The calibration curve was obtained using the last moisture profile that was determined first by the capacitance method and then after cutting the specimen into 1 cm thick pieces also by the gravimetric method.

The samples of calcium silicate and AAC had a rod shape with the dimensions 20 x 40 x 300 mm, the samples of ceramic brick 18 x 36 x 250 mm. Their edges were water and vapor proof insulated by thermally contractile PVC sheet to achieve a perfectly flat surface without air bubbles that is necessary for the proper function of the measuring method (an even very thin air layer in a series with the specimen can significantly affect the measured impedance). The moisture profiles were measured in 5 mm steps, so that certain space averaging was done (the width of the probe was 20 mm). The time intervals were chosen to cover the moisture penetration process by a sufficient number of curves.

The measurements were done with both horizontal and vertical positioning of the specimen to decide about the possible effect of gravity on the moisture transport. In the vertical suction experiment, the specimen was put on a viscous sponge in a water container so that its face was about 1 mm under water level. In the horizontal suction experiment, one face of the sample was in contact with a viscous sponge in a Plexiglas chamber sealed from outside that sucked water from a container. The water level in the container was kept on a constant level about 1 cm under the lower surface of the specimen using a float chamber system.

For the inverse analysis of moisture profiles, we have chosen the double integration method [1]. The moisture profiles for this analysis were approximated by the linear filtration method with Gaussian weights [3].

Table 1 – Moisture diffusivity of ceramic brick

| $u$ [kg/kg] | 0.010 | 0.015 | 0.020 | 0.025 | 0.030 | 0.035 | 0.040 | 0.045 | 0.050 | 0.055 |
|---|---|---|---|---|---|---|---|---|---|---|
| vertical: $\kappa$ [$10^{-7}$ $m^2s^{-1}$] | 1.46 | 1.75 | 2.10 | 2.59 | 3.33 | 4.40 | 6.47 | 11.9 | 29.0 | 65.6 |
| horizontal: $\kappa$ [$10^{-7}$ $m^2s^{-1}$] | 1.29 | 1.58 | 1.95 | 2.40 | 3.16 | 4.34 | 6.82 | 11.1 | 17.0 | 40.3 |

Table 2 – Moisture diffusivity of calcium silicate

| $u$ [kg/kg] | 0.05 | 0.35 | 0.65 | 0.95 | 1.25 | 1.55 | 1.85 | 2.15 | 2.45 | 2.75 |
|---|---|---|---|---|---|---|---|---|---|---|
| vertical: $\kappa$ [$10^{-7}$ $m^2s^{-1}$] | 0.54 | 0.84 | 1.17 | 1.55 | 1.99 | 2.52 | 3.23 | 4.62 | 8.25 | 24.6 |
| horizontal: $\kappa$ [$10^{-7}$ $m^2s^{-1}$] | 0.65 | 0.94 | 1.23 | 1.53 | 1.90 | 2.49 | 3.50 | 4.93 | 6.72 | 18.8 |

Table 3 – Moisture diffusivity of autoclaved aerated concrete

| $u$ [kg/kg] | 0.10 | 0.19 | 0.28 | 0.37 | 0.46 | 0.55 | 0.64 | 0.73 | 0.82 |
|---|---|---|---|---|---|---|---|---|---|
| vertical: $\kappa$ [$10^{-8}$ $m^2s^{-1}$] | 0.26 | 0.34 | 0.47 | 0.72 | 1.38 | 2.91 | 2.70 | 2.77 | 4.81 |
| horizontal: $\kappa$ [$10^{-7}$ $m^2s^{-1}$] | 0.62 | 1.00 | 1.81 | 3.47 | 6.48 | 1.15 | 4.53 | 3.36 | 4.61 |

Experimental results are summarized in Tables 1-3. We can see that for ceramic brick and calcium silicate, there was not observed any significant effect of gravity, the differences in high moisture range can be attributed to higher measuring and calculation errors in this range. However, for AAC this effect was very remarkable, one order of magnitude in all range of moistures. We believe that the main reason for this difference is the presence of larger pores, typically 0.1 mm – 1 mm in diameter, in AAC where the effect of capillary forces on moisture transport is lower than the effect of gravity forces.

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# Fabrication Carbon Planar Waveguides

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The waveguides are one of the fundamentals of the high technology field related to integrated optics. Recently, passive devices such as optical multipelxers and splitters have been fabricated in a variety of planar optical weaveguide materials on Si substrate. The next challenge is to doped such waveguide materials with optically active ions in order to realize planar active devices such as optical amplifiers [1]. There are several techniques for fabricating optical waveguides including epitaxial growth, plasma assisted chemical vapor deposition (PACVD), sol-gel technique, metal diffusion, sputtering, ion exchange and pulsed laser deposition (PLD).

Thin carbon films exhibit specific optical and mechanical properties, which make them promising materials for integrated optics. For this purpose we have investigated the preparation and optical properties of carbon films deposited on silicon or silicon oxide substrates.

The fabricated layers were investigated by talystep profilmeter, ellipsometry, Rutherford Backscattering Spectroscopy (RBS) and Elastic Recoil Detection (ERD), respectively. The attenuation was measured by the scattered light measurement method.

The five ways were realised for erbium doping into carbon thin films using PACVD method:

***Growth of carbon thin films using a carbon target and a separated piece of metallic erbium***

Thin carbon layers doped with erbium were sputtered from a carbon target with erbium metal in an argon atmosphere. For this purpose a carbon target (purity of 99.9999%) with erbium (purity of 99.99%) was used. The generator power was 500 W, the frequency being 13.5 MHz. Detail description is in [4].

***Growth of carbon thin films using carbon target containing metallic erbium***

The carbon targets were made using pressing mill graphite and erbium metal. The final targets had a diameter of 5 cm. The working pressure was 12 Pa. The voltage on the grounded electrode was -75 V. The time of deposition was 20 min in with a distance of the electrodes of 3 cm. The method of carbon layer fabrication doped with erbium was, in principle, the same as mentioned above [4].

***Growth of carbon thin films from a gas mixture ($CH_4$ + Ar + erbium isopropoxide)***

The deposition of carbon thin layers was carried out from methane (flow of 50 $cm^3$/min) and argon (flow of 30 $cm^3$/min). Erbium isopropoxide vapour was added to this gas mixture. The vapour of erbium isopropoxide was produced at temperatures of 240-260 °C and pulled into the reactor by the flow of methane and argon [2].

***Growth of carbon thin films from a gas mixture ($CH_4$ + "Erbium tris")***

The deposition of thin carbon layers with erbium was carried out from methane (flow of 50 $cm^3$/min). The vapour of [Tris (2,2,6,6 – tetramethyl – 3,5 – heptanedionate)] Er(+III) was produced at temperatures of 130-160 °C [5].

***Doping of carbon thin films using erbium nitrate dissolved in glycerol***

The PACVD method with standard reactor geometry were used for the carbon layer preparation [5]. The carbon layers was doped with erbium ions using diffusion. For difussion erbium nitrate dissolved in glycerol (5 ml glycerol + 1 g $Er(NO_3)_3$) was used. Glycerol allowed even lower reaction temperatures (25 °C and 120 °C) for doping times ranging from 10 min to 432 hrs to be used.

***Conclusions***

Five ways were utilized for erbium doping into carbon thin films. The first two methods used sputtering. The second two methods used PACVD. The last method used two step preparation. The first step was carbon layers fabricated by the PACVD method and finelly erbium diffusion was used. It was found that a successful erbium doping is closely connected with the composition and structure of carbon layers.

Thus erbium doping into a thin carbon layer has been demonstrated for the first time.

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# Possibility of Intercritical Heat Treatment of Cast Alloyed Steels

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The properties of cast microalloyed steels depend partly on used metallurgical technology partly on final heat treatment which must ensure optimum microstructure with respect to strength, plastic properties and fracture resistance [1,2,3,4]. It was found that suitable procedure of heat treatment for these steels is accelerated cooling from intercritical temperature interval $A_{c3}$ and $A_{c1}$ .In the event that temperature of partial austenitizing is sufficiently low and cooling rate sufficiently high, transformation austenite to bainite or martenzite realize. In case of large castings is not possible to reach needed cooling rate throughout the wall thickness and consequently ferrite – pearlite or ferrite – bainite form.

In the present work, the influence of intercritical heat treatment on mechanical properties of cast alloyed carbon manganese steels predetermined for radwaste container cask is analysed.

For the experiment were prepared on the one hand thin-wall castings of laboratory heats ( weight 1,5 kg ) and on the other hand thick-wall castings of pilot-plant heats from low carbon manganese steels. Initial experimental heats of basic manganese steels contained 0,13 wt.%- 0,28 wt.%C and 0,8 wt.% - 2,1 wt.% Mn ( steels 14Mn3, 15Mn5, 27Mn4, 16Mn4, 15Mn8, 14Mn8, 28Mn8 ) were successively modified with microalloying elements vanadium (steels 14MnV4, 13MnV51, 16MnV4, 27MnV4 ) and titanium ( steels 13MnTi4, 13MnTi5, 12MnTi4, 26MnTi4 ).

Heat treatment used consisted of :

N - normalizing ($930^oC/3hod/100^oC.hod^{-1}$)
I - intercritical hardening ( $780^oC/3hod/furnace\ 100^oC$)
NT - normalizing ($930^oC/3hod/100^oC.hod^{-1}$) + tempering ($650^oC/12hod/100^oC.hod^{-1}$)
NQT- normalizing ($930^oC/3hod/100^oC.hod^{-1}$) + hardening ($900^oC/3hod/furnace\ 100^oC$) + tempering ($650^oC/12hod/100^oC.hod^{-1}$)

On the base of mechanical characteristics ( tensile test INSTRON 5582 – yield strength YS, tensile strength TS, elongation A and impact test of Charpy type specimen– notch toughness KV ) and the assessment of microstructure ( light microscopy, TEM ) the following effect of intercritical heat treatment on cast microalloyed steels can be detected:

- Application of intercritical heat treatment ( I ) or combined treatment ( NQT ) have beneficial effect on mechanical properties of all studied steels.

- Combination of intercritical annealing and the microalloying by Ti ( 0,02 wt.% ) increases yield strength of carbon manganese steels of 16 % ( steel 27MnTi4 ).

- Utilizing of combined heat treatment ( normalizing, intercritical quenching, tempering ) on microalloyed steels by V improves yield strength of 26 % in comparison with normalizing ( steels 16MnV4, 27MnV4 ).

- Above mentioned procedures increase notch impact values ( steel 16MnV4 after NQI , $KV_{-20}$ 75 J ) and influences the transition temperature at which steel changes from brittle to ductile failure in positive way ( steel 16MnV4 ,temperature FATT 50 = $-10^{o}C$ ).

- Microstructure after intercritical annealing and combined process is uniform and is characterized by very fine ferrite and pearlite grain size ( 8μm resp. 4 μm ). The volume fraction of pearlite is principally unchanged but pearlite looses interdendritic character and becomes partially spheroidized.

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# High Temperature Oxidation of Thermally Sprayed Coatings

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Thermal sprayed coatings are used in many applications in industry. In this work we have examined high temperature isothermal oxidation of plasma sprayed coatings.
Protective coatings are frequently used in those cases, when there are increasing requirements for functional properties of surface components. At present many technologies are being evolved to create protective coatings. The use of coatings has been observed long, since its applications have several basic goals: improvement of utility properties of products, prolongation of products running life, material saving and renovation of components. Technology of thermal spraying coatings is highly productive way of production of coatings attendant to protective purposes of components working in different environments, where own coatings prevent from using expensive smelting materials.

This work described high temperature isothermal oxidation of plasma sprayed coatings. For spraying were applied four materials: steel ČSN 17 350 approximately to AISI 316, ČSN 17 021 approximately to AISI 410, unalloyed nickel and NiCr alloy (Ni 80%, Cr 20%). Into the experiment were inserted two smelting products into the experiment to compare results of high temperature isothermal oxidation of thermally sprayed coatings: AISI 316 and unalloyed nickel. Grain size of powders was at range of 100 up to 140 μm. The spraying distance (plasma gun nozzle – substrate surface) was 400 mm. A 160 kW water - stabilized plasma gun WPS PAL160 was used for the spraying. As a substrate we used low carbon steel ČSN 11 373 format 100 x 20 x 5 mm. After separation of plasma coatings the thickness of separated coatings did about 1,5 mm and their surface was from 6 to 9 $cm^2$.

The LEKO VMK 1400 furnace was used for high temperature oxidation process. For the measurement of weight gains on high isothermal oxidation was used the weighting machine KERN 770. High temperature oxidation runs at four temperatures, namely: 1000, 1050, 1100, 1150 K for 24, 48, 72, 96, 120 and 144 hours. From the measured results were educed kinetics curves of high thermal oxidation. According to specification procedure was used parabolic relation. This relation was chosen, because we supposed that creation of oxidic layer will be steered by diffusion and layers will grow into a compact layer. The layers were compact and they were not pealing from the coatings during the experiment.

Next reason was the work [2] where is a description of high temperature oxidation of bond coats in thermal barrier systems.The isothermal oxidation of bond coats composed of vacuum plasma sprayed (VPS) McrAlY (NiCoCrAlYTa and CoNiCrAlY) or palladium modified nickel alumides (NiPd + VPS) was studied in several oxygen partial pressures ($10^5$, 1 and $10^{-5}$ Pa) with two heating rates (20 and 60 K/min) at different temperatures (900, 1000 and 1100°C).

The oxidation weight gains allowed to calculate parabolic rate constants. Heating rates showed no influence on oxidation kinetics of McrAlYs coatings, whereas, for slower heating

rate, parabolic rate constants were higher. This study than shows that a specific heat treatment must be developed for each bond coat material.

Three materials NiCr, NiAl, NiCrAlY [1] were studied in a static air furnace at 1000°C during 1, 4, 14, 22, and 50 hours. The study of three different bond coating sprayed with same conditions revealed the best performance for NiCr coating and fact that the phases present at the as - sprayed coatings are strongly influenced by phases present in powders. The oxides formed during the spraying are not the most stables. Isothermal oxidation allows the oxides inside the coating evolution to the mast stables.

For description of oxidation mechanism high temperature oxidation of thermally sprayed coatings by water stabilized plasma gun were done lighting microscopy and the SEM electron analysis. For the SEM electron analysis was used scanning electron microscope CamScan 4 DV, for lighting microscopy was used NEOPHOPT 32. Four coatings after high isothermal oxidation were choosen for SEM analysis : NiCr alloy and unalloyed nickel (1150 K/120 hours), AISI 316 and AISI 410 steel (1050 K/120 hours).

After isothermal oxidation were founded new phases in the oxidic layers and phases analysis by SEM and light microscopy receipted that the oxides formed during the spraying are not stables. At unalloyed nickel was oxidic layer compact and thick. Other oxidic layers were not compact (the layers increased from islands). Oxidic layers at the steel materials increased into the coatings.

It can be concluded that after thermally sprayed coatings by water stabilized plasma gun the best temperature oxidation resistance offer NiCr and unalloyed Ni and oxidation resistance of AISI 316 and AISI 410 steels were lower. Two smelting products to compare results of high temperature isothermal oxidation of thermally sprayed coatings had more higher oxidation resistance than same materials in plasma sprayed coatings.

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# A Preparation and Study of Properties of Cr2O3 Layers

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The Cr2O3 thin layers, which are used as a protection of metal parts against a corrossion, are produced in two forms, i.e. in amorphous and polycrystalline states. Both differ in a processing, especially in a temperature of plasma, at which the evaporation process proceeds [1].The amorphous state results from the evaporation at the plasma temperature of 400°C and the polycrystaline state results from the evaporation at the plasma temperature of 750°C.

The aim of a microscopic analysis is a detection of defects on an evaporated surface,a measurement of thickness of evaporated layers, a hardness and a resistance of evaporated layers against a propagation of microcracks, when internal so external stresses act [2].

The detection of defects is carried out by using of optical microscopes. The detection of defects on the surface of the amorphous layer was carried out by the Zeiss Neophot 21 microscope, in which spots with interferential paterns are watched. Their nature is not clear yet and can be caused by the thickness change or by localized deformation. The determination of the origin of these defects will be investigated with application of the microhardness tester.The detection of defects on the layer surface with a crystalline structure was carried out by Olympus Videomikroskop OVM1000NM for its better resolution of grainboundaries. The defects of interference patterns kind are not seen there, but also no others.

A measurement of the evaporated layers thickness was done by Scanning Electron Microscopy (SEM) techniques.as the layer thickness is out of range of a resolutionof of optical microscopes.. The used SEM techniques are a) the imaging in the secondary electrons regime, b) the imaging in the backscattered electrons regime and c) determination the thickness of the layer from the point EDAX analysis.

A different preparation of specimens is needed when individual SEM techniques are applied.The a) one is convenient for specimens with expressive morphology. The face of the broken strip specimen is suitable for a good imaging of the cross-section of an evaporated layer. The disadvantage of this case of imaging is shining of sharp edges, which cause a lover level of resolution of about 50 nm at the magnification 10000x. The measured thickness amounts 650 +/- 50nm. The b) imaging is known as the material contrast and must not interfere with a surface morphology. The watched surface must be therefore polished, similarly as for the c) imaging, where the constant spot size of the electron beam play an important role. The decrease of a resolution in b) imaging is caused by the worse focusing near edges due to their making round at a polishing. A resolution of the boundary between a layer and its bed in c) analysis is influenced by the neccessary spot size D, which cause that transition between two materials is continuous along the distance 2D.

A study of mechanical properties of evaporated Cr2O3 layers is conducted from a point of view of their hardness by using of the Microhardness Tester PAAR- MHT 10V. The standard Vickers hardness of both layers types was investigated and compared with one of the clear Si plate oversurface, which was used for the evaporated layers bed.

Instead of indents also microcraks originate in their corners. The size of these cracks is comparable with the size of indents and can characterize a brittleness of evaporated layers. A quantitative evaluation of this efect is possible to reach experimentally, when idents were done into the bended strip. The crack which is oriented orthogonally to the strip length is then greater than that, which is oriented paralelly with the strip length. The length difference between them has then a relation to the value of bending stress and serves to a calibration.

The Vicker's hardness /Hv/ of the Si plate surface and one with the evaporated Cr2O3 layer surface are following

| Load F (mN) | Di(um) | Hv - Si plate | Di (um) | Hv - Si plate+Cr2O3 layer |
|---|---|---|---|---|
| 100 | 7,33 | 3519,4 | 7,05 | 3804,5 |
| 200 | 9,92 | 3843,1 | 10,45 | 3463,2 |
| 300 | 12,80 | 3462,4 | 11,00 | 4688,3 |
| 400 | 15,15 | 3295,4 | 12,55 | 4802,3 |
| 500 | 16,75 | 3369,9 | 13,45 | 5226,4 |

where Di is the mean length value of the ident diagonals and Hv is calculated according to the formula Hv = 1,89096e5*F/ Di*Di

The Vicker's britlleness /Bv/ of the Si plate surface and one with the evaporated Cr2O3 layer surface are following

| Load F(mN) | Dc(um) | Bv - Si plate | Dc(um) | Bv - Si plate+Cr2O3 layer |
|---|---|---|---|---|
| 100 | 10,15 | 1835,4 | 20,10 | 468,0 |
| 200 | 16,70 | 1356,0 | 28,50 | 465,6 |
| 300 | 24,20 | 968,6 | 36,15 | 434,0 |
| 400 | 34,55 | 633,6 | 42,35 | 367,0 |
| 500 | 37,50 | 672,3 | 52,95 | 337,2 |

where Dc is the mean value of the cracks length and Bv is calculated according to the formula Bv = 1,89096e5*F/ Dc*Dc

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# Fractographic Study of Cleavage Initiation in A508 Steel

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The large fractographic study focused on the change of cleavage initiation mechanism in the ductile-to-brittle transition temperature (DBTT) region was carried out on the A508 Cl.3 pressure vessel steel. Large experimental Charpy V-notch (CVN) energy and $J_c$ data were provided on CVN and CT specimens at different temperatures.

The fracture surfaces of all the specimens examined exhibit transgranular cleavage facets. Cleavage crack path deflection leaves unbroken ligaments fractured by ductile tearing when the crack further opens. At low magnification, this 'fan' tear ridges indicates the origin of cleavage. At higher magnifications, transgranular cleavage facets display more or less pronounced river pattern. Tracing back the river pattern, the most probable cleavage initiation sites could be found. It should be emphasised that this fractographic analysis is very difficult, because in many cases the lack of fractographic signs makes it impossible to identify the origin of cleavage. An evolution of physical mechanisms of cleavage initiation was found: cracked particle induced cleavage was observed at low temperature, whereas plasticity induced mechanism was suspected as temperature increases [1].

The values of maximum principal stress in the cleavage initiation sites identified in scanning electron microscope were computed by finite element method. For the simulations of Charpy impact test, the strain rate dependent (Cowper-Symonds) stress-strain law was employed in order to take into account viscous effect due to high strain rates. The ductile crack preceding the cleavage initiation was incorporated using the Gurson-Tvergaard-Needleman (GTN) model. Fracture toughness $J_c$ was computed from the work of the external forces according to the ASTM E1820 norm. The details about numerical modelling were published in Refs. [2,3]. The cases in which the cleavage initiated very closely to the actual ductile crack tip (<50 μm) have been excluded for the critical stress assessment because of the heterogeneity of the ductile crack front which is not taken into account in the GTN model and which can significantly modify the local stress field. The computed stresses versus testing temperature are given in table 1.

Following the Griffith equation, the cleavage fracture stress $\sigma_c$, can be related to the size of broken spheroidical particles of radius $a$ (considered as penny-shape crack) as:

$$\sigma_c = \sqrt{\frac{\pi E \gamma_{eff}}{2(1-\nu^2)a}} \tag{1}$$

where $E$ is Young's modulus, $\nu$ is Poisson's ratio, and $\gamma_{eff}$ is the effective surface energy.

At lower temperature, using the mean value of the maximum principal stress in the cleavage initiation sites (1750 MPa) computed by the finite element method, and the size of broken particles (2 μm), Eq. (1) yields the effective surface energy of 9 J m$^{-2}$. This value of $\gamma_{eff}$ was found to be constant in the temperature range from –120 °C to –60 °C, and is in the range of common values for ferrite [4].

At higher temperature (near DBTT), the cleavage initiates from microcracks induced by plastic deformation. It is very difficult to obtain the size of the critical defect, i.e. to determine the exact boundary line where the crack became unstable. Nevertheless, the size of nucleating facets was much larger than the size of broken particles. The propagation mechanism is similar to that at lower temperatures. At both temperature domains, the hypothesis of propagation-controlled mechanism with critical stress given by Griffith theory seems plausible.

| Specimen | | T [°C] | $\sigma_c$ [MPa] | Specimen | | T [°C] | $\sigma_c$ [MPa] |
|---|---|---|---|---|---|---|---|
| CT25 | T-S | -90 | 1825 | Charpy | L-S | -120 | 1740 |
| CT25 | T-S | -60 | 1810 | Charpy | L-S | -90 | 1720 |
| CT25 | T-S | 0 | 1720 | Charpy | L-S | -90 | 1800 |
| CT25 | T-S | 0 | 1780 | Charpy | L-S | -60 | 1780 |
| CT25 | T-S | 0 | 1850 | Charpy | T-S | -90 | 1660 |
| CT25 | T-S | 0 | 1805 | Charpy | T-S | -90 | 1810 |
| Charpy static | T-S | -60 | 1720 | Charpy | T-S | -30 | 1680 |
| Charpy static | T-S | -30 | 1700 | Charpy | T-S | -30 | 1790 |

Table 1 Maximum principal stress in the cleavage initiation sites computed by finite element method.

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# Fracture Toughness of Cast Steels

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The plane-strain fracture toughness tests yield, under fovourable conditions, the critical value of stress-intensity factor $K_{IC}$ or $K_{Id}$ that is related to a precracked specimen and the mode I of loading (opening or tensile mode). This factor allows to a designer to determine how large a crack can be tolerated in the critical section in particular thick-walled casting without the risk of sudden brittle fracture. The critical factor $K_{IC}$ is used as a linear-elastic fracture mechanics criterion for static loading in contrast to $K_{Id}$ used for dynamic loading and plane-strain conditions of maximum constraint.

High-toughness structural steels undergo extensive plastic deformation prior to fracture and therefore the concepts of linear-elastic fracture mechanics need to account for elastic-plastic behavior. Crack initiation under this behavior occurs at critical value of J-integral, i.e. $J_{IC}$ or $J_{Id}$. Moreover, the J-integral concepts is also applicable for crack propagation, what is very important as most steels fail into elastic-plastic range, where significant fracture resistance exists after crack initiation. Since plastic deformation prior to the onset of crack propagation does not invalidates the $J_{IC}$ or $J_{Id}$ measurement, smaller specimens can be applied. The critical J-values may be used to obtain an estimate of critical K-values by simple relation $K_J^2 = E \,.\, J / (1-\nu^2)$.

Fracture mechanics tests [1] have the advantage over conventional toughness tests of being able to yield values of material characteristics that can be used in design computations. However, because of complexity and cost those tests, approximations above all of $K_{IC}$ are also made on the basic of other mechanical properties, such as notch toughness energy, yield strength, etc. Most of these correlation are dimensionally incompatible, ignore differences between loading rate and notch acuity, nevertheless some of them can provide a useful guide for estimating fracture toughness. For example, the possible relationship between $K_{IC}$ vs. notch toughness energy KV obtained by Charpy impact test with V-notched specimen and yield strenthg $R_p0{,}2$ was investigated [2, 3]. After transformation of conventional English units into SI-units the relationships have following form :

$$(K_{IC} / R_p\,0{,}2)^2 = 0{,}6445 \,.\, (KV / R_p\,0{,}2) - 1{,}27 \,.\, 10^{-3} \qquad (1)$$

$$(K_{IC} / R_p\,0{,}2)^2 = 0{,}359 \,.\, (KV / R_p\,0{,}2) + 2{,}29 \,.\, 10^{-3} \qquad (2)$$

The equation (1) as compared to eq. (2) has a slightly steeper slope. The difference may have been caused by different fracture toughness specimen size. Authors [1] used 25 mm thick specimens of wrought steel, while authors [2] tested specimens taken from 75 and 125 mm thick cast plates. Hence, for heavy castings the eq. (2) is recommended because it gives more realistic values of $K_{IC}$. For a cast steel having KV = 100 J and $R_p$ 0,2 = 400 MPa, we can obtain from eq. (1) $K_{IC} \cong 160$ MPa . $m^{1/2}$, but only 121 MPa . $m^{1/2}$ from eq. (2).

Barsom correlated dynamic fracture toughness with Charpy impact energy. After above mentioned transformation of units we obtain :

$$K_{Id} / E = 6{,}44 \,.\, 10^{-4} . KV \qquad (3)$$

where E [MPa] is the Young modulus of elasticity. For quoted a cast steel (KV = 100 J, $E = 2{,}1 \,.\, 10^5$ MPa) we can obtain from eq. (3) $K_{Id} = 116$ MPa . $m^{1/2}$.

All the parameters $K_{IC}$, $K_{Id}$, $J_{IC}$ and $J_{Id}$ depend on temperature, particularly for those steels exhibiting a pronounced transition from ductile to brittle behavior. In following table, there are gathered selected results of our investigations on two low-carbon manganese cast steels16Mn4 and 16MnV4. The latter one was microalloyed with 0,13 % V, both steels were normalized, quenched, intercritically heat treated and tempered.

Table 1. Experimental and predicted fracture toughness parameters

| Steel | Temperature T [°C] | Experimental values | | | | Predicted values* | | |
|---|---|---|---|---|---|---|---|---|
| | | $R_p$ ,2 [MPa] | KV [J] | $K_{Id}$ | $K_{Jd}$ | $K_{IC}$ (1) | $K_{IC}$ (2) | $K_{Id}$ (3) |
| | | | | [KJ/m$^2$] | | [MPa . m$^{1/2}$] | | |
| 16Mn4 | 20 | 310 | 136 | - | 232 | 164 | 124 | 132 |
| | -40 | 359 | 32 | 38 | - | 86 | 66 | 64 |
| 16MnV4 | 20 | 325 | 199 | - | 362 | 204 | 153 | 160 |
| | -40 | 377 | 43 | 88 | - | 101 | 78 | 74 |

* values of $K_I$ computed from eq. (1), (2), (3)

The effect of temperature on Charpy impact energy KV and fracture toughness parameters is significant. The impact transition temperature lies between 20 °C and –40 °C , according to [4] exactly at –18 °C. Since for dynamic fracture toughness tests were used Charpy type of specimens (10 x 10 x 55 mm), better prediction of $K_{IC}$ we can expect from eq. (1), particularly if we assume that $K_{IC} > K_{Id}$. The agreement between predicted and experimental values of $K_{Id}$ is acceptable.

It can be concluded that (a) fracture toughness characteristics should be preferred above commonly used notch impact toughness, (b) because of time-consuming evaluation of fracture toughness, it can be correlated with Charpy impact energy by means of relationships (1), (2) and (3), (c) original experimental values of dynamic fracture toughness are presented and compared to the predicted values for steels 16Mn4 and 16MnV4.

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# Macromolecular Structures Modelling with Materials Studio Software

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Methods of computational modelling have became one of the basic tools in processes of designing and simulating diverse artificial structures, as well as analysing processes and properties related to natural objects. Early after the first electronic computers came in existence, they were applied to solve problems related to inner structure of matter. Because of the growing practical role of organic, and namely polymer chemistry, one of the steadily developing streams was concentrated on computational simulations of macromolecular structures. Several concepts/approaches has been gradually developed in computational physics and chemistry of macromolecular systems: quantum mechanical electronic structure theory including *ab initio* and *semi*-empirical methods, molecular mechanics (MM) utilising classical physics and approximating the 'engaged' interactions by a force field's parameters, and mesoscale dynamics incorporating statistical laws for the forces acting over groups of atoms. The Materials Studio (MS) from Accelrys Inc. is very likely the first software tool incorporating all the approaches (and much more from the areas of solid state simulations, diffraction structural analysis, surface science etc.) in one user-friendly, client-server environment [1].

In the reported research, we apply MS to analysis of homo-polymer system consisting of syndiotactic poly(methyl methacrylate) (s-PMMA) macromolecules. It is well known that s-PMMA dissolved in some solvent forms so called self-aggregates, structure of which is then also preserved in solid state [2]. Despite the long-time effort, no satisfactory model is available explaining the role of solvent in the aggregation process. However, understanding of the phenomena can bring us valuable information about the interactions between small molecules and PMMA macromolecules, applicable e.g. in further material engineering of PMMA polymer [3]. Computational modelling was chosen in the attempt to contribute to the solution of the mentioned problem.

In the first stage which is here reported, we have concentrated on the simplest case of conformational analysis of homogeneous s-PMMA ensemble and verified the applicability and reliability of the MM approach embedded in MS-module Discover [1]. We have started with model of two interacting s-PMMA molecules (with variable number of monomer units ($N$)) and applied the MM force field method to find the overall conformation(s) corresponding to the minimum/minima of the total free energy of the system. In the case of shorter oligomers ($N \leq 10$), the intramolecular interactions outweighed, because of the high steric freedom of the functional side-groups. With $10 < N \leq 60$, the inter-molecular energy contributions grew and the resulting conformations contained ascending portion of the chains oriented parallel each to other. Finally, for $60 < N$, the intermolecular interactions prevailed and the systems converged to the expected conformation of double helix proposed in virtue of results obtained by diffraction and NMR techniques, as well as further considerations [2]. The calculated energy contributions are summarised in the following table.

| *N* | *Potential energy (kcal/mol)* | | | | *Intermolecular interaction energy (kcal/mol)* | |
|---|---|---|---|---|---|---|
| | total | internal energy | non-bonding | vdW | total[1] | vdWk |
| 120 | 8912,7 | 3108,5 | 5804,1 | 396,7 | -510,9 | -481,8 |
| 90 | 6625 | 2274 | 4350,4 | 293,2 | -378,8 | -367,5 |
| 60 | 4316,6 | 1428 | 2888,6 | 182,5 | -248,1 | -241,9 |
| 40 | 2872,9 | 943,8 | 943,8 | 126 | -158,5 | -150 |
| 30 | 2171,3 | 727,3 | 727,3 | 101,7 | -111,1 | -105,1 |

From the table it follows that the van der Waals contribution dominates to the intermolecular interaction energy and its absolute size is growing with the *N* increasing. The resulting double helix conformation is of "12/1" type, i.e. one turn *per* 12 monomer units. The helix conformation implies the average triad conformation with torsion angle 150°. However, from the detail calculated atomic structures follows that most of the triads show conformation ca. 170°, and the difference is compensated by presence of one *tg* triad with conformation 90° *per* one helix period.

Further well known, experimentally verified feature accompanying formation of s-PMMA self-aggregates is that the probability of their existence is growing with the level of stereoregularity of the participating polymer chains [2]. This tendency is also compatible with our model, as the result in the following table approves.

| *Stereoregularity level [2](%)* | *Total potential energy (kcal/mol)* | *Intermolecular interaction energy (kcal/mol)* |
|---|---|---|
| 100 | 8912,7 | 510,9 |
| 96 | 8815,6 | 483,8 |
| 92 | 8816,1 | 474,5 |
| 85 | 8845,2 | 471,1 |
| 70 | 8861,7 | 450 |
| 50 | 8926,8 | 455,4 |

The final set of calculations also proved that the double helix conformation is stable against mutual interactions with other pairs. Though the calculated total potential energy of two interacting pairs (4314,7 kcal/mol) is lower then those of two free pairs (2*2171,3 = 4342,6 kcal/mol), i.e. an attractive interaction is taking place, it is not strong enough to erode the original double helix structure.

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# Investigation of Santonin/Poly(Methylmethacrylate) Mixtures

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Recently, we have observed [1] an effect of the optical activity enhancement in the planar waveguiding layers prepared from an atactic poly(methyl methacrylate) (at-PMMA) doped with a chiral dopant α-Santonin. To understand better the processes preceding the solid state formation, we focused on study of interactions between at-PMMA and α-Santonin in liquid phase.

It is a well-known that PMMA dissolved in some solvents can spontaneously aggregate at the formation of a dense gel. A comprehensive review [2] of the results so far obtained documents that the macromolecules of PMMA easy aggregate in certain solvents and the aggregation process strongly depends on the tacticity of macromolecules. Two basic types of aggregates have been identified [2] - the stereo-complexes formed in solutions containing mixtures of iso- and syndio-tactic PMMA macromolecules and the self-aggregates in solutions of homotactic polymers. The aggregation is more pronounced for PMMAs with a higher level of tacticity and is suppressed at higher temperatures. No aggregation of at-PMMA has been observed in chloroform solutions.

Atactic PMMA (at-PMMA) (ICI Diakon LG 15), Mw = 44 000 and Mn = 8100 determined by GPC, and α-Santonin (Sigma-Aldrich, grade 99%) were used in the experiments. The at-PMMA and α-Santonin solutions were prepared in chloroform (Fluka, PRA grade) at room temperature and stirred overnight. Optical rotatory power measurements were carried out by an assembly consisted of a precise goniometer (Siemens M1386-X-A9), He-Ne laser (Uniphase, 10 mW, $\lambda$ = 632.8 nm, polarisation ratio 500:1), polariser, optical chopper, mirror, measuring glass cuvette, analyser, Si-PIN detector, and SRS 830 lock-in amplifier. The intensity of light passing through the cuvette (fixed parallel with the goniometer axis) was registered, its angular dependence was recorded and specific rotation [α] calculated. The cuvette filled with chloroform was used as the reference. To characterise the phase separation occurring in at-PMMA/α-Santonin/chloroform system at ambient conditions, 16.7 wt.% solutions of at-PMMA + α-Santonin with various ratio of the components (at-PMMA only, 20:1, 10:1, 6:1, 4:1, 3:1, 2:1, 1.5:1, 1:1, 1:2, α-Santonin only) were prepared and let to evaporate slowly at room temperature. The turbidity curve was determined by measurement of the He-Ne light beam scattering and correlated with the concentration of the tested solutions. Quasi-elastic light scattering (QELS) experiments were performed with assembly consisted of He-Ne laser (Uniphase, 10 mW, $\lambda$ = 632.8 nm), goniometer with sample holder, GaAs avalanche diode, and digital correlator unit attached to the PC control. The scattering angle was fixed to 90 deg. The illuminated sample volume was 30 $\mu m^3$. Recorded autocoorrelation functions were analysed using the Laplace inversion routine CONTIN with constraining parameter P=0.5, and size distributions of hydrodynamic radii calculated. Solutions with various ratio of at-PMMA/α-Santonin were prepared with constant concentration 2 wt.% and filtered (0.45 μm PTFE filter) prior the measurements.

From the turbidity measurements follow that the critical concentration (cloud point) is decreasing with the decreasing content of α-Santonin, but still being observable till at-PMMA/α-Santonin ratio = 4:1. No phase separation was observed for the ratios larger then 6:1. On the contrary, no phase separation was observed [1] even for the ratio 1:2 when a rapid evaporation of the solvent was forced by the spinning procedure. It suggests that the structure of the prepared films is of a meta-stable nature, resembling those of an under-cooled molten mass. The fast solvent evaporation in all likelihood reduces the spatial diffusion of α-Santonin molecules, thus disabling the process of phase separation and dopant moieties are left dispersed in the solidified polymer matrix. The rotatory power of chloroform solutions of pure α-Santonin and its mixtures with at-PMMA growths linearly with the α-Santonin concentration. Presence of at-PMMA has no influence on the specific optical activity of the system α-Santonin/at-PMMA/chloroform. The obtained specific rotation $[\alpha]_{632.8} = -110.8 \pm 1.8$ deg cm$^3$ dm$^{-1}$ g$^{-1}$, is consistent with the expected levorotatory nature of α-Santonin and its known data [3], $[\alpha]_{546} = -205^o$, $[\alpha]_{589,3} = -170^o$. The QELS measurements show that the size distribution curve of pure at-PMMA is monomodal with the single maximum at ca. 2 nm. The observed distribution of $R_h$ corresponds very likely to dissolved macromolecular coils. After addition of α-Santonin solutions, the size distribution curves become multimodal (the concentrations being still far from the critical turbidity curve) with new maxima in the μm-region. Very surprisingly, the size distribution curve of pure α-Santonin chloroform solution was found to be also multimodal ($R_h^1 \cong 230$ nm, $R_h^2 \cong 50$ μm). Presence of the larger aggregates in the filtered solution suggest that some re-aggregation process is taking place. Very likely, the similar process influences also on the aggregate formation observed in the mixture solutions. In the later case, the observed size distribution decreases exponentially with the increasing α-Santonin concentration.

It can be concluded that both α-Santonin and its mixtures with at-PMMA form aggregates in chloroform solutions, suggesting that there are strong interactions among α-Santonin molecules alone, as well as among α-Santonin and at-PMMA chains. The later aggregates do not affect the rotatory power of α-Santonin molecules in solution. Since the aggregates are strongly swollen by chloroform, the mobility of polymer chains is high in comparison with the solid state. By analogy, a similar aggregation process can be expected in the case of films prepared by spinning. However, due to the fast solvent evaporation, the diffusion of α-Santonin molecules from the at-PMMA matrix is very likely suppressed (therefore no phase separation is observed) and the structure is "frozen" in solidified at-PMMA matrix. Because of the observed excessive enhancement of the optical activity [1], a stereospecifical orientation of polymer chains can be assumed. This assumption is a subject of our continuing study.

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# Development of Organized Structure of Carbonaceous Particles in Polymeric Composite LDPE + CB

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This paper deals with development of self-acting organisation structure in polymer composite material, which comprises polyethylen matrix (LDPE) and carbon black particles (CB). The aim of our research is to achieve regular organisation of conductive particles in dielectric polyethylen matrix under various conditions, e.g. intensity of electrical field, temperature, atmospheric pressure, rate of heating, inert air, type and concentration of metal ions and their combinations.

The measurement of changes in conductivity of composite materials LDPE + CB is generally known. This change in conductivity is based on generation of conductive network from conductive carbonaceous elements. This change in organization of conductive particles in polyethylen matrix, and also consequent change of conductivity, are caused with external factor effects, which have strong impact just on generation of that organization. This type of materials has a lot of positive properties and advantages already during the production. Energy intensiveness of producting this composite materials is relatively low, and requirements are posed for cleanness and dimension of carbonaceous particles. It has a main impact on their characteristics [1]. The polymeric composites (LDPE + CB) with this type of impacts have a property that they make possible to process generated material by means of identical technology as an original polymer [2]. Detailed description of changes in behavior of polymers after adding fillers is shown in [3]. An independent section for using the polymeric composities is a domain of their micro-applicability [4] (due to the dimensions of carboneous particles) or perspective of artificial muscles.

We use an experimentally attested polyethylene BRALEN RA-2-9 with content of 6.5%vol carbon particles CHEZACARB EC or A as a testing material. We apply experimental samples with $\phi$ of 9 mm cutted out from a plastic foil with thickness of 0,5 mm, which has a guarantee properties and content of admixtures. The temperature of the experimental sample is from 110°C to 200°C during testing because of organization of carboneous particles in matrix that can arise under conditions with temperature above temperature of melted polyethylene matrix (≈106 °C). We used temperature sample is safely melted. The temperature of experiment guarantees an ideal melting of polyethylene matrix, and also provides good conditions for agglomeration and organisation of carbonaceous particles. The change in organisation of structure is observed indirectly by means of measurement of electrical parameters changes of tested composite.

The sample is located between two electrodes. A fixture for the sample is put in heater; electrodes are connected to RLC metre, which is directed by computer. The temperature of sample is kept in interval of 110 - 200 °C in heater during the all measurements, and electric

parameters are automatically measured in periods of three minutes. The sample is tested during the measurements under various conditions, e.g. electric field, protection atmosphere Ar, lower pressure (1Pa), rate of heating and their combinations. The measured values are recorded automatically and compared with previous measurements. Optimal conditions for generating the organization of structure are selected in this way. The further samples are prepared from selected types of tested composite (before and also after testing). They are ready for mechanical experiments, various analyses and for preparation of the plastic foils with different thickness (50nm - 500μm), which are analysed, documented, and evaluated concerning the organization of carbonaceous particles in polyethylene matrix.

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# Assessment of Carburizing Potential of Furnace Atmosphere by Lambda Probe

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For reservation reproducibility of the industrial process and requisite qualities of the product is necessary to use control, regulation and automatization systems. At the heat and chemical-heat treatment of the steel is important to keep constant constitution of protective and cementation atmospheres. Modern method of their metering and regulation is using of the lambda probe.

Lambda probe is using for recognition quantity of the carburizing potential in furnace atmospheres. Output from lambda probe is voltage, where of is quantity of carburizing potential determine by calculation. The voltage quantity depend upon partial pressure of the oxygen in furnace atmosphere, on temperature of the lambda probe sensor and on partial pressure of the oxygen in referential air. Sensor is made from $ZrO_2$, which is stabilizated by $Y_2O_3$. On one's side of the sensor is the furnace atmosphere and on the oposite side is the referential air. Thanks the ionic conductivity of $ZrO_2$ ceramics so among those two oposite side originate the voltage, which is metered.

Because voltage quantity of the different lambda probes are not the same, every lambda probe has to be calibrated before using. Calibration is pursued according to etalon. For it is usually used oxygen probe, which is more accurate and for measured voltage they are tabular fixed values of carburizing potential. Oxygen probe is set directly in the furnace, in the nearest position by the processing material and the temperature of sensor is equal to the temperature of heat treatment. Lambda probe is set outside of the furnace and furnace atmosphere flow to the lambda probe in supply pipeline. Lambda probe sensor is warming by personal heating body.

Through the carburizing potential of the atmosphere is in the output from lambda probe the voltage higher than in the output from oxygen probe. For possible explication of this phenomenon are offers several possibilities. If the constructional dissimilarities among lambda probe and oxygen probe are go-by, the difference of voltage able to be given by the different temperature of probe sensors, unequal chemical constitution of $ZrO_2$ ceramics of sensors or changes of chemical composition of the furnace atmospheres during flowing to the lambda probe.

Several measuring of voltage of the oxygen probe and the lambda probe were done. Lambda probe was measured with various longitude of supply pipeline. Further was measured the temperature of warming sensor of the lambda probe and the chemical composition of the $ZrO_2$ ceramics. During the measuring was temperature in furnace 830 $^oC$.
The temperature of sensor of lambda probe was 670 $^oC$. Optimum temperature for the function of the lambda probe is about 600 $^oC$. Higher temperature is better for ionic conductivity of $ZrO_2$ ceramics. Because the temperature of oxygen probe is the same with the temperature in furnace (830 $^oC$) and the temperature of lambda probe is lower (670 $^oC$), it is impossible to give reasons for higher voltage on lambda probe. At lower temperature of sensor of lambda probe the voltage in output should be lower than on the oxygen probe, which isn´t.

After fulfilment of the semiquantification analyse on radiographic spectrometer was find out, that the chemical composition of $ZrO_2$ ceramics of the lambda probe and oxygen probe is

almost like. It means, that neither the chemical composition of the ceramics probably doesn´t make the difference of voltage among the probes.

At exclusion of both previous possibilities should be the difference of voltage caused by the taking of furnace atmosphere, which will change the chemical composition during the flowing through the supply pipeline to the lambda probe. To that leads following thinking:

Definite quantity of oxygen $O_2$ and further C, CO, $H_2$, $CO_2$, $N_2$ flow from the furnace to the lambda probe. For the voltage on lambda probe is decisive the quantity of $O_2$. The more is lambda probe away from the point, where is the output of the atmosphere from furnace (it means, that the supply pipeline is longer), thereby longer can proceed this chemical reaction

$$2CO + O_2 \rightarrow 2CO_2 \ ,$$

whereby decreases the quantity of oxygen in atmosphere and the voltage of the lambda probe in distant metering places are higher than the voltage in metering places, which are more closely to the output of combustion gas from furnace. Because lambda probe, appearance to the construction, cannot be set right in furnace, must the metering atmosphere always flow definite course, on that can the chemical composition changes. That is probably why is the voltage of oxygen probe lower than the voltage of lambda probe. For confirmation of those thinking is necessary to make more experiments, which should be sight on recognition of the changes of chemical composition of atmosphere.

Measurement had also to find the optimum placing of lambda probe in gauging system, let us say the optimum longitude of supply pipeline. As optimal was find the place, which is the nearest to the output of combustion gas from furnace, it means that the supply pipeline would have be the shortest. Lambda probe has in this place the best sensitivity and short response time for changes of the composition of furnace atmosphere. Was also fulfilment metering, when sensor of lambda probe was placed in the edge of the furnace space. It showed, that sensitivity of lambda probe and response time aren´t already almost better, so that is unnecessary to arrange the lambda probe in this way (to the furnace), because it caused more problems, like are the problems with high temperature, which affect to lambda probe and the necessity of perfect stuffing, because combustion gas is very poisonous.

These findings contributed to the knowledge about lambda probes and can be apply in the technology of heat treatment.

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# Physical Properties of InP Epitaxial Layers Prepared with Dysprosium Admixture

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The development of InP solid state particle detectors, realization of InP microwave devices destined for very high frequency operation and fabrication of optoelectronic components are several examples for new interest in the preparation and study of InP-based semiconductor layers and structures. Parameters of the devices are to a large degree determined by properties of component materials and by technology employed in the fabrication process.

We report the effect of Dy addition during the epitaxial growth on the resulting structural, electrical and optical properties of InP layers. Suitability of Dy in the context of particle radiation detectors in comparison with previously explored rare-earth elements (REEs) is discussed. Detectors on the basis of InP can be used over the quantum particle energy range 10 keV-1 MeV. Sufficiently high bandgap energy ($E_g$=1.423 eV) allows room temperature operation. The high atomic number of In (Z=49) and high density ($\rho$=4.8 g/cm$^3$) predicates high stopping power [1].

A suitable technology for the growth of thick semiconductor materials with low concentration of undesirable impurities and of good structural quality that are required in radiation detector structures is liquid phase epitaxy (LPE). Commonly prepared InP – bulk crystals as well as epitaxial layers – are of n-type. This is because InP contains intrinsic donor impurities. In the context of structures for semiconductor radiation detectors p-type layers are of importance since high quality Schottky barriers cannot be prepared on high purity n-type InP at present. By means of conventional growth procedures p-type material can be obtained by the addition of suitable acceptors, such as Zn. In such a case the purity of the material is not sufficient for the standards of particle detectors. Different situation starts up in the case of thick liquid phase epitaxial layers prepared with the addition of rare-earth elements into the growth melt.

It was recognized a long time ago that admixture of rare-earth element (REE) into the growth solution for preparing InP layers by liquid phase epitaxy (LPE) can decrease the background donor concentration by several orders of magnitude [2]. This is because highly reactive REEs form stable compounds with residual impurities that are insoluble in indium melt and therefore do not incorporate into the grown layers. Especially oxygen and other main group-six elements acting as shallow donors in semiconductors are effectively gettered due to high REEs activity towards them [3]. Preferentially donor impurities are gettered. Acceptor impurities are also suppressed but to a lesser extent [4].

A conventional horizontal sliding LPE system was applied to the growth of InP layers. The apparatus consisting essentially of a three-zone resistor furnace with precise temperature regulation, a quartz reactor tube, a multiple-bin graphite boat, and a source of ultrahigh purity hydrogen is interfaced to PC. Single crystal (100)-oriented InP substrates were chosen in these experiments. The growth melt contained besides the basic components an admixture of Dy.

The whole process was carried out in two cycles. The In and InP melts were prepared in the first cycle and the growth of epilayer was accomplished in the second cycle with the initial temperature of 650 °C. Supercooling technique with cooling rate 0.6 °C $min^{-1}$ was used. InP thickness varied from 8 to 15 μm.

Conventional optical and scanning electron microscopy was employed to study structural defects, layer thickness, surface morphology and the substrate-layer interface. Electrical properties on contact-less samples were obtained from capacitance-voltage measurements using the mercury probe. The layers were further characterized in more detail by temperature dependent Hall effect measurement using van der Pauw configuration. Low-temperature photoluminescence spectra were taken at various temperatures and levels of excitation power to characterize optical properties of layers.

The structural properties were influenced by the Dy concentration. InP epitaxial layers with mirror-like surface, sharp interface and low defect density were prepared when the Dy concentration did not exceed 0.25 wt%. For higher concentrations the surface was rough with isolated areas and the layers became imperfect. The growth rate slightly decreased with increasing concentration of Dy. N-type material with a reduced concentration of shallow impurities were grown when a small addition up to 0.02 wt% of Dy was used. Higher concentrations lead to reversal of conductivity type from n to p.

The density of structural defects was reduced by more than one order of magnitude, the concentration of shallow donors was reduced by more than three orders of magnitude. Photoluminescence peaks were substantially narrowed and fine spectral features were resolved. Dy produces the change in electrical conductivity type at the lowest concentration in comparison with other REEs. From this point of view, Dy appears to be the promising candidate for application in the semiconductor technology.

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# Preparation of Multilayered Coatings by PVD

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Very strong requirement for industry products in several branches leads to development, limited by nowadays technological possibilities and knowledge simultaneously, of new kinds of coatings as multicomponent, multiple-layer, multilayered, dispersion, nanoscaled and hybrid coatings, which are predetermined to displace "older" single layered coatings.

Today's thin engineering coatings, which are mostly presented by hard or tribological coatings usually fail as a result of very high mechanical or chemical loads or a combination of both. In many cases, the lifetime is governed by fragmentation due to poor toughness. Improvement of the tribological performance properties can thus be accomplished by, e.g., increasing the coating fracture toughness while retaining its hardness. A possible solution is to replace single layered fracture resistance as compared with today's single layer coatings with multilayered ones. In several investigations it has been shown that ceramic multilayered coatings can exhibit an improved fracture resistance as compared with today's single layered ceramic coatings [1,4].

Such ceramics multilayred coatings are obtained by alternately depositing two (or more) mechanically different materials, especially by several PVD techniques in laboratory scale by passing the samples in front of the different sources and in technical scale in industrial systems on the base of a multifold substrate rotation. Some further improvement can be thought in intermediate etching by ion bombardment for modification of the interfaces between the individual layers.

In this work PVD multilayered coating, prepared by reactive magnetron sputtering with 0V substrate bias, consisting of the two metal nitrides, TiN and TaN, has been evaluated. The aim of this work is to evaluate the influence of bilayer thickness ($\Lambda$), i.e. thickness of one TiN/TaN lamellae, on basic mechanical and tribological properties of perspective TiN/TaN multilayred coating [1,2]. Several coatings with four different bilayer thickness of 390, 120, 60 and 10 nm, were deposited on hardened cold work steel (19421.4) and glass – ceramic („Sitall") substrates. All coatings, including referenced single layered TiN and TaN were deposited in BALZERS LLS 801 apparatus by rotation of substrate holder in front of the magnetrons. During coatings deposition nitrogen partial pressure was $7{,}7\text{x}10^{-4}$ mbar and total pressure was kept constant $2{,}5\text{x}10^{-3}$ mbar, while the magnetrons sputtering power was 4kW. The coating hardness,Young's modulus, residual stress, cohesion and adhesion to the substrate as well as morphology and wear resistance of the coatings were determined. Single layered TiN and TaN coatings were included for comparison to some results. The major conclusions are:

1. Universal hardness of multilayered coatings ($H_{multi}$) in the case of samples with lowest bilayer thickness ( i.e. $\Lambda=\lambda_{TiN}+\lambda_{TaN}$ ) exceeded expected value, obtained from lamellae thickness ($\lambda$) and hardness (H) of TiN and TaN single coatings :

$$H_{multi} = H_{TiN}(\lambda_{TiN}/\Lambda) + H_{TaN}(\lambda_{TaN}/\Lambda)$$

2. Variation of the hardness versus $1/\Lambda^{1/2}$ for multilayered coatings was plotted and fits can be performed to the linear region.There exist some saturation point of hardness for given bilayer period. Further decreasing of bilayer thickness leads to insignificant increasing or for very small periods also to possible decreasing of hardness.

3. The DSM (Depth Sensing Microindentation) dF/dh = f(h) dependence shows that multilayer interfaces are effective inhibitors of dislocation motion during plastic deformation.

4. Decreasing of bilayer thickness leads to better wear resistance, but brittle behaviour during adhesion – cohesion tests, because of higher hardness and residual stress for smaller $\Lambda$.

5. The universal hardness of TaN was higher than TiN. TaN coating exhibit better wear resistance but worse adhesion and higher residual stress in comparation with TiN.

6. Hardness and Young's modulus of multilayered and single layered coatings was lower in case of softer glass-ceramic substrate ("Sitall").

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# The Influence of Spray Technique on Fatigue Behaviour of Ni-5Al Coated Bodies

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Thermal spray technology is a rapidly evolving field, which services a broad industrial community. Thermally sprayed coatings are applied whenever high resistance to mechanical or thermal load is required. The aircraft and automotive industry together with medical applications are the fields where the thermal spray technology is already well established. However, despite of numerous applications, little is known about the factors that influence fatigue resistance of coated bodies. The fatigue behavior of the composite substrate-coating is a result of many factors such as porosity and anisotropy of the coating, thermo-mechanical properties of the bulk materials and residual stresses in both the coating and substrate [1].

This article describes the influence of various thermal spray techniques on fatigue behavior of Ni-5Al coated bodies. Wire arc, gas stabilized plasma and HVOF was used to deposit approximately 0.4 mm thick coatings on both sides of dog bone shaped flat specimens. The results of the fatigue tests were statistically processed. The influence of the coating technology on the fatigue life of coated specimens was proved by means of the Wilcoxon test.

The specimens for the fatigue tests were machined from low-carbon steel sheet. The specimens had a gauge width of 20 mm, shoulder width of 40 mm, length 200 mm and thickness 4 mm. Prior to spraying the specimens were grit blasted with $Al_2O_3$ powder (average ∅610 μm, blasting pressure 0.5 MPa) in order to invoke sufficient surface roughness for good coating to substrate adhesion and also to clean the samples. A reference series of samples without any surface treatment and of grid blasted samples were prepared. The samples were sprayed with Ni-5Al coating using the following techniques.

**Two wire arc**: the Metco 8400 wire feedstock sprayed using a Tafa 8830 instrument on both grit blasted samples and samples without any surface treatment (cleaned in ethanol)

**HVOF**: Praxair NI-357-1 ∅ 45 μm powder sprayed using Diamond Jet Hybrid 2700 gun

**Plasma:** Praxair NI-357-1 ∅ 45 μm powder sprayed using Metco 3MB gas stabilized gun on both sides of grit blasted samples and samples without any surface treatment (cleaned in ethanol)

The specimens were tested in scope of a wide experimental program including various coating materials and techniques [2]. The specimens were loaded in reversible bend (as a cantilever beam) at room temperature on a special loading device SF-test developed at the department of materials. The free end of the specimen was deflected by a yoke driven by electromagnetic field. The deflection amplitude of the free end (in this case 4.2 mm) is measured by an optical sensor and is maintained constant during the test. Resonance is used to obtain desired deflection amplitude of the free end. The changes of the resonance frequency

of the set specimen-yoke were used to estimate the specimen cross-section damage. The experiment was stopped when an approximate 30% of the cross-section was damaged.

The fatigue experiments indicated following influence of the surface modification technology on fatigue lives of tested specimen. The average fatigue life relative to the reference series was 60% for grit-blasted specimens, 20% for plasma sprayed grit-blasted specimens, 20% for plasma sprayed specimens without grit-blasting 20% for wire arc sprayed grit-blasted specimens, 30% for wire arc sprayed specimens without grit blasting and 230% for HVOF sprayed grit-blasted specimens. The application of grit blasting caused noticeable decrease of fatigue lives for both uncoated and coated specimens. In all cases the fatigue life length was about 70% of the fatigue life of samples without grit blasting. The notch effect of grit blasting accelerated crack nucleation and because it was not accompanied by sufficiently large peening effect it caused fatigue life decrease.

The linear thermal expansion coefficient of Ni-5Al alloy is 13.2e-6/K which is only slightly higher that the expansion coefficient for low-carbon steel (11.3e-6/K). The secondary stresses that arise from cooling of the composite coating-substrate to the room temperature are therefore tensile and the primary stresses are also tensile. The tensile stresses in coating will decrease towards the substrate and may possibly become compressive as a result of continuous buildup of the coating. The HVOF sprayed coating will have the stress profile shifted towards compressive stress as a result of HVOF peening effect [3, 4].

The notch effect of the rough surface of the coating, combined with tensile residual stresses that exist on the surface of plasma sprayed and wire arc sprayed coating force crack initiation on the surface of the coating. As the crack propagates, the concentrated stress on the crack tip enables the penetration of the crack into the substrate and therefore the fatigue life is decreased. In the case of HVOF sprayed coating, the tensile peening stress delays the crack initiations and therefore the fatigue lives of HVOF sprayed specimens are significantly longer.

The estimation of the value of residual stresses in the coating and substrate is subject of future research.

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# Fatigue Lives of Bodies with Thermally Sprayed Coatings

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The fatigue properties of thermally sprayed bodies have been studied since a long time at the department of materials [1], [2]. Fatigue samples with standardized geometry loaded under standardized conditions enabled to compare fatigue lives of thermally sprayed bodies prepared with various combinations of thermal spray techniques and feedstock materials.
The specimens for the fatigue tests, machined from low-carbon steel sheet were flat dog bone shaped with gauge width of 20 mm, shoulder width of 40 mm, length 200 mm and thickness 4 mm. The surface of the specimens was prepared by various methods. To provide the reader a rough idea about the sample preparation process and to enable simpler orientation in the fatigue test results, we provide here a naming convention for the sets of specimens with the same surface treatment. Each set of specimens has a code that is based on the *substrate material* (first character, materials 1 and 2), *the method of grit-blasting* (second character, 0-not blasted, t-grit-blasted, T-grit-blasted with higher blasting duration), *the coating technology* (third character, 0-no coating, p-plasma, w-wire arc, h-HVOF), *feedstock material* (fourth and fifth characters, Al-$Al_2O_3$, Mo-Molybdenum, IN-Inconel 625 superalloy, OL-olivine, Cr-$Cr_2O_3$, Ni-Ni-5Al ) and *coating thickness* (the number separated by slash from the rest of the code divided by ten gives the average coating thickness in mm). This code will be used when referring to a set of specimens in the following text.

| set code | $N_{max}$ ($10^4$ cyc) | $N_{max}/N_{ref}$ (%) | set code | $N_{max}$ ($10^4$ cyc) | $N_{max}/N_{ref}$ (%) |
|---|---|---|---|---|---|
| 1 | 348 | 100 | 2 | 175 | 100 |
| 1t0Al | 298 | 85 | 2t0Al | 211 | 120 |
| 1T0Al | 492 | 141 | 2T0Al | 207 | 118 |
| 1t0IN | 364 | 105 | 2t0Mo | 234 | 133 |
| 1tpAl/4 | 725 | 208 | 2t0Ni | 108 | 61 |
| 1tpAl/8 | 663 | 190 | 2TpAl/4 | 333 | 190 |
| 1tpAl/9 | 587 | 169 | 2tpMo/3 | 181 | 103 |
| 1tpOL/7 | 955 | 274 | 2twNi/4 | 42 | 24 |
| 1tpOL/13 | 1101 | 316 | 20wNi/4 | 60 | 34 |
| 1thIN/4 | 589 | 169 | 2tpNi/4 | 28 | 16 |
| 1tpCr/10 | 946 | 272 | 20pNi/4 | 37 | 21 |
| | | | 2tpMo/4 | 40 | 23 |
| | | | 2thNi/4 | 401 | 229 |

Tab. 1: The absolute and relative (to the set with no surface treatment) length of the average fatigue lives of specimens with various surface treatments for two variants of substrate.

The specimens were loaded in symmetrical bending as cantilever beams in a special loading device SF-test. The deflection of the free end was 4.2 mm. The number of cycles to failure (corresponding to ≈30% cross-section damage) was recorded and statistically processed.

Strong influence of the coating technology on the fatigue life of coated specimens was proved by means of the nonparametric Wilcoxon test. The average fatigue lives of specimens from various sets are presented in Tab 1.

According to Wilcoxon test the process of grit blasting has no significant influence on the fatigue lives of specimens with the exception of the set 2t0Ni (grid-blasted by robot, other sets grit blasted by hand). The sts of plasma sprayed and wire arc sprayed metallic coatings, i.e. 1tpMo/3, 1toMo/4, 2tpNi/4 and 2twNi/4 have significantly shorter fatigue lives then the corresponding grit-blasted specimens without coating, i.e. 1t0Mo, 1t0Ni. The HVOF sprayed metallic coatings 1thIN/4 and 2thNi/4 showed fatigue life increase compared to specimens without surface preparation 1 and grit-blasted specimens 1t0IN, 1toNi. The sets with plasma sprayed ceramic coatings, i.e. 1tpAl/4, 1tpAl/8, 1tpAl/9 , 1tpOl/7, 1tpOl/13 and 2tpAl/4, showed significant increase of fatigue lives.
The increased fatigue resistance of HVOF sprayed coatings is caused by the peening effect of HVOF deposition [3]. The failure processes in wire-arc sprayed and plasma sprayed coatings are influenced mostly by the existence of primary (induced by the splats cooling after impact) and secondary stresses (induced by the cooling of coating-substrate composite from deposition temperature to room temperature). The secondary stresses can be computed from known linear thermal expansion coefficients of both substrate and coating [4]. The primary stress value can be obtained on the surface of the coating by measuring the residual stress at the surface of the coating for examples by X-ray diffraction and substracting the value of secondary stress. For $Al_2O_3$ coating the value of secondary stresses was estimated at 300-350MPa in tension using this principle. Towards the substrate the primary residual stresses shift to tension as a result of incremental layer buildup. The gradient of primary stress can be established for example from the curvature radius of coating separated from substrate. This simple way of estimating the primary residual stresses in the coating will be subject of future research.
The fatigue resistance of coated bodies is dependent on mechanical and thermal properties of both the substrate and the coating. The properties of the substrate are already well known. However the thermo-mechanical properties of the coating differ significantly from the properties of the same bulk materials due to the coating porosity, anisotropy and residual stresses, which is in turn a result of spraying technique. Therefore the thermomechanical properties of the coating have to be examined for each set of spraying parameters in the future research.

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# Application of Wavelet Transform in Textural Fractography

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QUANTITATIVE FRACTOGRAPHY of fatigue failures is aimed especially at the reconstitution of the history of a fatigue crack growth process in practice. It is performed by integration of crack growth rate (CGR) along the crack growth direction. The local macroscopic CGR must be estimated from the fracture surface. The relation between crack morphology and CGR is analyzed on SEM-fractographs of crack surfaces from laboratory fatigue tests. All conditions of laboratory testing (material, loading, environment, temperature) must be identical with the damage process in practice.

The textural image analysis can be applied as an alternative to traditional fractographic methods. Under suitable magnifications, typical structures in images can be understood as image textures - random structures of similar elements with some kind of ordering. A texturally homogeneous image of fracture surface can be characterized by a vector parameter – a set of statistical or model characteristics of image texture. As they are related to the whole image, we talk about "fractographic integral parameters".

The SEM magnification must be optimized to satisfy several (partly contradictory) conditions. Typical magnifications for the application of the textural method fill the interval between traditional areas of macro- and microfractography (about $30 \div 500$ x). This region could not be used for quantitative analyses until computational image processing was possible, due to the absence of measurable objects in images.

To remove large-scale fluctuations of brightness and contrast, images are normalized.

The relation between a set of textural parameters and the value of CGR can be expressed in the simplest way by a multilinear function optimized in regression manner. A minimal set of image parameters should be selected which explains the value of CGR satisfactorily. The system of equations must be strongly overdetermined – the number of finally accepted image parameters must be much lower than the number of images.

In recent years, several methods of fractographic textural analysis [1] were developed, completed up to computer programs and tested on results of laboratory fatigue experiments: spectral analysis, Gibbs random field model, and fibre process analysis.

A relatively new decomposition scheme which can be used also for images is WAVELET TRANSFORM [2]. In contrast to Fourier transform and other transforms, wavelet analyzing functions are localized. Consequently, wavelet transform is more than an integral decomposition: it captures the degree of similarity between the analyzing function and the analyzed image separately for different positions in the image.

Many types of wavelet functions may be used. The simplest of them is Haar wavelet - a rectangular pulse. It was fully sufficient for our purposes.

One step of the wavelet transform of images can also be intuitively understood as decomposition into four separate images. The first image – the approximation - is simply a scaled down (downsampled) version of the original. The remaining three images – the details – contain information in the horizontal, vertical and diagonal directions lost in the scaling,

expressed by multiples of the wavelet. In the next step, the approximation from the previous step is analyzed in the same way, which allows for scale-dependent analysis (i.e. at each scale the wavelet transform selectively captures only objects of certain size).

In order to use the information obtained from the wavelet decomposition a suitable feature vector must be constructed. As Mallat [3] has shown, the histograms of the coefficients of the transformed images, the approximations and details, are only two-parametric. Consequently, only two parameters for each of these data sets may be used to describe it in the statistical sense. Two such parameters are the mean absolute value and variance of the coefficients. If the wavelet transform is carried out to the level $n$ (the scaling-down is repeated $n$ times), the number of details is $3n$ (horizontal, diagonal and vertical) and the number of the feature vector coefficient is $6n$. After several steps of decomposition, resulting last approximation contains only mean gray value and therefore it is not included.

Subsequently, regression methods mentioned above can be used to express the relation between the image feature vector and the value of CGR. In tested cases, the feature vector could be reduced to only few parameters related to relatively small details. Results obtained were comparable or better than if other decomposition methods were used, while the information contained in wavelet coefficients is much more suitable for fractographic interpretation.

Generally used image transformations are based on decomposition of the image into a linear combination of apriori given basic images (harmonic waves, wavelet functions, etc.). To adapt the decomposition to the individual character of images, the method of AUTO-SHAPE DECOMPOSITION was proposed [4]. Images are expressed as a linear combination of basic subimages selected directly from the training set. Methods for setting dimensions of basic subimages and selecting of them were proposed. The application proved a high stability of the method even when a small set of training images was used.

The textural fractography was developed to complement or substitute traditional methods. However, textural analysis discloses new sources of information on fracture process coded in the morphology of fracture surface. Two goals of the future research were set:

- generalization of the traditional concept of fractographic feature into its random analogy, fractographic textural element,
- generalization of the method of fractographic (textural) reconstitution of the history of fatigue crack growth to the case of variable cycle loading.

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# Study and preparation of Cr2O3 layers, as a protection of metal substrates against corrosion

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Different metals, used in chemical, nuclear so as in the thermal plants (and so in other industry) are frequently exposed to corrosive ambient. To prevent such materials against chemical corrosion we need some methods of surface protection. Most typical such protection is a surface anticorrosive passivation layer.

The requirements on these layers are relatively high. They include e.g.: - resistance against acids, resistance against moist and dry hot water steam, good adhesion to protected surface, low porosity and high hardness. All range of this particular requirements fulfils only specific type of layers, especially layers of Cr, Zr, Va, or their combinations. From Cr – based layers we can pick out $Cr_2O_3$, CrN carbonitrides Cr-N-C or chromium nitrides.

Chemical methods of layer preparation are more and more often used for industrial applications so as PVD (Physical Vapour Deposition) method [1,2]. From chemical methods it is especially CVD (Chemical Vapour Deposition) method. As a sample we can mention chromium coatings deposition from the vapour phase using different halogen-derivatives of chromium, so as nitration of chromium coatings at 700-800°C in the ammonia atmosphere [3]. In the last years the new chemical processes are intensively looking for to decrease the temperature of the treatment and, in the result, to be able to use these reactions on the materials which are not compatible with high temperatures. Way out of this situation is using of organo-metallic compounds (for CrN and CrC layers) or some alcoholats or acetylacetonat for $Cr_2O_3$ layers preparation. The main requirement on these compounds for industrial application is to be non toxic, non inflammable and easy convertible to the vapour phase.

To prepare $Cr_2O_3$ layers is a good solution to use acetylaceton of chromium $C_{15}H_{21}CrO_6$. It has low toxicity and it is easy convertible to the vapour phase. The preparation of $Cr_2O_3$ layers using this procursor can be made in the temperature range 350-650°C. The deposition methods are following:CVD (temp. range 400-450°C) and PACVD (Plasma Assisted CVD), temp. range ~ 350°C.

**Experimental**

**$Cr_2O_3$ layers** has been prepared by all mentioned methods on Si (111) substrates or on different metallic (steel) substrates. In all cases has been used oxidation atmosphere.

Layers prepared at the temperatures below 450°C were *amorphous,* layers prepared at 550°c and above were generally *polycrystalline*. Measured refractory index of these layers varied in the range 2,3 – 2,5. The hardness of the deposited layers ( measured on Si substrates) was 20-25 GPa.

From the measurements of the layers composition by the EPMA (Electron Probe MicroAnalysis) is evident that the layers contents not only Cr and O, but in all cases also some amount of the carbon (C). This amount of C depends on the type of the preparation method.

Tab.1 Composition of the layers prepared by LPCVD method at 450°C and 550°C

| Element | Deposition temperature | | | |
|---|---|---|---|---|
| | 450°C | | 550°C | |
| | atom % | weight % | atom % | weight % |
| O | 49,08 | 24,36 | 61,80 | 37,90 |
| Cr | 45,70 | 73,40 | 28,98 | 57,75 |
| C | 5,22 | 1,94 | 9,02 | 4,15 |
| Al | ** | ** | 0,19 | 0,20 |
| | **100** | **100** | **100** | **100** |

**CrN layers** one can prepare from the organo-metallic compounds containing Cr (not from the alcoholats). Typical example of it is using of bis-benzene-chromium. This is a organo-metallic compound, stable at room temperature. It ignite on the air above 85°C. For this reason it is suitable for industrial deposition of CrN (or Cr) layers at temperature range of 350-550°C [4]. Except this described compounds it is possible to use also other chemical compounds based on carbon and chromium for deposition of CrN (precisely Cr-N-C) layers.

To prepare CrN layers we have two ways. First method is based on single source (as e.g. $Cr(NEt_2)_4$ – tetrakis(diethylamido)chromium. The source molecule contains not only Cr, but in addition N in the form of aminogroup. The deposition is then made in inert atmosphere. Appropriate layers contain relatively great amount of carbon and their composition corresponds with formula $Cr_3(C_{0,8}N_{0,2})$.

The second method is to use the double source. The procursor is thus bis(benzene)chromium, which contains only Cr and the deposition is made in the ammonia or hydrazine atmosphere. The main advantage of this method is in possibility of regulation of the layer composition through the $NH_3$ pressure in the reaction chamber.

The experiments made with bis(benzene)chromium has confirmed the applicability of this method for CrN layers preparation. The temperature we has reached was 350°C, respectively 600°C (depending on the mentioned method).

Chemical methods of the preparation of Cr-based layers seems to be suitable for their deposition. Wide range of deposition temperatures allows to process not only the high temperature stable substrates, but also the substrates with relatively low melting points. Described organo-metallic compounds are applicable for industrial use and more, not only for their low decomposition temperatures but also for the high deposition rate

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# Influence of Carbon Black on the Creep Behavior of Linear PE

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Linear PE becomes still more important and starts being frequently used as a construct polymer. It is therefore important for constructers to know its behavior under different conditions. This leads to research not only of a short time behavior, which is usually very important for metals, but also of a long time behavior which depends on a period, temperature and stress. On the basis of these characteristics a prediction of the construction lifetime is possible.

In this work we investigated a long period test under a constant load - creep. The experiments gave us information about the long period strength ($\sigma_t$), time to fracture (t) and other important results.

For the experiment we used two types of HDPE from the production of Chemopetrol a.s. (Liten FB 10 and PL 10). These materials are based on the same polymer compound where the first one FB 10 is a natural grade and PL 10 is filled with 2,2 to 2,4 % wt. of carbon black (Elfex TP, produced by Cabot). Although these materials are not absolutely identical (the filled type PL 10 has a different molecular weight distribution due to the processing when compared to the unfilled grade), their structural parameters are close enough for comparing their creep behaviors. Specimens were produced according to Euro standards ISO 3167 type A. Testing conditions: 23°C (1 MPa; 2MPa; 3MPa); 40°C (1,1 MPa; 2,4MPa).

The effect of carbon black on basic mechanical properties (short period tests) is negligible. Carbon black increases Young's modulus a little and it also does not affect the yield strength. The effect of carbon black is in this case suppressed by the effect of the wider distribution of the molecular weight.

Both Liten PL 10 and Liten FB 10 show similar creep behavior. From the point of view of the creep deformation ($\varepsilon_t$) behavior the filled polymer is better at higher stresses (2 MPa and more) and higher temperatures (40°C). This means that the most important effect at lower temperatures (20°C) and stresses (1 MPa) has the difference in molecular weight. From the point of view of the creep modulus ($E_t$) the filled polymer shows a better performance in a longer period. There is also an important effect of the different distribution of the molecular weight and the not-filled polymer has a higher creep modulus even at higher temperatures (40°C) and low stresses (1 MPa). At loads higher than 1 MPa the effect of the stabilization by carbon black starts being more important. At a stress of 2 MPa the filled polymer has a higher creep modulus than the unfilled one. From the point of view of the creep speed $\dot{\varepsilon}_t$, at useful application times (longer than 100 minute), the filled polymer is better at regular temperatures (20°C) but the not-filled one is better at higher temperatures (40°C). At shorter periods and

lower stresses (up to 100 min,1 MPa) the main effect has the distribution of the molecular weight. At longer periods, higher temperatures (40°C) cause a slower creep speed; this is due to a higher deformation leading to a more pronounced hardening of the polymers. At higher temperatures, the higher creep speed of the filled polymer is insignificant, and the final deformation ($\varepsilon_t$) at higher stresses is lower. This leads to the equal deformation of both polymers in the longer period.

We can conclude that the main effect on the creep behavior at loads of 1 MPa has a polymeric matrix and this explains the lower creep deformation of the not-filled polymer under these loads. If the stress increases than the effect of the carbon black starts being more important than the effect of the matrix and the filled polymer has better creep resistance.

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# Laser Treatment of Plasma Sprayed Ceramics

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First joint activity of the Material Engineering Department, Institute of Plasma Physics ASCR (IPP) and Department of Manufacturing Technology, Faculty of Mechanical Engineering CTU in Laser Center Prague (LCP) was concentrated on boring of alumina plasma deposits by $CO_2$ laser two years ago. Later IPP performed surface laser treatment of various plasma sprayed ceramic materials in joint research with Tampere University of Technology, Finland. Nd:YAG laser was used. It was demonstrated that microhardness and wear resistance increases and surface roughness decreases in the same time in the part of ceramic body influenced by laser remelting /laser annealing [1]. At comparison of alumina microstruture treated in Tampere and those treated at LCP we see the same character of the changes.
Grey alumina ($\alpha$-$Al_2O_3$ + 3 wt.% $TiO_2$ + 1 wt.% $Fe_2O_3$) was tested. Pure $Al_2O_3$ was also tested before, but the changes in the structure were negligible compare to grey alumina. Also reflection of alumina-based materials was compared by reflectivity measurement.
Reflectivity was measured at the Prague Asterix Laser System ASCR, where scanning spectrophotometer MPC 3100 (Shimadzu, Japan) was used. The comparative reflectivity was measured in the range from 400 – 2000 nm, which represents the whole range of visible light and the near infrared region. As the standard was used barium sulfate with reflectivity independent of the used frequency. Lower reflectivity represents better conditions for energy absorption at corresponding wavelength of incident radiation.

Table 1 – Comparison of measured values of reflectivity at working wavelength of Nd:YAG laser

| MATERIAL | Reflectivity at 1064 nm [%] |
|---|---|
| Barium sulfate (standard) | 100 |
| Pure $Al_2O_3$ | 81.71 |
| $Al_2O_3$ mixture with 6wt. % of Al | 44.96 |
| Grey alumina | 20.28 |

In this paper we are concentrated on the description of alumina-based ceramics microstructures influenced by Nd:YAG laser installed at LCP (JK 701H, GSI LUMONICS) .
We also compare pure $Al_2O_3$ plasma deposits with sintered ceramics. Plasma deposits were repeatedly annealed before laser treatment to stabilize phase composition – mixture of $\alpha$ and $\gamma$ phases with dominant $\gamma$ phase is often found in as-sprayed state compare to dominant $\alpha$ phase after annealing.
Position of the laser focus was found as more important parameter than specific energy of laser radiation. For surfacial glazing the focal position must be above the treated surface to ensure acceptable results. On the sample surface thin influenced layer could be seen by microscopy.

In the case of sintered alumina increase of distance between focal position and substrate surface leads to deeper profile creation on the treated surface.

In the case of as-sprayed grey alumina, if we have focal position on the substrate surface, we create craters on the surface. Shift of the focal position above the surface decreases depth of the crater but increases its diameter. Increase of specific energy increases both dimensions – depth and diameter. If we introduce relative movement between the laser and the surface at focal position fixed, increase of the shift leads to local thermal shock in the alumina and cracking below the surface occurs. Surfacial glazing observable by the microscope was obtained only at certain combination of parameters.

Alumina belongs to very hard materials. Its thermal treatment by laser consists -in general- of remelting of certain thickness and annealing of deeper region of material. Laser treatment represents thermal shock applied on ceramic material whose composition is metastable thank to previous thermal shock, which was the manufacturing process by plasma spraying. Also the process in influenced layers is very complex.

We measured microhardness of plasma sprayed pure alumina before and after laser treatment. Microhardness was measured using Hanemann head mounted on the light microscope with fixed load 1N and Vickers indenter. Table 2 summarizes the results based on 10 indents per sample.

Table 2 – Microhardness of $Al_2O_3$ plasma deposits before and after laser treatment

| **Mater. state** | **Focus – surface distance [mm]** | **HVm** | **St. deviation** |
|---|---|---|---|
| Before laser treatment | - | 1404 | 50 |
| Nd:YAG laser | +3 | 2053 | 142 |
| Nd:YAG laser | +5 | 2032 | 129 |
| Nd:YAG laser | +5,8 | 1739 | 172 |

We can see that maximum increase of microhardness was obtained for the smallest focus – surface distance. Then the HVm value decreases and layer homogeneity decreases, which is indicated by the growth of standard deviation at maximal focus – surface distance.

Further work will be concentrated on founding of proper conditions for $CO_2$ laser, especially in terms of specific energy, to ensure surfacial hardening of plasma sprayed alumina. Structural, chemical and phase change in laser-treated layers will be studied to join the hardening also with improvement of wear resistance of coatings – to found proper penetration depth of the heat transported by laser, to prevent stress gradient or phase mismatch leading to delaminating of the coating.

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# Study of Failure Processes of Nickel Superalloys

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Development of new structures and components working under the severe conditions (high temperature, corrosion environment, and/or high external forces) desires new specific materials. Industrial applications of these new materials explicitly demand to ascertain their mechanical properties and microstructure characteristics. Also understanding of failure processes and their relations to microstructure characteristics is very important. This need of better understanding material's properties requires to develop new special research techniques and/or to use the old ones in a new original way. This paper is concerned with new methodology of study of relations between failure processes and microstructure of Ni-superalloys strengthened with primary carbides. These alloys are intended for usage in corrosive environments at high temperature. In recent time there is running a large research program in cooperation of PBS Velká Bíteš a.s. and UJP Praha a.s..

There has been done a lot of research to obtain as much material characteristics of these alloys as possible, e.g. chemical composition and its variation, mechanical properties, structure properties, creep behaviour. Fractographic analysis was used for examination of failure processes, which proceed in specimens during tensile and Charpy's tests. The main goal of our research work was to describe influence of material's structure on the failure mechanisms in alloy 141I. Set of specimens either in a cast stage or in an annealed stage broken at tensile and Charpy's tests at different temperatures was used in this study.

The following methodological steps of study were used (see [1]) :

1) Fractographic analysis :
   Description of macroscopic features – reduction or deformation of specimen's cross-section, declination of the fracture surface from lengthwise axis, etc. (light stereo-microscope).
   Description of microscopic features – number and position of initiation sites, fracture micromorphology corresponding to the fracture mechanisms, size and shape of particles on fracture, etc. (SEM).
2) *Metalographic analysis of cuts perpendicular to the fracture surface* :
   Description of microstructure characteristics (light microscope).
   Observation of fracture line (the intersection of the fracture surface and the cut) – description of its course in microstructure components (light microscope).
3) *Simultaneous observation of fracture and cut perpendicular to the fracture surface*
   Study of the relation between the microstructure characteristics and the different micromorphological features (SEM).
   Determination of chemical composition of different microstructure components (local electron microanalysis).

Described methods can offer very useful information about failure processes in real microstructure. Unfortunately, there are many problems and troubles during their realization.

The special epoxy resin is used for preparation of metallographic cut perpendicular to the fracture surface. This resin has to be removed before investigation of relation between microstructure and fracture micromorphology. This step is very difficult, and rests of resin generally remain on fracture surface. Charging of remaining resin considerable complicated the SEM observation and also local electron microanalysis. The SEM observation was originally carried out in JEOL JSM 840A, [2], [3], only some parts of specimen could be observed. Later we used microscope JEOL JSM 5510LV equipped with energy dispersive analyser IXRF 500. Using low vacuum mode allow us to observe the whole specimens. Influence of resin is negligible in this mode. Three basic modes of local electron microanalysis were used for determination of chemical composition of structural components.

Failure behaviour of alloy 141I in Charpy's test was studied with methods mentioned above. The following information about the relation between microstructure and failure processes were obtained:

1) The side-dilatation of specimen was found in the place of hammer's impact.
   The main fractographic features correspond to the fracture mechanisms – ductile separation along carbide skeleton. This process is dependent on number, size, and configuration of carbide particles in the structure of alloy.
2) Alloy 141I is a cast alloy, it consists of nickel-chromium matrix hardened by dendritic skeleton of primary chromium and niobium carbides. Secondary carbides have precipitated during annealing. The fracture line passed either through primary carbides or along heir boundaries with the matrix. Many secondary cracks in the carbides were found in a relatively big volume of material under the fracture surface.
3) Local electron microanalysis proved that most of particles on fracture surface are chromium carbides. It means that failure process in 141I alloy is realised by ductile separation, predominantly along chromium carbides.

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# Structural Characterization of Cations and Methyl Groups in Zeolites NaY, NaX and NaLSX with Powder Neutron Diffraction

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Cations and especially extra-framework cations play an important role in determining the adsorption, separation and catalytic properties of zeolites. The positive charge of the cations produces electric fields within the zeolite pores, which can strongly influence absorptive behavior and catalytic activity. The locations of the extra-framework cations in the dehydrated faujasite zeolites such as NaY, NaX and NaLSX have been determined by powder neutron diffraction. Sites I and I´ are located in the hexagonal prism and the sodalite cage, respectively, while the site II and the site III positions are in the supercage. The knowledge of the position and the occupancy of these cations after chemisorption processes are very important for understanding in controlling and catalytic properties. Therefore, the careful structural studies of these faujasite type of zeolites under as real as possible conditions (the sorption or catalytic environmets) are needed.

Chemical composition of investigated dehydrated zeolites NaX and NaY was $Na_{80.0}Ca_{1.2}[(AlO_2)_{82.4}(SiO_2)_{109.6}]$ and $Na_{48.9}Ca_{1.6}[(AlO_2)_{52.1}(SiO_2)_{139.9}]$, respectively. Sample of NaLSX was a sodium form of faujasite structure with ratio of Si/Al = 1. Chemisorbed methyl groups were prepared in the structure by chemical reaction of methyl iodide with reactive sodium cations available in SII and SIII positions of faujasites. Methyl cations $CH_3^+$, evolved in the reaction, react immediately with the lattice oxygen forming surface bonded methyl groups in bridging configuration. $^{13}C$ NMR signals of chemisorbed surface species and their linear dependence on the intermediate electronegativity of the zeolite lies in the interval from 53 ppm for most basic CsLSX to 58 ppm TMS for stabilized and acid leached sample of H,NaY, respectively.

Neutron powder diffraction patterns were collected at temperature of 298 and 7 K on the KSN-2 diffractometer, which is placed at the LVR-15 research reactor in Řež near Prague. This device - was equipped with close circuit liquid helium cryostat - type CP-62-ST/5 (Cryophysics SA). The wavelength of 0.1362 nm was used and the resolution $\delta d/d=0.00075$ was achieved (d is the interplanar spacing). The complete structural parameters were determined by Rietveld analysis of powder neutron diffraction data using the GSAS package. The crystal structure parameters of NaY, NaX and NaLSX zeolite with (and without) chemisorbed methyl cations (surface methyl groups) have been determined by powder neutron diffraction and by high resolution solid state $^{13}C$ MAS NMR. Our structural parameters for the initial dehydrated bare NaX sample are in agreement with results refined in the Fd3 space group by Olson [1]. Structural parameters of NaLSX were refined in both recently discussed

space groups [2], as in Fd3 space group as in Fddd (orthorhombic) group but without significant difference. Changes in the distribution of structural sodium cations in the lattice after chemisorption of methyl cations have been detected. Distancies of C-O in surface methoxy groups in empty cavities were found to be longer than in ordinary crystalline metalloorganic compounds with bridging methoxyls. The location of chemisorbed methyl groups at $O_1$ lattice oxygen type was found to be most probable for NaY [3]. Nuclear densities of chemisorbed methyl were detected in NaX at $O_1$ and at $O_4$ lattice oxygen.

Zeolite LSX (low silica X) has a Si/Al ratio of 1 and represents the highest number of charge-compensating cations among all faujasites. Cations are distributed over six possible sites as proposed by Olson [1] in the frame of Fd3 space group. The NMR results altogether confirm the results from diffraction methods. It is obvious that also our neutron diffraction results agree well (in the frame of experimental deviations and various composition of materials) with the observed cation distribution in all NaY, NaX and NaLSX samples.Our experimental data allow us to compare the changes in the occupation of positions of the lattice atoms in original evacuated NaX and in the same sample after chemisorption of methyl iodide. We observed serious changes in the distribution of the lattice elements after chemisorption of methylium ions [4]. These changes were observed not only in occupation factors but sometimes also in coordinates of $Na^+$ cations. Typical example was found for NaX in the cases without and with chemisorbed species where is demonstrated a splitting of the position SI' into two sites Na2 and Na3. These positions are separated at helium temperature but fused together at room temperature. On the other hand, cations in SII positions, are represented after chemisorption only with fully occupied Na4 site. Na4 (32e position) as well as Na5, Na6 and Na7 (96g position) take part in the reaction of $CH_3I$ preferentially due to their easy accessibility in large $\alpha$-cavities.

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# Neural Networks and Data Mining

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With a need to store large amounts of data, there is also a need to use the data not only for primary purpose. There is a group of methods called data mining, which can explore these large data stores and get some relevant information from it. One of these methods is a method based on using neural networks.

Data mining is a field situated at the border of statistics, artificial intelligence and database systems. There are many different definitions of data mining. One of them is the following: Data mining is analytic process used for exploration of large data stores to find and verify new information and relations in the data.

Data mining is oriented more to practical use than to finding basic rules of the exploration process. In other words, the result of data mining process is usually more important than knowing the way to reach it. Here are some typical tasks, which can be solved using data mining methods:

- Classification and valuation – for set of objects, we have defined values of both input and output variables. Our task is to analyze the relation between input variables and the output ones so that we can valuate the output variable for object, which's output variable is not known.
- Prediction – we have a set of values of one or more variables. Our task is to analyze relations between these variables and predict its future values.
- Segmentation – our task is to divide a set of input values into groups of values with similar properties.

There are many methods used for data mining. We can call them classical. The most common method is to use statistics, but decision trees or expert systems are usable too. In most cases, a combination of all these methods is the best way to reach the result.

Neural networks are one of available methods used to solve data mining problems. Neural networks have several properties that can be helpful for data mining. The most important property is the ability to predict values of specified variables, or to segment a set of input data.

There are five phases of data mining called SEMMA.

1. Sample, which means to get relevant samples of data that contains important information.
2. Explore, which means to find out important information and/or relations.
3. Modify, which means to remove all unsubstantial information.
4. Model, which means to prepare model of data to interpret them.
5. Assess, which means to assess the model using large amount of data.

The way to use neural network consists of three steps. First step is to find right neural network. Its size and architecture must correspond to size and type of the problem we are solving. Second step is to start learning process. During this process, neural network changes its internal parameters to describe training set of data. The result of this learning is neural network, which represents relations between data in training set. Of course, finding right set of training data is not easy, because this set must be representative for the rest of the data. Third step is to use this neural network. It can be used for two purposes:

- For preprocessing data. It means to use it in Explore and/or Modify phase of data mining. In Explore phase we can use for example Kohonen's neural network for doing segmentation, in Modify phase we can use neural network for finding main components, which can remove redundant or unsubstantial information.
- For building a model of data. The building of a model is done during the learning process and it is done automatically. The model is the network itself after finishing learning process. All the relations between data are coded into weights of synapses. The advantage of using neural networks here is their good ability to approximate nonlinear functions and dependencies.

So we can say that neural networks can be used as an analytic component of data mining system, because they can help with exploration of data and building model.

But, as we can read above, neural networks are replaceable by other methods. So there is a question why to use them and in which cases?

The main advantage of using neural networks is that we can use unified tool for many cases and types of problems. Normally, using classical methods, it would be necessary to develop specialized modules for each kind of problem. Using neural network, all we have to do is to start learning process with another set of training data without any need to change its structure.

Second advantage is that neural networks are theoretically able to approximate any nonlinear function, so we don't need to know any hypotheses about solved problem or about importance of input variables.

There are, of course, some disadvantages, which we have to think about. First, neural network behaves like a black box. It can solve a problem, but we are not able to look inside it and analyze, why the neural network behaves the way it behaves. In other words, we have to believe that the result is correct and we cannot answer the question why.

For getting relevant output, it is necessary to choose right architecture of network. Very often, we have to use try-fail method, especially when we want to use back propagation network. The decision about how many layers is necessary and how many neurons should be in each layer is not easy.

So, we can say, that using neural network in data mining process is helpful in all cases, when we don't need to know the way how to reach the result and all we need to know is the result itself.

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# Mechanical Properties of Plasma Sprayed Coatings at Low and High Deformations

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Ceramic or metal coatings deposited by plasma spraying consist of thin splats and porosity between 2 and 15 %. The structure is one of the main factors, controlling mechanical properties of the coating. Sprayed materials are known to be elastically anisotropic and having Young's modulus at small deformations much smaller than those of sintered materials [1]. The typical splat and porosity structure also results in nonlinear behavior when the coating is subjected to higher external loading.

In our research we focused on mechanical properties of plasma sprayed alumina ($Al_2O_3$) and cromia ($Cr_2O_3$) coatings on steel substrates. Coatings in thickness of ≈ 0.3 mm, 0.6 mm and 1.8 mm ($Al_2O_3$) and 0.6 mm ($Cr_2O_3$) were deposited by WSP® water-stabilized plasma spraying system at the Institute of Plasma Physics AS CR in Prague. This system is characterized by high spraying temperature (≈ 25 000°C) and high throughput (approx. 25 kg of powder per hour), which enables spraying of large-particle powders.

**Experimental**

Measurements of Young's modulus and stress-strain behavior of the coatings were carried out on Instron® testing machine with a special four point bending equipment. The displacement rate of outer supports was 0.0065 mm/s (inner supports of the equipment were non-movable), the maximum load was 900 N. Displacement, load and radius of specimen curvature were recorded during the test. Using linear elastic theory formulas the data acquired were recalculated on strain ($\varepsilon_{h/2}$) and stress ($\sigma_{h/2}$) in the center plane of the coating thus obtaining the stress-strain curve. The four point bending tests were performed in two modes with the coating placed:

- in tension and
- in compression,

to study in detail changes in the coating's stiffness.

**Results and Discussion**

Low deformations ($\varepsilon_{h/2} < 0.1$ %): Young's modulus of 0.3 mm thick $Al_2O_3$ coating was found to be 46 GPa at deformations both in tension and compression. In several cases the $Al_2O_3$ coating of 0.3 mm thickness exhibited Young's modulus of 46 GPa in tension and 57 GPa in compression. The increase of Young's modulus of thermally sprayed coatings loaded in compression has recently been mentioned by several authors [2, 3]. Measured values of coating's Young's modulus were characterized by a large scatter of experimental data when the coating was placed in tension.

$Cr_2O_3$ coatings sprayed on 4.0 mm thick substrates exhibited Young's modulus of 57 GPa, $Cr_2O_3$ coatings sprayed on 2.5 mm thick substrates exhibited Young's modulus of 41 GPa (both in tension and compression). Only non-significant difference (approx. 2 GPa) between Young's modulus in tension and compression was found for the $Cr_2O_3$ coatings.

High deformations ($\varepsilon_{h/2} > 0.1$ %): Nonlinear behavior of both $Al_2O_3$ and $Cr_2O_3$ coatings was observed at higher (up to ±0.35 %) deformations. The stress-strain curve of the coating at higher *tensile* deformations can be divided into three parts, which are characterized by different stress-strain relations. In the first part ($\varepsilon_{h/2} = 0$ % to $\varepsilon_{h/2} \approx 0.1$ %) the stiffness of the coating remains constant. The second part ($\varepsilon_{h/2} \approx 0.1$ % to $\approx 0.2$ %) is characterized by decrease in stiffness (both stress and deformation increase but the tangent Young's modulus decreases) until certain maximum stress is achieved. Loading above this stress results in increase of deformation whereas stress decreases (in some cases to zero value). This behavior is characteristic for the third part of the loading curve in tension. The shape of the unloading curve in tension depends on the maximum deformation achieved but in most cases unloading generates wide hysteresis loop due to changes in the structure of the coating.

In the case of *compressive* loading, the stress-strain curve remains linear until certain level of deformation. Beyond this level of deformation stress-strain curve becomes non-linear and stiffness of the coating increases. Unloading the sample generates hysteresis loop, which is in most cases narrower than hysteresis recorded in tension. Unlike unloading in tension, the curve returns to zero deformation, i.e. no deformation remains at zero load.

This nonlinear and non-elastic behavior was attributed to the existence of structural defects, such as imperfections in intersplat bonds (*intersplat thin voids*), i.e. defects approximately parallel to the spraying plane and microcracks in the splats (*intrasplat microcracks*), formed inside of the splats. These defects are believed to be generated by quenching and subsequent stress relaxation during the cool-down process [4]. In the case of *tensile* loading, intersplat thin voids are opening and the bonds between splats are fractured by shear forces, induced by bend loading. This is reflected as hysteresis in loading-unloading curve and it is also responsible for changes in stiffness of the coating during loading. In the case of *compressive* loading, intrasplat microcracks become gradually closed. This leads to increase in stiffness (i.e. Young's modulus) of the coating. Specific structural features of plasma sprayed coatings (intersplat thin voids and intrasplat microcracks) are thus possible explanation of nonlinear and non-elastic behavior during bending tests. For future research, microanalysis of polished cross-sections of the coating subjected to external loading is planned to precise the role of structural defects in stress-strain relations.

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# Wear Mechanisms of $Al_2O_3$ and $Cr_2O_3$ Coatings Deposited by Water-Stabilized Plasma Spraying

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Plasma sprayed $Al_2O_3$ and $Cr_2O_3$ coatings are known for their superior wear resistance [1]. A proper understanding of the wear mechanisms is essential to achieve the highest wear resistance. In our recent work, the influence of WSP® water-stabilized plasma torch on the wear properties of $Al_2O_3$ and $Cr_2O_3$ coatings was studied. The results of wear test were compared with wear test results of several metal coatings.

Surface layers of $Al_2O_3$ and $Cr_2O_3$ were sprayed by WSP® water-stabilized plasma system at the Institute of Plasma Physics AS CR. This plasma system is characterized by high throughput (approx. 25 kg of powder per hour) and high temperature of the plasma (≈ 25 000°C), which enables spraying of large-particle powders. Investigated $Al_2O_3$ and $Cr_2O_3$ coatings were sprayed using powders with particle size of –50+40 μm ($Al_2O_3$) and –90+45 ($Cr_2O_3$). Thickness of the $Al_2O_3$ coating was ≈ 0.3 mm, thickness of the $Cr_2O_3$ coating was ≈ 0.6 mm. Rectangular substrates in thickness of 2.5 and 4.0 mm were manufactured from mild carbon steel.

Two methods for determination of wear resistance of plasma sprayed coatings were combined: wear abrasion test according to ASTM G75-95 (slurry abrasion) and scratch test. In the wear test according to ASTM G75-95 standard the specimen is pressed against neoprene lap and periodically moved in a mixture of water and alumina powder. Constant load of 22.4 N was applied during the test. The test consists of four consecutive cycles. Between each cycle specimen weight and volume loss is calculated. After completing the test the average wear rate in $mm^3/m$ is calculated. The damaged surface of specimens was analyzed in scanning electron microscope (SEM) after each cycle and the wear mechanisms were identified.

Scratch tests were performed on the surface of the coating using a CSEM Revetest® test machine equipped with Rockwell-C diamond stylus of 200 μm-radius. The scratching was performed at the planar surface of the coating in increasing load mode. Surface of samples that had undergone scratch tests were analyzed in SEM both in backscattered (not requiring gold-platting) and secondary electrons.

Experimental results show that $Cr_2O_3$ coating has wear resistance superior to that of $Al_2O_3$ coating. Wear rate of $Cr_2O_3$ coating was found to be $0.55\ 10^{-2}$ $mm^3/m$ while wear rate of $Al_2O_3$ coating was found to be $1.24\ 10^{-2}$ $mm^3/m$. Comparative measurements with the same experimental setup carried out on samples coated with steel and nickel-based alloys proved excellent wear resistance of ceramic coatings (see tab. 1).

SEM observations of the surface morphology after each cycle of the wear test revealed that wear of both $Al_2O_3$ and $Cr_2O_3$ coatings was realized by *splat decohesion*, *interconnection of voids and pores* and *splat cracking* similarly as described in [2, 3].

Tab. 1 – Comparison of wear rates of different plasma sprayed coatings.

| **Coating** | $Cr_2O_3$ | $Al_2O_3$ | AISI 316L Steel | NiCr20 | Ni |
|---|---|---|---|---|---|
| **Wear Rate [$10^{-2}$ $mm^3$/m]** | 0.55 | 1.24 | 1.32 | 1.54 | 2.9 |

It was found that $Al_2O_3$ coating exhibited extensive splat cracking, which was enabled by internal columnar structure of the splats. $Cr_2O_3$ coating exhibited considerably less of the splat cracking, probably due to fine microstructure of the splats. The microstructure of $Cr_2O_3$ splats was randomly oriented with average unit dimensions of ≈ 5 μm.

Scratch morphology observations in SEM confirmed the results of SEM analysis of the damaged surfaces. Morphological features similar to those which were found on the damaged surface of both ceramic coatings were recognized and several new micromorphological features were identified. Based on the SEM analysis the main wear mechanisms such as *spallation* [4], *splat cracking* and *interconnection of voids* were recognized. The new morphologic features correspond to the scratch: *re-deposited debris* (originating probably from cracked splats) and *microcracks in the splats*, formed by high pressure and shear forces, induced by the sliding indenter. Detailed analysis of the scratch morphology on both ceramic coatings proved different microstructure of the $Al_2O_3$ and $Cr_2O_3$ splats as found by the SEM analysis after wear tests.

Analysis of SEM images of wear and scratch tests lead to the following conclusions:
the essential factor influencing the wear resistance of plasma sprayed coatings is not only the macroscopic splat structure of the coating but also internal microstructure of the splats.

In the case of $Cr_2O_3$ coating, fine and randomly-oriented microstructure of the splats lead to superior wear resistance compared to wear resistance of $Al_2O_3$ coating.

Slurry abrasion wear test was proved to be an effective method leading to successful determination of wear resistance of plasma sprayed coatings. The results of the SEM analysis of samples after both wear and scratch tests enabled to determine the major wear mechanisms of plasma sprayed ceramic coatings.

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# Three-Dimensional FEM Model of the Curved Front of the Growing Fatigue Crack

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Conditions of fatigue damage of material in the cyclic stress and strain field along the curved front of a through-thickness planar fatigue crack are theoretically studied. The final purpose of the project lies in the development of a method for theoretical prediction of the fatigue crack behaviour in thick-walled structural elements.

According to the simplest 3D generalization of the classical Paris concept, the local fatigue crack growth rate in direction perpendicular to the front should be controlled by the local value of the stress intensity factor range $\Delta K$. Unfortunately, experimental results show that the local crack front behaviour depends not only on the local $\Delta K$ but also on another factors, namely on the local level of constraint, which shall be characterized by some another parameters (e. g. the stress triaxiality) [1], [2]. To improve such multiparameter fracture mechanics concept, the authors try to perform the direct 3D elastic-plastic FEM simulations of the low cycle fatigue ahead of a moving crack front. Such modelling can help to solve some important problems: the prediction of the crack front shape and rate, the crack "memory" under variable amplitude loading, differences between the crack behaviour in the thick and thin wall, the creation and the role of the shear lips etc.

At first, the growing fatigue crack with the *straight crack front* in a thick CT specimen has been modelled [3]. The computations have shown that the low level of constraint at the free surface extends only to a very thin surface layer. Moreover, three-dimensional results for this layer surprisingly correspond neither to the plane strain nor to the plane stress. The surface plastic deformation is restrained both by nearby subsurface material and by intensive crack closing. Therefore low normal stresses are similar to the plane stress state, however, the plastic zones size in the crack plane together with the low plastic strain range correspond rather to the 2D-plane strain simulation. These results are contradictory to previous assumptions about the nature of the fatigue process in surface layers of material.

Now, the situation at the end part of *the real curved fatigue crack front* is studied [4]. Previous experiments performed on CCP specimens (aluminium alloy 2024 -T42, dimensions 58 x 6 x 180 mm) are modelled. The tensile loading is periodic with the different stress amplitude and the stress ratio for each specimen. The crack length always corresponds to the moment when shear lips start form on the surface. In all specimens, the shear lips rise at the same level of 2D stress intensity factor range: $\Delta K = 6.7$ Mpa $m^{1/2}$ . The shape of the crack front at this moment has been determined fractografically. The modelled crack path is of approximately 80 μm.

3D elastic-plastic model with small strain assumptions was created using the FEM software MSC.Marc. The size of the smallest elements around the crack front is only 2 x 2 x 2 μm. The model enables the detailed study of the crack front deformation mechanics including crack closing and opening. The corresponding 2D plane stress and plane strain simulations are also performed. The present results of computations can be briefly summarized as follows:

1) The length of the plasticity induced crack closure in the surface layer is high, which means that there is only a small effective part of the loading cycle in this area. This is in a good agreement with known experimental results.
2) The stress and plastic strain cycling ahead of the central part of the curved crack front is the same as the cycling under corresponding plane strain conditions.
3) The margin of the straight crack front, which intersects the surface perpendicularly is slower than the remaining part due to the local low stress and low plastic strain range. The marginal part of the straight crack front lags behind the middle. Therefore the real fatigue crack front is curved and it intersects the free surface at acute angle.
4) The material ahead of the marginal part of such curved crack front suffers relatively high local load which gives larger plastic zone and higher plastic strain range. Therefore, the end of crack front can move at the same rate as the middle. The stress and strain cycling in the crack plane ahead of the marginal part of the real curved fatigue crack front is qualitatively similar to that which takes place under 2D plane stress conditions. These results are very different from that obtained for the straight crack front and correspond with well known experimental data.
5) Even in case of the same rate along the whole front of the crack propagating in the tensile mode without shear lips, material ahead of the surface part of the front is loaded quite differently than material deep inside the wall.
6) In the middle of the wall, material is loaded by intensive triaxial tension-compression with the high level of normal stresses. However, the restrained plastic strain is small.
7) Ahead of the marginal part of the crack front, the tension in the loading direction is relatively small and accompanied by negative normal stress in the crack growth direction. The shear stress range in planes of possible shear lips is high. Very intensive cyclic plastic deformation includes also shear strain between planes perpendicular to the axes of coordinate system. The increment of the strain energy density during every loading cycle is very high. Under such conditions the tensile mode of the crack growth becomes unstable at a certain level of $\Delta K$ and shear lips start to develop on the surface. So far, there is no suitable local stress or strain criterion for this crack mode transition.
8) Energetic criterion for direct calculation of the local crack growth rate based on low-cycle fatigue predicts higher values than measured in the experiments. Therefore, it is possible that the critical strain energy density to fracture depends on local loading conditions.

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# Transmission Electron Microscopy Study of Microstructure of Low Alloyed Steel A508 close to the Zones of Ductile Tearing and Cleavage

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Although known for more than a century, the ductile-to-brittle transition (DBT) of ferritic steels with decreasing temperature remains a fundamental issue in engineering, metallurgy and material science. Reactor pressure vessel steels show this transition in fracture toughness with temperature and their resistance to brittle fracture plays an important role in the safety assessments of nuclear power plants. High toughness of the material is obtained by thermal treatment leading to a bainitic microstructure. Above the DBT temperature the bainitic steels are characterized by a ductile dimple fracture accompanied by high energy (upper shelf energy – USE) absorption. Below the DBT temperature, the fracture mechanism is transgranular cleavage and only little energy (lower shelf energy – LSE) is absorbed. When the specimens are tested in the ductile-to-brittle transition region, cleavage crack initiation is frequently preceded by ductile crack growth and the energy to fracture lies between LSE and USE values. Since brittle fracture can lead to a catastrophic failure of the structure components, the fracture behaviour of bainitic steels has been extensively studied [1-3].

Material used in this study was the French tempered bainitic pressure vessel steel 16MND5 (equivalent to the American standard A508 Class 3). After forging, the steel was subjected to two austenitisations for 4h40 at 865-895°C, water quenching followed by a recovery annealing for 7h30 at 630-645°C and a stress relief annealing for 8h at 610°C. The samples, CT25 specimens for fracture toughness tests, were taken at 3/4 thickness of the forging. The normal to the crack plane was T, the crack propagated in the S direction of the forging. The ductile-to-brittle transition temperature in the T-S orientation, as evaluated from Charpy tests, is –20 ºC, other mechanical properties are described in detail in [4]. After fracturing of CT25 specimens in quasistatic loading (crosshead speed 0.5 mm/min) at the temperature 0°C, the fracture surface was nickel electroplated to 1.5 mm thickness. In the central part of the CT25 sample, slices were cut in the T-S plane sample using slow-speed diamond saw. In the next step, standard TEM discs 3 mm in diameter were taken from the bulk material (not affected by the crack formation) and at the nickel-steel interface in the zones of ductile tearing and cleavage fracture. Thin foils from the bulk material were electrolytically polished using the Struers TENUPOL 2 apparatus filled with the solution of 6% perchloric acid in methanol (T = – 40°C, U = 30 V), TEM samples of the interface cross-section were prepared by dimpling and ion thinning on Gatan PIPS 691 or Technoorg LINDA IV3/F/L facilities. A JEOL JEM 2000FX electron microscope operated at 200 kV was used for the observations.

Microstructure of the steel is developed by the bainitic transformation. The main microstructural units are laths, packets of laths and upper bainite carbide colonies. Sometimes

it was possible to find out triple-junction points indicating primary austenitic grains. The size of primary austenitic grains was estimated to 30~40 μm. From TEM observations it follows that the lath width ranges from 0.5 to 2 μm, the width of lath packets extends up to 8 μm. The laths in packets show only a small crystallographic misorientation. The lath boundaries, often formed by dislocation walls, can be taken as low-angle subgrain boundaries. The density of dislocations inside the laths is relatively low, the dislocations are often arranged in regular networks, typical for a recovered material. Fine carbides were found on dislocations in the interior of some laths, some isolated coarse particles were situated on the lath boundaries.

The microstructure in the zone of ductile tearing was very inhomogeneous. The dislocation density was apparently higher than in the bulk (non-deformed) material. The dislocations were mostly arranged in tangles, only in some cases a well developed cell structure was found. Some isolated twins were found close to the fracture surface. The microstructure was very inhomogeneous also along the fracture surface. In most cases the material in the nearest neigbourhood of the fracture surface was heavily deformed, showing very fine (~200 nm) equiaxed subgrains. No twins, shear bands or dislocation cells were observed in these areas. In several cases, the plastic deformation was localized into two shear bands intersecting at a low angle at the fracture surface. In the vicinity of these shear bands, a well developed dislocation cell structure was found.

A predominant feature in the microstructure of the steel in the zone of cleavage was twinning. The twins occurred in a layer about 200 μm in depth under the fracture surface and not in deeper parts of the material. The dislocation density was mostly low. In some areas near the fracture surface, the twins were nearly uniformly distributed, having different orientations and showing numerous intersections. Being often very thin, they can be designed as micro- or even nano-twins, because their width did not attain more than 300 nm. The majority of twins was much narrower – about 50 nm. Many of the twins nucleated at grain or subgrain boundaries and propagated through the subgrains (laths). The twins ending inside the laths had often faceted boundaries. Sometimes the twins nucleated and ended inside the laths. There was no apparent interaction of twin tips with dislocation tangles.

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# Comparison of DC-Cast and Twin-Roll Cast Sheets of AlMg3 and AlMg4.5Mn0.4 Alloys

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Aluminium sheets are produced either by conventional direct-chill (DC) casting and hot rolling method or by a continuous twin-roll casting (TRC) technology. Twin-roll casting offers high productivity, larger coils, low investment costs, and energy and materials savings. The TRC method is well established for producing aluminium foil, heat exchanger fins and several grades of building and construction sheet. A primary goal in today's automotive industry is weight reduction resulting in fuel economy improvement and emission reductions. Aluminium alloys, having one-third density of steel and a superior strength-to-weight ratio could provide up to 50 % weight reductions when used in automotive sheet applications. However, to perform the same function, Al alloy sheets produced by conventional DC casting and hot rolling route cost usually four or five times more than steel sheet. Therefore, production of low-cost/high-quality Al-Mg (AA5xxx) sheets by twin-roll casting can help to increase the employment of wrought aluminium alloys in automotive applications. The first results of research and development efforts have shown that the mechanical properties, formability and corrosion resistance of Al-Mg twin-roll cast alloys are equivalent or superior when compared with DC cast and hot-rolled materials [1,2].

Twin-roll cast strips of AlMg3 and AlMg4.5Mn0.4 alloys 6.2 and 5.7 mm in thickness, respectively, were cast at 1400-1700 mm width on FATA Hunter *Speed Casters*® by Assan Aluminium Works, Tuzla, Istanbul, Turkey. Equivalent DC-cast and hot rolled plates of 9 mm thickness were supplied by Aluminium Works Al Invest, Břidličná, Czech Republic. The chemical composition of the experimental materials is in this table:

| Alloy | | Si | Fe | Cu | Mn | Mg | Cr | Al |
|---|---|---|---|---|---|---|---|---|
| AlMg3 (AA5754) | TRC | 0.172 | 0.294 | 0.038 | 0.258 | 2.770 | 0.066 | 96.170 |
| | DC | 0.160 | 0.230 | 0.041 | 0.280 | 2.889 | 0.017 | 96.440 |
| AlMg4.5Mn0.4 | TRC | 0.184 | 0.289 | 0.046 | 0.331 | 4.096 | 0.169 | 94.750 |
| (AA5182) | DC | 0.160 | 0.270 | 0.091 | 0.460 | 4.300 | 0.015 | 94.610 |

The downstream processing was carried out in laboratory conditions in Research Institute of Metals, Panenské Břežany. In order to obtain approximately the same starting condition as this of the TRC alloys, the DC cast materials were first hot-rolled (starting temperature 490°C) to 5.5 mm thickness. All materials were then cold rolled to 3 mm (reduction 35-39 %) and subjected to homogenisation annealing for 4 h at 450 °C. After cold rolling with reduction 70-72 % to 1 mm thickness the sheets were annealed for 4 h at 350 °C to obtain sheets in the soft

(O) temper. Both heat treatments were performed in a furnace with atmosphere circulation and controlled slow heating and cooling in order to simulate industrial conditions of annealing in large coils.

The as-cast TRC samples contain different intermetallic phases in the form of eutectic colonies or individual particles. A characteristic feature of twin-roll cast alloys is the formation of centerline segregation channels (CLSC), situated approximately in strip mid-thickness [3,4]. These channels are fragmented (discontinuous) and the fragments have different length and width. The mean length and thickness of the fragments in the studied alloys are about 900 μm and 130 μm, respectively. The CLSC take the form of large clusters of fine intermetallic particles surrounded by aluminium matrix. Besides the fine particles the channels often contain coarse compact particles of different appearance. Surface segregation, individual coarse particles or elongated clusters of coarse eutectics, were observed in a surface layer of 20 to 30 μm in thickness at both strip surfaces. Outside the segregation patterns, the primary second-phase particles form small eutectic clusters. The microstructure heterogeneities observed in as-cast strips are not eliminated by consecutive downstream procedures such as homogenisation and cold rolling. Appropriate tuning of the casting conditions of TRC strips should be carried out in order to eliminate coarse segregation patterns.

The size and distribution of intermetallic particles in DC-cast and hot-rolled materials significantly differ from these of TRC strips. The particles in both DC-cast materials are coarser that in TRC strips and they are aligned in rows along the rolling direction. The particles in the sheets become finer during the downstream processing, regardless the casting technology used. Nevertheless, at the final gauge thickness of 1 mm, the particles in the DC-cast materials are still coarser than those in TRC strips.

The results of tensile tests show that the twin-roll cast alloys compare well with their DC-cast counterparts. The somewhat higher yield stress and tensile strength of the DC-cast materials are probably due to the higher solute content in these alloys (Table). The anisotropy of the yield stress and tensile strength is not pronounced, the elongation values of all alloys are very similar.

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# Fatigue Damage of Hot Rolled and Hot Extruded Ordered Alloys Based on Fe-28Al-4Cr (at%)

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Iron aluminides - $Fe_3Al$ and FeAl - are investigated as new high-temperature structural materials because of their low cost, low density (approx. 6.7 $gcm^{-3}$) good wear resistance, ease of fabrication and resistance to oxidation and corrosion. These alloys offer also the potential for reducing the use of Ni and Cr indispensable in common high temperature steels or nickel superalloys. Iron aluminide based alloys are expected to be used in the coal gassification plants or furnaces for burning garbages, in the chemical industry, automotive industry and other applications [1].

Fracture and mechanical properties of vacuum cast and hot extruded or hot rolled Fe-28Al-4Cr (at.%) alloys with cerium addition were studied as a function of heat treatment, testing temperature and strain rate [2, 3]. This paper reports an introductory study of fatigue behaviour of two Fe-28Al-4Cr (at.%) based alloys. The chemical composition of the alloys is given in the following table:

| Alloy | | Al | Cr | Ce | C | Mn | Si | Fe |
|---|---|---|---|---|---|---|---|---|
| hot rolled plate | at.% | 28.4 | 2.6 | 0.02 | 0.12 | 0.40 | - | balance |
| | wt.% | 16.1 | 2.8 | 0.06 | 0.03 | 0.46 | - | balance |
| hot extruded tube | at.% | 28.9 | 3.6 | 0.08 | 0.16 | 0.20 | 0.07 | balance |
| | wt.% | 16.5 | 3.9 | 0.23 | 0.04 | 0.23 | 0.04 | balance |

The fatigue crack growth experiments were performed on single edge notched (SEN) and compact tension (CT) specimens. Both type of specimens were 5 mm thick. The SEN specimens from the hot rolled plate were 110 mm long and 33 mm wide, the longer dimension was oriented in the direction of hot rolling. The specimens machined from the extruded tube were 75 mm long and 13 mm wide, with the longer dimension in the direction of extrusion. The CT specimens machined from the hot rolled plate were 33 mm wide and 32 mm high. In the CT specimens, the fatigue crack propagated in the perpendicular direction to the direction of rolling, similarly as in the case of SEN specimens.

The specimens were loaded in tension at room temperature on a computer controlled servohydraulic loading machine INOVA ZUZ 50. The frequency of loading was 10 Hz, the stress ratio parameter R was in the range from 0.05 to 0.1.

The test area of specimens was polished and the crack length was measured during the fatigue test as a function of elapsed cycles by means of direct visual technique by means of a low

power travelling microscope. However, the measurement of the fatigue crack growth rate by the optical method was difficult to perform, because the crack propagates in a discontinuous manner and often the surface measurement is not representative for the bulk crack front advance. Some fatigue damage was found also ahead of the crack tip. To overcome these difficulties, the crack growth rate was measured also by the potential method at alternative current with the frequency of 4Hz, using TECHLAB SRT-2K device, controlled by Fatigue Crack Growth Monitor software.

First measurements of the fatigue crack growth rate as a function of the stress intensity factor show that thermal treatment of the alloys in order to form Cr-Fe-C precipitate different in size [4] does not influence crack growth rate in an important manner.

It was found that the micromorphology of fracture depends on the amplitude of loading. Owing to a very similar character in the micromorphology of fatigue and static fracture surfaces, it is very difficult to recognize the boundary between fatigue crack and final rupture. The fatigue fracture surface shows a very interesting micromorphology. Besides striations, known from some common alloys, another micromorphological features were found. However, an unambiguous interpretation of these features in the relation with crack growth rate is not clear and so it is necessary to continue the study of fatigue damage micromechanisms in this type of material.

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# Tribological Properties of Wear Resistant Coatings

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Over the past decade, considerable attention has been paid to the development of physical vapour deposition (PVD) processes and their ability to deposit hard coatings over a large range of compositions. Modern PVD techniques, such as magnetron sputtering and arc ion plating, allow various coating compositions on various substrates with strong adhesion to be obtained, with the potential for wider applications. A considerable number of investigations have been performed on the tribological behaviour of these hard coatings. However, there is still a need to understand in more detail the wear mechanisms occuring hard coatings. The wear of coatings depends on many variables, such as the substrate hardness, coating thickness, applied load, sliding speed, counter-material and, especially, temperature. Understanding the correlation between the wear performance and these variables will help to optimize the coating and to select the appropriate combination of coating and substrate materials for a particular application.

The purpose of this study is to investigate the tribological behaviour of coated high speed steel samples. The coatings TiCN, CrN were tested on a ball-on-disk tribometer at temperatures ranging from room temperature to 500 $^{o}$C. Our high temperature tribometer made by CSM Instruments allows to measure tribological parameters at temperatures up to 800 $^{o}$C. The following information can be deduced from the ball-on-disc experiments:

- friction coefficient, which is measured and recorded continuously
- wear of coating: measurements of the width of the wear track using scanning electron microscopy (SEM), profile measured by standard profilometer and optical observations give valuable information of the wear process
- wear of ball: measurements of the wear rate of the ball

Coating thickness was measured by Kalotest method (CSM Instruments), X-ray diffraction was used to obtain information about structure an stresses in coatings.

At first, uncoated high speed steel samples were tested on the ball-on-disc equipment. Two kinds of test were performed in order to study the role of the normal load (the normal load ranged from 5 to 15 N, tests were made at room temperature) and the temperature (samples were tested with a normal load of 15 N at temperatures in the range 20 – 200 $^{o}$C using the steel ball and 20 – 500 $^{o}$C using the ceramic one). We have recognized friction coefficient is not dependent on normal load in our range and very slightly on temperature for ceramic ball. At room temperature friction coefficient of uncoated substrate against Cr6 ball is 1.1, against $Si_3N_4$ ball is 0.85.

Obtained results at the room temperature have showed friction coefficient is independent of normal load (in range 5 – 15 N), in contrast to wear rate, which increases with normal load. Friction coefficient of TiCN against Cr6 ball was 0.24, against $Si_3N_4$ was 0.22. The beginning of failure at some locations increases the friction coefficient and wear rate, because hard and sharp steel debris increases abrasive wear.

We have carried out experiments with two counter-materials at elevated temperature: steel ball (material Cr6) and ceramic ball ($Si_3N_4$). It is not very useful to measure with steel ball at temperatures higher than 200 $^oC$, because the hardness of steel balls drops rapidly (hardness at room temperature is 62 HRC) at high temperatures and wear rate of ball is much higher than the wear rate of the coating. Advantage of ceramic balls is constant hardness independent of temperature in our scales. Therefore, wear rate of ceramic balls decreases with increasing temperature and at temperatures higher than 300$^oC$ is negligible. Tests at elevated temperatures were provided under these conditions: air humidity 33%, linear speed 4 cm/s, normal load 15 N, 5000 cycles.

Experiments have shown that the wear resistance of TiCN and CrN coatings decreases with increasing load. The influence of the temperature on the friction coefficient reveals that the formation of thin oxide films at the surface of the samples above 300 $^oC$ reduces the friction coefficient.

Future experiments will investigate the tribological behaviour of these coatings under different conditions, such as humidity of air and higher load. Also oxidation of coating under load at elevated temperatures will be evaluated thanks to testing in nitrogen atmosphere. Final step will be the comparison of tribological behaviour of different hard coatings.

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# Abrasive Wear Resistance of Hard Coatings

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The most prominent applications of hard coatings to lower the wear are the cutting tools, but they are also used in various branches of industry in order to improve lifetime of machine parts. Often used coatings are TiN, TiC, TiCN, (Ti,Al)N, ZrN, CrN, CoCrN, WC and other. All these coatings are hard ones and in their wear applications the main process of strain is sliding against steel. There is a variation in the contact mechanism and the wear process in sliding contacts between hard coatings and steel depending on contact parameters such as geometry, speed, load, roughness etc. There is, however, still no general agreement about the classification of wear mechanisms and modes, but we can diversify four basic wear mechanisms – adhesive, abrasive, fatigue and chemical wear.

- Adhesive wear occurs, when asperities of one surface come into contact with asperities of the counterface they may adhere strongly to each other and form asperity junctions. Relative tangential motion of the surfaces causes separation in the bulk of the softer asperities and material is removed. In adhesive wear the surface material properties, as well as possible protecting surface films or contaminants, play important roles.
- Fatigue wear is a lifetime limiting failure mechanism in ball and roller bearings and in gear contacts. In these concentrated contacts the Hertzian pressure at the surface creates a stress field beneath the contact zone. The maximum shear stress occurs about one third of the contact length beneath the surface in the case of pure rolling and moves to the surface with increasing traction.
- In chemical wear is process dominated by detrimental chemical reactions in the contact, iniated by the influence of the environment and strongly dependent on mechanical contact mechanism.
- Abrasive wear occurs in contacts where one of the surfaces is considerably harder than the other or where hard particles are introduced into the contact. The harder surface asperities are pressed into the softer surface which results in plastic flow of the softer material around the hard one. When the harder surface moves tangentially, ploughing and removal of softer material takes place with grooves or scratches in the surface resulting.

In case of sliding contact between hard coating and softer counter-material is dominant abrasive wear mechanism, if the wear proces run at room temperature and in non-reactive environment such as acid, vapour, etc. It is very difficult to describe wear, because of the complexity of the process, which depends on material, contact conditions and environmental parametrs in a number of different combinations.

However, it is possible to identify four regimes in the wear process that are typical of wide range of contact conditions. The mechanism of wear is different in each regime. These four regimes are:

Initial wear is present in the first few contact events between two surfaces that have not previously been in contact. Very small wear fragments are produced in the collisions between steel and hard coating asperities.

In the regime of the layer formation a more stable surface layer with agglomerated material is built up mainly on the steel surface. Friction heating in the contact results in oxidation of the layer and surfaces. Larger material segments may roll or be dragged between the surfaces and cause abrasive wear.

Steady state wear represents the regime where a stable layer or thin film has been produced on the steel surface and some wear products may also be present on the coating surface as well. Both the wear and the coefficient of friction have decreased to lower but stable values. The explanation for the lower friction is probably that the thin oxidized surface layer inhibits direct adhesion between steel and coating and the ploughing effects are minor because of the absence of large wear particles and the smoothened surfaces. Dominating wear mechanisms are typically oxidative and delamination wear but the wear rate is low.

Layer destruction and fracture in the thin coating layer occurs producing larger wear particles that cause abrasive wear – chipping is common. The thin protective oxide layers are destroyed and direct contacts between steel and substrate occur resulting in increased friction and wear.

Our study have been focused on testing of hard wear resistant coating TiCN and CrN, prepared by physical vapour deposition methods. We have tested these coatings on high temperature tribometer measuring continuously friction coefficient. Wear rate of the coatings and ball was evaluated from optical, SEM and wear track profile measurement. All four wear regimes mentioned above were identified. Initial wear is very short process occuring during the first cycles. Formation of layer (regime layer formation) was of considerable long duration, in case of TiCN 700 cycles and 850 cycles for CrN.

Experiments have shown that lower abrasive wear resistance has TiCN coating, which is explained as a result of oxidation of the surface under load. It is very important assignment that after the first fracture of the coating follows rapid destruction of the coating, because of appearance of steel wear debris, which significantly increases abrasive wear.

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# Residual and Applied Stress Distributions in Thermally Sprayed Coatings

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Thermally sprayed coatings are useful for protecting surface of components against heat, wear, corrosion or other influences. One of the important attribute of component's lifetime is resistance against fatigue. Therefore, the detailed stress distribution in substrate and coating has to be known. Many authors have measured stress distributions in coatings experimentally (e.g. [1]). In the present work, residual and applied stresses in a ceramic coating deposited onto steel substrate have been theoretically predicted by numerical finite element method.

In thermal spray processes, residual stresses mainly arise from two different sources: (i) shrinkage of the spray particles after solidification - primary (quenching or deposition) stresses, (ii) differences between the coating ($\alpha_c$) and substrate ($\alpha$) thermal expansion coefficients - secondary (or differential thermal contraction) stresses. At present, only secondary residual stresses, which usually dominate in the coatings, are considered in following computations.

To be able to determine stresses, mechanical properties of coatings should be known. Elastic stiffness constants of thermally sprayed, especially ceramic coatings measured at small stresses are substantially lower than those of well sintered materials, due to the presence of microcracks [2]. However, under higher compressive or tensile stresses the behaviour of coatings is strongly nonlinear, due to the effective elastic decrease or inelastic increase of the microcrack densities. Moreover, elastic constants are different in the direction parallel and perpendicular to the spraying plane. In all computations, nonlinear stress – strain relationship proposed in [3] have been used: $\sigma = E_1 (e - K e^2)$, where $-0.5\times10^{-2} < e < 1/K$ and $E_1$ is Young's modulus for small stresses. The value of the dimensionless material constant $K$ in the region $200 < K < 600$ for sprayed ceramics can be expected. The value of $K$ can be expected in some cases to be different for elastic compression, $K = K_C$, $-0.5\times10^{-2} < e < 0$, and for inelastic tension, $K = K_T$, $0 < e < 1/K$. The limit value for compressive deformations, $-0.5\times10^{-2}$, was chosen rather arbitrarily as it depends on the material. For higher compressive deformations, most microcracks become closed and a linear elastic behaviour follows.

In [3], pure bending due to initial deformation in the coating and due to external moment was studied. To obtain stresses, standard equations of theory of elasticity were used. The conditions of equilibrium of forces and moments over the cross-section led into a system of two nonlinear algebraic equations for the two unknown constants, which was solved numerically.

Numerical verification has been performed by means of finite element package MSC.Marc. Standard four point bending test have been modelled as a plane stress problem. Four-node, isoparametric, quadrilateral elements with a modified interpolation scheme, which improves the bending characteristics (MSC.Marc "assumed strain element"), were used. Nonlinear elastic material bahaviour were entered through the standard user routine HYPELA. Model parameters was chosen as follows: $E_1 = 50$ GPa as a typical value for a ceramic coating (e.g. $Al_2O_3$), two values of the coating thickness $h = 2.5$ mm and $h = 0.5$ mm are chosen as typical values of thick and thin coatings on 5 mm thick steel substrate. The values of the material constant $K$ (taken the same under compression and tension, i.e., $K_C = K_T = K$),

characterizing the nonlinearity of the stress-strain relation, are chosen as $K = 0$ (linear coating), 200, 300 and 400. The stresses have been calculated for different combinations of initial deformations (0.002 and 0.004) and of loading forces per unit width (~ 0 – 25 N/mm).

Both numerical approaches gave the same resulting stress distributions. In the case of bending under initial or external deformations, the nonlinear solution ($K > 0$) gives higher values of compressive stresses and lower values of tensile stresses than the linear solution ($K = 0$). In the nonlinear case, the combination of the nonlinear terms due to initial and external deformations is also nonlinear. Therefore, the calculated or measured dependence of external stress on external deformation or of Young's moduli on external deformation (or external stress) in specimens with residual stresses also depends on initial deformation (or residual stress). It is in contrast to the linear case where the effects of residual and external stresses are independent. The nonlinear treatment can improve the evaluation of measurements of residual stresses in coatings on substrates from residual bending. The nonlinear treatment is also important for determination of Young's moduli in the coatings on substrates from the bending experiments under external loading [4], by taking into account their dependence on external stresses and the effects of residual stresses.

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# Properties of Erbium in APE Er:LiNbO3 Waveguides

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Optical amplifiers and lasers based on rare earth dopants are important integrated optical devices with large application potential [1]. In recent years $LiNbO_3$ has emerged as one of the main host materials due to its very favorable electrooptical, acustoptical and non-linear properties. Among the rare earth ions $Er^{3+}$ plays a prominent role due to its optical transition around 1.5 μm which makes it of choice for optical communication applications. Despite the well shielded character of the 4f electrons the optical transitions are influenced within a crystal by the presence of the other ions. Most notably the degeneracy of the states is removed leading in $LiNbO_3$ to a splitting in (2J+1)/2 Stark sublevels. These splittings and the separation between states is determined by details of the local environment. It was found on bulk material that several different environments ("sites") are present in $LiNbO_3$, which are distinct by the way the required charge compensation is achieved. An earlier systematic study [2] under application of external perturbations established an intuitive tool to connect spectral shifts in the optical transitions to changes in the nearest neighborhood and long range intrinsic electric fields and to distinguish between these two interaction types. The results on waveguides produced by Ti-diffusion show that the $Ti^{4+}$ ion strongly influence the local electric field experienced by the $Er^{3+}$ while leaving the direct neighbor unchanged. The influence is manifested in the optical spectra by a significant inhomogeous broadening. The proton exchange (PE) waveguides is one of the methods for fabricating optical waveguides [3]. PE is based on a reaction of the lithium niobate wafer with a suitable acidic source which results in a large increase of the extraordinary refractive index. The PE waveguides have high loss and degraded electro-optic properties. However, they can be substantially improved by the annealing of the waveguides. Properties of the resulting annealed proton exchange (APE) waveguides strongly depend on the exchange conditions as well as on the subsequent annealing conditions. One of the main advantages of APE waveguides is that they guide only TM polarization or TE polarization in the Z-cut or in the X-cut of the $LiNbO_3$, respectively.

The samples of $LiNbO_3$ used were grown from the congruent melt to which the $Er^{3+}$ was added. The planar waveguides were fabricated by annealed proton exchange process in adipic acid. For comparison we used $LiNbO_3$ channel waveguides produced by Ti-diffusion. The $Er^{3+}$ doping levels in these samples were comparable to those of the bulk doped samples but the $Er^{3+}$ incorporation was achieved by indiffusion from Er metal layer evaporated on the surface of the samples. In order to study the lattice location of $Er^{3+}$ we used the RBS (Rutherford Backscattering Spectrometry), which was performed in the Forschungzentrum Rossendorf, Dresden (Germany) using Van de Graaff accelerator. The beam of alpha particles 1.8~MeV was used. Combined excitation-emission spectroscopy (CEES) is a very powerful

tool to investigate subtle changes in the optical transitions to investigate the local energetical environment of erbium. The CEES measurements were performed in the Lehigh University, Dept.Physics, PA, USA. RBS: In the structure of $LiNbO_3$ four different lattice sites are available to be occupied by foreign ions: two substitutional octahedral sites ($Li^+$ and $Nb^{5+}$), an additional free octahedron and a tetrahedral vacancy sites. The scan along the z axis is useful to disregard any position out from the z axis. The signal from $Nb^{5+}$ ions is practically identical to that of $Er^{3+}$ ions and so it can be concluded that they are located in three possible positions along the z axis i.e. $Nb^{5+}$ site, $Li^+$ site or structural octahedral site. For precise determination of $Er^{3+}$ position inside the $Li^+$ octahedron we studied the scan along y and x axis. In the case of the octahedral position we should see the maximum in the scan along x axis, but it is not our case. Finally, on the basis of computer simulations of the RBS data we can conclude that the $Er^{3+}$ ion sites on the $Li^+$ site and is shifted in the direction along -z axis, similar as has been found for bulk material [4]. Excitation-Emission Spectroscopy: Inspecting the CEES data of the emission at around 550 nm obtained in the APE waveguides under excitation at around 450 nm and comparing it to bulk material and Ti:diffused waveguides reveals that the major sites are essentially unchanged. Subtle differences are found when individual emission spectra under identical excitation energies are compared for APE waveguide, the bulk and in the Ti-diffused waveguide. Comparing first the APE waveguide and the bulk area we find a small tendency to the more perturbed sites, in which the secondary charge compensation or other perturbations are closer. Quite apparent is the absence of inhomogenous broadening (found in Ti-diffused waveguides) in the APE waveguides. Although a quantitative interpretation of the difference between the perturbation induced by Ti and H require a more profound knowledge of the underlying defect configurations, a qualitative explanation is quite apparent. Both defects exchange for the $Li^+$ ion or occupy in congruent $LiNbO_3$ crystals the abundant Li-vacancies. While $H^+$ requires on this site no charge compensation, the $Ti^{4+}$ ion is quite "out of place" in terms of its charge and requires a complex compensation. This will result in changes in the electric field, which then are experienced by the $Er^{3+}$. These changes will increase as the Ti concentration increases and will hence lead to the observed inhomogenous linewidth. This phenomena is completely absent for $H^+$. The absence of any special new sites indicates that the $H^+$ ions - despite its charge neutrality - still seems to avoid the vicinity of the $Er^{3+}$ ion. They only slightly perturb the more distant environment as indicated by the reduction of unperturbed sites. In summary, it appears that the APE treatment leaves the environment of the Er ion almost unperturbed such that almost no waveguide specific properties could be observed.

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# Residual Stresses in Oxide Layers and Corrosion Kinetics of Zr-based Alloys

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The results of X-ray diffraction analysis of macroscopic stresses in oxide layers and substrate of zirconium alloys are presented in this contribution. Stresses were studied on the tubular specimens of two types of alloys: low tin Zircaloy-4 (Zry-4 W) and standard Zircaloy-4 (Zry-4S) which were simultaneously exposed for various time in water with 43 ppm $O_2$ at 360 °C. Microstructure characteristics (crystallite size and lattice strains) were evaluated for oxide layers and the metal underlying. The relation between the stress development in oxide layers and kinetics of the alloys investigated was outlined.

The „sum of the surface principal stresses“ technique with a reference substance was used with regard to the specific experimental conditions, especially to the marked texture of oxide layers and the shape of specimens. The same method was applied to determine the stresses in substrates near the oxide-metal interface. The evaluation of the crystallite size and lattice strains was performed by using „single-line“ method with the Pearson VII approximation of the profiles´ shape.

A $\theta/2\theta$-goniometer SIEMENS with Cr radiation was used to measure lattice strains. X-ray measurements were performed on 15 mm long tubular specimens with a outer diameter ca 9-10 mm. Specimens were embedded in the special holder with a 2 mm wide slit to keep optimal conditions same for the measurements performed. Four partially overlapping diffraction lines were recorded into the $2\theta$ range of measurement: (10-4) of $ZrO_2$ and (112), (201), (004) of $\alpha$-Zr; thus, the fitting procedure had to be used to obtain the accurate peak positions.

The high compressive stresses (up to –1,1 GPa) were found in zirconia layers after oxidation, especially in the range of small (up to ~4 μm) oxide thickness. With further increase of the layer thickness stresses decrease for both the alloys studied. The tensile stresses up to 250 MPa were determined in metal underlying for all investigated specimens.

The size D of crystallites in oxide amount to values from 9 nm to 20 nm. The crystallite size D values in metal are considerably higher (from 30 nm to 100 nm) than those of oxide and increase with oxide thickness. The observed values of strain $\varepsilon$ in oxide are between 0,005 and 0,008.On the other hand the strain values in metal are considerably lower (0,002 against 0,006 in oxide).

All the given results are in a good agreement with the habitual conception about mechanical behaviour of the oxide/metal system as a whole. Both the small crystallite size D and large strains $\varepsilon$ in oxide compared with those in metal demonstrate the higher level of plastic deformation of oxide layers due to P.-B. ratio. For metal underlying effect of plastic deformation can be neglected. The similar results have already been obtained on other Zr-based alloys and oxidation environments [1].

It is difficult to make general conclusions about the relation between quantities determined by using XRD and the oxidation kinetic of different alloys, especially for posttransition oxidation. Partially it can be due to the specific property of method used when

all the quantities within the effective X-ray penetration depths are averaged. However the quantities under investigation are usually variable in the layer thickness and effect of "screening" can occur, especially in the case of thick oxide layers.

Let us define a new quantity $\mathbf{R = \sigma/t}$, where $\sigma$ is the experimental value of stresses and **t** – oxidation time for appropriate experimental oxide thickness Tox.

The relation of this quantity and Tox obeys the simple power law $\mathbf{R = A\ Tox^{-m}}$ for set of experimental points in the pre-transition oxidation period.

Using constants **A** and **m** calculated from the experimental values $R_i$ we can recalculate the oxide thickness for all the values of corrosion expozition.

The experimental values Tox declared as first points after transition for both the alloys actually occurs deviation from the courses calculated. It worth noticing that result can be influenced by the accuracy of the both independently determined basic quantities, i.e. $\sigma$ and Tox.

This result enables to make conclusion about the close relation between stress development in oxide layers and kinetics of alloys investigated.

- Only compressive stresses (up to 1,1 GPa)were determined in the oxide layers of samples investigated.
- Only tensile stresses (up to 250 MPa) were determined in metal underlying for all the specimens investigated.
- All the given results are in a good agreement with the habitual conception about mechanical behaviour of the oxide/metal system as a whole. Both the small crystallite size D and large strains $\varepsilon$ in oxide compared with those in metal demonstrate the higher level of plastic deformation of oxide layers.
- The relation between the stress development in oxide layers and kinetics of the alloys investigated was outlined.

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# Local Directions of Fatigue Crack Propagation in Microvolume of Aluminium Alloy 7010

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The macroscopic fatigue crack growth rate $v = da/dN$ may not be generally identify with the striation spacing $s$. The ratio $D = v/s$ is not even constant and its values can vary in the range of four orders (approximately from $10^{-3}$ to $10^{1}$). The relation between macroscopic crack growth rate and striation spacing is influenced by three fundamental factors [1]:

a) Inhomogeneous character of fatigue crack growth both from space and time point of view. This fact results in the existence of idle cycles, i.e., the load cycles which produce no striations. Although each individual striation is forming by the only load cycle, it is necessary to apply $n$ cycles ($n \geq 1$) to crack length increment $\Delta a = s$. During ($n$-1) idle cycles the local part of crack front stops and their effect on fatigue process is latent. Value of $n$ is generally decreasing function of $\Delta K$ whereas the particular character of this function strongly depends on the material. Determination of $n$ only on the fractographic findings is impossible.

b) Deflections of local directions of fatigue crack growth from the macroscopic one. On a screen capture, the divergence can be quantified by angle $\vartheta$ between local normal line perpendicular to striations in observed individual patch and specimen border side where the direct optical monitoring of the macroscopic crack growth has been usually carried out.

c) Participation of other micromechanisms on the crack growth than the striating one, e.g., ductile fracture, quasi-cleavage, intergranular decohesion etc. The information on the contribution of the individual micromechanisms is encoded in fracture morphology. The proportion of striation mechanism can be quantified by the area percentage of striation patches $p_s$ on the fracture. Generally, the lower $p_s$ (the higher participation of other "quicker" micromechanisms), the higher ratio $D = v/s$. It is possible to present factor $D$ as an empirical function of $p_s$ the character of which depends on the material, testing conditions etc.

Our recent research work was focused on the study of local directions of crack growth. Experimental data were obtained by extensive quantitative microfractography of fracture surfaces of fatigued specimens of Al-alloy 7010 (i.e., AlZnMg) widely used especially in aircraft industry. For the alloy, the relation between macroscopic crack growth rate and striation spacing is controlled especially by the divergence of local crack growth directions; as the influence of both idle cycles and participation of other micromechanisms is negligible. The measurements of the local crack growth directions were performed on the monitor of PC linked up to scanning electron microscope by means of the image processor. Software specially developed for these purposes was used both for measuring and data processing. This research period prosecutes the preliminary study the results of which were summarized in [2].

Angles $\vartheta$ quantifying local directions of fatigue crack growth were measured and presented as a function of crack length $a$ ad/or stress intensity factor range $\Delta K$. Altogether about 4500 individual values were obtained. Most substantial results of the voluminous experimental program are following:

In the fatigue experiments, influence of following factors was studied: environment (air, vacuum), orientation of specimen in blank (TL/L, TL/TC), and structure (fibrous,

recrystallized) [3],[4]. Data set is characterized by considerable dispersion. This fact was superimposed the influence of all mentioned factors. In all cases, both mean value and standard deviation of $\vartheta$–data are increasing with increasing $\Delta K$ but with respect to huge dispersion, this dependency is rather weak. Furthermore the factor $D = v/s$ is controlled by $\cos(\overline{\vartheta})$ the value of which varies in relatively narrow range. Thus the dependence of $\vartheta(\Delta K)$ was not reflected and all data under the same conditions were processing as only one set. Distribution function of the data set is asymmetrical thus there is a difference between mean value and median. The results of statistical processing are summarized in Table 1, where $\overline{\vartheta}$ is mean value, $STD(\vartheta)$ is standard deviation and $\vartheta_m$ is median value.

Table 1 – Local crack growth directions in Al-alloy 7010 at $T = 20°C$ and stress ratio $R = 0.1$

| Structure | Orient. | Envir. | $\overline{\vartheta}$ [deg] | $STD(\vartheta)$ [deg] | $\vartheta_m$ [deg] | $\cos(\overline{\vartheta})$ [1] | $\cos(\vartheta_m)$ [1] | Number of Data |
|---|---|---|---|---|---|---|---|---|
| Fibrous | TL/L | Air | 21.1 | 13.3 | 20.7 | 0.933 | 0.9352 | 624 |
| | TL/L | Vac. | 16.3 | 13.8 | 14.4 | 0.960 | 0.9684 | 80 |
| | TL/TC | Air | 14.9 | 13.0 | 11.9 | 0.967 | 0.9787 | 501 |
| Recryst. | TL/L | Air | 14.5 | 11.9 | 12.8 | 0.968 | 0.9751 | 1098 |
| | TL/L | Vac. | 15.0 | 13.4 | 12.6 | 0.966 | 0.9761 | 698 |
| | TL/TC | Air | 15.0 | 12.4 | 12.7 | 0.966 | 0.9755 | 928 |
| | TL/TC | Vac. | 14.5 | 11.9 | 12.6 | 0.968 | 0.9758 | 567 |

Results of the statistical evaluation of experimental data imply that from practical point of view, neither material factors under study (structure, orientation) nor environment (air or vacuum) have substantial effect on local directions of fatigue crack propagation in microvolume. Two-parametrical microfractographic information $[[\bar{s}_i(a_i), \overline{\vartheta}_i(a_i)]]$ can be transformed into the macroscopic characteristic $v_i(a_i)$ by simple equation $v_i = \bar{s}_i \cdot \cos(\overline{\vartheta}_i)$.

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# Environment Assisted Fatigue Crack Growth in Austenitic Steel AISI 304 L

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The structural alloy AISI 304 L is austenitic chromium-nickel steel with very low carbon content. Because of good corrosion resistance in as-welded conditions, the steel is applied for weldments exposed to an aggressive environment. Previous periods of research work were focused to the study of influence of stress ratio and specimen geometrical factors on the fatigue crack growth in the steel [1],[2]. The main goal of the most recent research stage [3] was to study the fatigue crack propagation in environment simulating exploitation conditions of nuclear power plant, i.e., in PWR primary water at elevated temperature.

High cycle fatigue tests were carried out at CT-specimens of thickness $B$ = 5 mm and width $W$ = 50 or 38 mm at the stress ratio $R$ = 0.3 and load frequency $f$ = 1 Hz. Fatigue crack length was measured by means of compliance or drop potential techniques. Macroscopic crack growth rates determined by the secant method were presented as a function of stress intensity factor range $\Delta K$. According to [4], $\Delta K$ for CT-specimens are given by the equation

$$\Delta K(\bar{a}) = \frac{\Delta P}{B W^{1/2}} \cdot \frac{\left(2+\frac{\bar{a}}{W}\right)}{\left(1-\frac{\bar{a}}{W}\right)^{3/2}} \cdot \left[0.886 + 4.64\frac{\bar{a}}{W} - 13.32\left(\frac{\bar{a}}{W}\right)^2 + 14.72\left(\frac{\bar{a}}{W}\right)^3 - 5.6\left(\frac{\bar{a}}{W}\right)^4\right],$$

valid for $0 \le \bar{a}/W \le 1$, where $\Delta P$ = load range [N], $B$ = specimen thickness [m], and $W$ = specimen width [m]. Experimental data $v = da/dN$ vs. $\Delta K$ fitted by regression function in the form of general Forman relation represent fundamental fatigue characteristics of the AISI 304 L steel under the given environmental conditions..

At the room temperature, macroscopic crack growth rate in aqueous environment is rather higher than in air, but the difference is gradually vanishing with increasing crack length and/or stress intensity factor range. There is substantial influence of temperature in PWR primary water – in whole $\Delta K$ range, macroscopic crack growth rate at $T$ = 300 °C is notably lower than at $T$ = 20°C, i.e., elevated temperature decelerates the fatigue degradation process in the aqueous environment.

Next to the macroscopic study, qualitative and quantitative fractographic analysis of the fatigue fractures was carried out by means of both light optical and scanning electron microscopy. Fractographic examination was focused on study of fractographic features and their correlation with macroscopic characteristics of fatigue crack growth with aim to explain the influence of the water environment and/or elevated temperature on micromechanisms of fatigue process in AISI 304 L steel. Striation spacings $s$ were measured on the fracture surface of the fatigued specimens and these microfractographic data were compared with the macroscopic crack growth rates $v$; the ratio

$$D = v / s$$

was presented as a function of $\Delta K$. The relation $D = D(\Delta K)$ depends on the testing conditions. Results of fractographic analysis are following:

a) **Air, T = 20°C** : In the range of low $\Delta K$ values, fatigue fracture morphology is markedly influenced by the material microstructure. Transgranular striations prevail in the range $\Delta K > 17$ MPa.m$^{1/2}$. Boundaries between striation patches are formed by very low steps thus fracture surface is relatively smooth. The higher $\Delta K$, the higher frequency of secondary microcracks. The factor $D$ is increasing function of $\Delta K$ and it varies in the range (0.3; 1).

b) **PWR primary water, T = 20°C** : Similarly as in air at room temperature, fracture morphology is influenced by the microstructure in the range of low $\Delta K$ values and striations dominate above $\Delta K = 17$ MPa.m$^{1/2}$. The higher $\Delta K$, the higher steps between adjacent striation patches, the higher frequency of transversal secondary microcracks and thus the higher roughness of fracture surface. Beside the transgranular fracture, there are intergranular facets on the fracture surface. The microrelief of these facets is changing with increasing $\Delta K$: proportion of facets with striations increases instead of the smooth facets of intergranular separation. The participation of intergranular fracture induces the higher fatigue crack rate in aqueous environment than in air. With increasing $\Delta K$, the area percentage of intergranular fracture decreases thus difference between crack growth rate in water and in air is gradually dropping away. The third fractographic feature of the fatigue fracture unambiguously tied up only to the given testing conditions is a type of indecipherable transgranular fracture. In the whole range of $\Delta K$, the factor $D$ is higher than 1 and $D(\Delta K)$ function is increasing only in the range of lower $\Delta K$ values, whereas in the range of higher $\Delta K$ values, this function is decreasing.

c) **PWR primary water, $T$ = 300°C** : Observation of the fracture was very complicated due to layer of corrosion products on the fracture surface. Thickness of this layer decreases with increasing crack length. Special cleaning technique had to applied to enable the fracture analysis. Also in this case, the predominant fractographic feature was transgranular striations but the abundance of secondary transversal microcracks was higher. Intergranular facets with striations concur only rarely. Contrary to the fracture of specimens fatigued at room temperature, both in air and water environment, neither transgranular corrosion fracture nor intergranular separation was observed. In a final part of fatigue fracture corresponds to the high $\Delta K$, large ductile dimples with serpentine glide were observed. The factor $D$ is increasing function of $\Delta K$ and it varies in the relatively wide range (0.4; 2).

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# Shear Lips and Their Effect on Fatigue Crack Growth

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In thin sheets of metals with f.c.c. or b.c.c. structure, a transition from square (tensile mode) to slant (shear mode) fatigue crack growth is often observed at increasing $\Delta K$. When the $\Delta K$ is high enough, shear lips start to develop from the plate specimen surface. Shear lips are regions of fatigue fracture surfaces, which are inclined at about 45° to the plate surface. The mechanism leading to initiation and developing of shear lips is still studied. A simple mechanical explanation is that the process is induced by plane stress conditions, leading to maximum shear stress in planes, which are inclined at 45° to the specimen surface. However, when the environment is changed, e.g., from air to salt water, it appears that shear lips development is shifted to higher values of $\Delta K$. Flat tensile mode is favored when the environment is more aggressive [1]. It is also observed that the character of shear lips is influenced by the loading frequency. A high frequency leads to rough surfaces of the shear lips, while a lower frequency results in a smoother surface. It thus might be a complex matter to describe which factors are responsible for the stability of shear lips on fatigue crack surfaces.

The occurrence of shear lips on the fracture surface has an effect on the fatigue crack growth rate *da/dN*. For several materials (steels, Ti-alloys, Al-alloys etc.), it was observed that shear lip development decreases the slope of the log(*da/dN*)-log($\Delta K$) relation. The specimen thickness effect on *da/dN* is often given to the coincidence with shear lips - there is no influence of the thickness if shear lips are not presented on the fatigue fracture surface. The fatigue crack growth resistance is not the same for shear mode as for tensile one.

In experimental part of the research, the width of shear lips $t$ was measured on the fatigue fracture surfaces of specimens of 2024-T42 Al-alloy. The following analysis of data obtained was focused on studying the correlation between shear lip width and fracture mechanics parameters that control the fatigue crack growth rate.

High cycle fatigue tests of center cracked plate specimens of thickness $B$ = 6 mm and width $2W$ = 58 mm had been carried out in the laboratory of Aeronautical Research and Test Institute, plc in Prague. An influence of stress range $\Delta\sigma$ and stress ratio $R$ was under study (see Table 1). At department of materials, the shear lip width $t$ was measured optically by means of binocular light microscope and micrometric surfacing screw [3],[4]. The experimental data were presented as a function of the crack length. Sizable scatter characterizes the data set obtained.

It was detected that the shear lip width is controlled by stress intensity factor range $\Delta K$ instead its effective value $\Delta K_{eff}$ or $K_{max}$. In the first stage of the results evaluation, values of $\Delta K$ were calculated for the pure tensile mode and plane strain condition. The relation between relative shear lip width $t/B$ and $\Delta K$ was considered as linear and fitted by the regression function in the form of $t/B = C \cdot (\Delta K - \Delta K_s)$, where $\Delta K_s$ corresponding to the $\Delta K$ at which the development of shear lips start, seems to be independent of both applied stress range $\Delta\sigma$ and stress ratio $R$. The second coefficient in the linear regression function, i.e. constant $C$, is proportional to the reciprocal value of stress range $\Delta\sigma$ and the product $A = C \cdot \Delta\sigma$ decreases with increasing stress ratio $R$ (see Table 1).

Table 1 – Loading parameters and coefficients of linear regression function

| Loading Conditions | | Coefficients of $t/B = C \cdot (\Delta K - \Delta K_s)$ Relation | | |
|---|---|---|---|---|
| $R$ [1] | $\Delta\sigma$ [MPa] | $\Delta K_s$ [MPa.m$^{1/2}$] | $C$ [MPa$^{-1}$.m$^{-1/2}$] | $A = C \cdot \Delta\sigma$ [m$^{-1/2}$] |
| 0 | 77,57 | 7,56 | 0,0510 | 3,96 |
| 0 | 44,96 | 6,72 | 0,0907 | 4,08 |
| 0,2 | 61,76 | 6,36 | 0,0347 | 2,14 |
| 0,2 | 33,36 | 6,45 | 0,0631 | 2,11 |
| 0,5 | 31,34 | 6,48 | 0,0533 | 1,68 |

The results of high cycle fatigue experiments were presented in the form of *da/dN* as a function of $\Delta K$. In correspondence with previous findings (e.g.,[2]), a perceptible decrease of the *da/dN* vs. $\Delta K$ gradient was observed in the range of $\Delta K \geq \Delta K_s$, whereas the lower stress ratio $R$, the more pronounced drop-off. This effect has been associated with shear lip development - occurrence of shear lips on the fracture results in the elongation of the fatigue crack front and thus in the reduction of "effective" $\Delta K$ -value [1],[2].

According to Zuidema and Mannesse model [2], the reduction of $\Delta K$ is proportional to ratio of shear lip width $t$ and specimen thickness $B$: $\Delta K_{appl} / \Delta K_{red} = 1 + 2 \cdot \left(\sqrt{2} - 1\right) \cdot t / B$. The applied model does reflect neither the influence of shear fracture mode III (and/or II) nor mixed plane stress and plain strain conditions.

Influence of both the factors is taken into account in the alternative approach proposed by Kunz [3] that is based on the energy release rate range $\Delta G$. Corrected $\Delta G$-value is given by the weighted sum of two contributions corresponding to pure tensile fracture mode I in plane strain conditions and mixed out-of-plane shear and tensile mode I+III in plane stress conditions: $\Delta G = \frac{B - 2t}{B} \Delta G_I \left(plain\ strain\right) + \frac{2t}{B} \left[\Delta G_I \left(plain\ stress\right) + \Delta G_{III}\right]$.

Correlation between fatigue crack growth rate *da/dN* and $\Delta K$ or $\Delta G$ corrected by the two foreshadowed techniques taking into account existence of shear lips is much more better than in the case of $\Delta K$ or $\Delta G$ values computed by standard procedures.

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# Experimental Investigation of Composite Material Properties of Aircraft Structures

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There are more composite materials exert in building light and very light aeroplanes. Published research results and tests of composite materials done by autoclave technology can hardly be used for proposal and production of very light aeroplanes. Therefore, at CLKV Department of Aerospace Engineering, CTU in Prague has been decided to create Composite Material Database which respects specific technology processing in very light aeroplane category.

Rising Composite Material Database contains material properties, measured composite material and engineering characteristics, material components tests (passed from the manufacturers), description and philosophy of experiments, specimen technological processing and notation key.

Tested materials are composite materials with glass, carbon or carbon-aramid reinforcement and epoxy matrix used for building light and very light aeroplanes, produced by contact lamination. The orientation of specimen reinforcers with respect to load direction is 0°, 45° and 90°. There is considered static tensile test, pressure, bend test, shear and interlaminar shear test. All static experiments are provided at temperatures 23°C, 54°C, -55°C and 23°C with increased moisture ( the specimens are soaked in water for 30 days before experiment).

The unique registration number is assigned to each specimen, which is taken up from the manufacturer. After completion and wrapping of the whole specimen set for one test case it is passed togeather with the test reports to the test-room. Static tests of material properties are provided on the test machine Instron, with maximum force of 10kN. The machine is equipped with two isothermic chambers for different temperature zones. All specimens are registered. The procurement of the photo-documentation, statistic data proccessing and corrupted specimens archiving follows the tests.

The measurement of the Young‘s module of elasticity and Poisson number is carried out with an extensometer for deformation under 0,5 %, deformations over 0,5 % are measured by the motion of the jaws of the Instron machine.

There is larger scatter of measured results ( i.e. tension test in the room temperature, tension test in the room temperature with increased moisture and tension test in the increased temperature) with respect to values published in literature. These differences are given by the distinct technology of production. There is also interesting the way of the filament wound or the effect of the specimen moisturing to the material strength. The different character of the specimen wounding shows for one material. For example Torayca T 700 embodies two different ways of the fracture. In the first one, 60% of tested specimen shattered, in the second the rest had the diagonal fracture.

The object of the following research is to justify these deviations and differences, determine manufacturing technology and ambient conditions influence and the way of loading to the specimen fracture.

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# Implementation of the Scanning Electron Microscope XL 30 ESEM –TMP in the Frame of Advanced Methods within the Faculty of Civil Engeering of CTU Prague

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The implementation of Environmental Scanning Electron Microscopy (ESEM) and EDX multielemet analysis into the experimental methods in the frame of the Faculty of Civil Engeering CTU was the aim of the proposal project (IP). In recent years the SEM and EDX methods has seen many developments, and one of them is that ESEM are now capable of allowing a controlled pressure in the microscope chamber, instaed of just a high vacuum. The electron beam ionizes some of gas atoms (as well as water wapor) and these positive ions are attracted to the sample, neutralizing the negative charge built-up at the surface of the specimen.

The target of the most of microscopic investigations were the detection of surface features (i.e. detection of "primarily" microstructures and external stresses involved microdefects) as well as microchemical compositions of materials and the inhomogeneities of this composition in relationtionship of known external factors. The following materials were examined: foundation subsoils and rocks, compositional materials – glass and polymer fibres reinforced concrete, cement pastes and concretes during hydratation, polymers, woods etc.

A lot of microscopical measurements were carried out on the investigation of bentonites – artificial barriers for radioactive vaste disposals. Special attention was devoted to the detection of defects of Cr/Co (nitrides and carbides) thin layers. Selected fields of investigations in which the microscopical measurements were significantly used are as follows:

**1. Study of mechanical and micromechanical properties of materials (in cooperation with R. Novák, T. Polcar from FSI CTU Prague and L. Berka and N. Murafa from FCI CTU Prague).**

The Cr-Co nitrides and carbides ultrathin layers (thicknes not exceeded 50 nm) both in the amorphous and polycrystaline form sputtered on the silica monocrystal plate show (the homogeneous and/or polygonal structures) the several types of defects in sputtered surface. Several microscopical measurement, in the secondary electrons (SE), back scattered electrons BSE and EDX analyses, were carried out. The cause of the defects, i.e. the lacks of sputtered thin layers of Cr/Co nitrides, have been identified as the organic contaminations (detected as C) on the surface of silica plates. The another cause of defects could be the inhomogeneities of the crystal lattice of the silace plate (bed). Aplication of the BSE detection shows very good contrast (so called "material contrast") between the homogeneous thin layers and the defects of sputtering.

**2. Investigation of microchemical composition of foundation subsoils and rocks (in cooperation with J.Schroefel FCI CTU Prague).**

The chemical analyses of the ground waters from the locality of remedial works (ČKD Vysočany) have detected the extreemly high As-concentrations in the ground waters of the unknown source of As. The microchemical EDX analyses in ESEM mode of particular minerals of shales proved the accesoric sulphidic minerals (mostly pyrite) as a carriers of high content of arsenic. Water-rock interaction processes release the As from weathered sulphides to the ground waters.

**3. Study of microchemical composition of concrete minerals and the composition of matter in transition zone between the reinforced beams of glass fibres and cemente paste matrix (in cooperation with R.Chudoba and Bong-Gu Kang, Lehrstuhl fűr Baustatik and Baudynamik Rheinische Westfälische Technische Hochschule Aachen).** The glass reinforced beams in concrete matrix proved poor results in mechanical tests. The microchemical analyses EDX in ESEM mode of the concrete, transition zone and intersticial matrix between the glass microfibres indicate the critical elements. Indicated elements have made possible to interprete the mineralogical composition of tested matrix. It has been proved the prevailing content of the clay minerals in matrix of tranzition zone as well as in the interstitial matrix between the glass fibres. Thus the strengthening function of cement paste almost absented.

**4. Comparative microchemical studies of concrete matrix with nanoindent micromechanical testing (in cooperation with K.Trtík, FCI CTU Prague).** The perfect polished samples of concrete were tested by nanoindetation. The microchemical composition in the each point of such indent was obtained by EDX analysis in ESEM mode. The indicated elements have made possible to interprete the mineralogical composition of tested matrix in each indent points. The perfect imaging in high magnification (100 000x and more) of each of the indents and the morphology pattern of the deformation structures caused by indentation aloves the better interpretation of the properties of tested material on micro-leavel. In the case of constant deep of each of the indent the more easier interpretation of hardness is possible.

**5. Microscopical documentation and microchemical testing of hydratation processes in cement paste (in cooperation with V.Šmilauer, FCI CTU Prague).** The selected specimens of cement paste (portland) were hydrated in well defined time relation (1 hour, 12 hours, 1 day, 3 days etc.). The face of the broken side of each specimen was measured in ESEM mode and typical hydrated minerals were observed. The EDX analyses indicate the selected elements. Elements have made possible to interprete the mineralogical composition of tested particles. Special atention was put on the composition of secondary minerals in pores.

**6. Microscopic study of bentonites – material for barriers of radioactive vaste disposal.** The several types of bentonites from the North Bohemia have been tested as suitable materials from the point of view of isolants. Large amount of microspic measurement of selected samples were done. The surface morphology and the granulometric distribution of particles (individual crystals of clay minerals and aglomerates) were obtained for each of the bentonite types.

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# Influence of MnS Inclusions on Cleavage Triggering in Reactor Pressure Vessel Steel

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In low alloy mild steels, the critical fracture event is commonly assumed to be a propagation of carbide microcracks into the surrounding ferrite matrix. Besides carbide particles of relatively small size (< 1 μm), big non-metallic inclusions (mainly composed of MnS) are present in killed steels. These inclusions are elongated in the rolling direction and they are often situated in clusters. Although the influence of the size and the morphology of the MnS inclusions on ductile fracture is well known, their role on the triggering of cleavage remains unclear.

A direct role of MnS inclusions as micro defects initiating cleavage has been reported in [1], but in most cases cleavage is thought to be initiated by dislocation pile-up or carbide microcracking. The presence of clusters of debonded elongated MnS inclusions in the vicinity of cleavage initiation site was found in the 16MND5 pressure vessel steel [2]. A probabilistic model based on the spatial distribution of MnS inclusions has been proposed in [3]. Nevertheless, this model cannot explain several cases in which the cleavage initiation is not associated with presence of MnS inclusions.

In the present work the influence of MnS inclusions as the stress concentrators is studied. An extensive metallographic study of the statistical distribution of size and geometry of MnS inclusions was therefore undertaken. 3-D reconstruction of the fracture surface of CT 25 specimen broken at 0 ºC containing one cluster of MnS of typical elliptical shape was created in order to trace the profiles along $x$ and $y$ axis. The cluster was idealized by ellipsoidal defect of measured dimensions. Obtained information served for finite element computations of the stress concentration effect of these inclusions.

The stress-strain fields around ellipsoidal defect located in front of the ductile crack tip of a CT specimen is computed using the finite element method (ABAQUS *ver.* 5.8 software package). The failure probability $P_F$, is estimated using the Beremin model [4]. In the beginning of loading, the Weibull stress is higher in the defect containing cell than in the uniform cell because of the earlier occurrence of plasticity due to the stress concentration effect of the void. However, since the plasticity is present in the entire cell, the trend in Weibull stress is reversed, so that the fracture probability of the void containing cell is slightly lower than the fracture probability of the uniform cell. This is due to the effective volume which is smaller in the cell containing a void because of the unloaded zone above the cavity. In the case studied here, the unloading effect is greater than the stress concentration effect of the cavity.

In the presence of such a defect, the fracture probability is enhanced at the beginning of loading, when the matrix remains globally elastic, but as plasticity develops in the matrix, and cavity growth takes place, an unloaded region extends above the free surface of the cavity, and the fracture probability can even be reduced. The presence of MnS clusters on the fracture surfaces could therefore be more probably related to an unloading effect of the associated cavities, attracting the propagating crack.

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# Experimental Investigation of Failures of Fired Clay Units

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The failures of the floor structures comprising the clay units HURDIS have revealed the same feature - the clay units have failed in the same characteristic way. The failure curves are passing through the webs of the plates HURDIS and the entire bottom parts of the plates below are falling down suddenly, after the short-time cracking noise period. The failure is not preceded by any visual or distinct acoustic warning. Exceptionally, almost soundless cracking may be heard.

The very probable cause of the failures of the floor structures with the fired plates HURDIS consists in the contemporous action of the following loads and effects upon the clay material of the plates HURDIS:

- the continuous horizontal shear flow caused by the shrinkage of the concrete layer placed on the upper surface of the clay plates HURDIS, accompanied by sufficient adhesion between both materials;
- horizontal compressive forces caused by the irreversible moisture expansion of the clay material; the magnitude and the points of application of those forces depend on the quality of the contact between the end faces of the plates and their supports; similar horizontal forces may appear in the direction perpendicular with the longitudinal axes of the plates;
- less intensive effects of the temperature changes inside the floor structures;
- certain effects of the vertical permanent and variable loads.

While the rheological properties of concrete layers are thoroughly described in the technical reports and standardised in the relevant documents, there is a wide-spread lack of both the experimental results and of the common knowledge on the volume changes of the clay products.

The irreversible volume changes of the clay material belong to the characteristic properties of any fired clay product. Their magnitude and their evolution in time depend on the properties of fired clay material and also on the environmental conditions.

The moisture expansion of the contemporary fired clay material is up from 0.2 to 1.0 mm/m. It's depends on the testing method used, on the raw material composition, on the firing temperature and on the duration of the maximum firing temperature. The higher presence of alkaline oxides and noncristalline and other against water instabile phases in the ceramic body increases the moisture expansion. On the contrary, the presence of earth metals oxides and presence of stabile cristalline compounds in the body decreases the moisture expansion.

Apart from irreversible moisture expansion, there exists also reversible moisture expansion, provoked by capillar elevation in the pores smaller then $10^{-7}$ m. The values of that moisture expansion are up to 0.1mm/m.

The increase of the length of the sample is caused by bonding of water in ceramic body by the forces which are greater than the physical forces (i.e. the forces of chemisorption type). The dependence of loss of the weight of the samples after the boiling in the autoclave on the linearly increasing temperature has been determined by means of the thermal gravimetric analysis.

It has been proved that there exists no direct relation between the loss of the weight of the sample and the moisture expansion of the ceramic body. The only suitable method for the

determination of irreversible moisture expansion which had been run in the ceramic body is the shrinkage of the sample by annealing (600 $^{o}$C , 240 min.) $\varepsilon_a$ (mm/m).

Many experimental investigation have been made. The curves expressing the length changes of the specimens taken from the HURDIS units during more than 700 day has been determined: moisture expansion in the conditioned environment after the heating in the autoclave, after the treating in the boiling water, moisture expansion at the exposition to natural atmosphere conditions.

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The aim of the seminar is to present and discuss the latest results obtained by researchers especially at the Czech Technical University in Prague and at collaborating institutions.

The organizing committee has selected a total of 563 contributions divided into 15 different areas of interest:

- **Part A:**
  - mathematics
  - physics
  - informatics and automation engineering
  - electronics and instrumentation
  - materials engineering
- **Part B:**
  - mechanics and thermodynamics
  - mechanical engineering
  - production systems and technology
  - energetics and power engineering
  - nuclear engineering
  - chemistry
  - biomedical engineering
  - civil engineering
  - architecture and town planning
  - transportation, logistics, economy, management



*Prague, January 2003*

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# CONTENTS

## 6. MECHANICS & THERMODYNAMICS

Dynamic Performance of a Single-pipe Heating System ..... 638
*J. Bašta, J. Eisner*

Starting up of Radiators in By-pass ..... 640
*J. Bašta, B. Šourek*

Steady State Heat Analysis of Diesel Engine Cylinder Head ..... 642
*M. Španiel, R. Tichánek, M. Diviš*

Models of Dynamical Mechanical Systems with the Possibility of Simulation of Operating Behaviour Solved by MATLAB and SIMULINK and Present on the Web Pages ..... 644
*J. Vondřich, S. Jirků, R. Havlíček, E. Thőndel, V. Kůla, K. Znamenáček*

Ductile Crack Growth Modelling Using GTN Model ..... 646
*P. Haušild*

Optimizing of Laminate Plate Elastic Behavior ..... 648
*T. Mareš*

A Fan Duct Design of a Very Light Aircraft Power-Plant and Its Experimental Aerodynamic Investigation ..... 650
*R. Theiner, J. Jerie, D. Hanus, T. Čenský, E. Ritschl*

Air Flow Patterns in Cleanroom with Personnel Protection Zone ..... 652
*J. Kužel, J. Hemerka*

Heat Storage in the Ground ..... 654
*J. Říha, J. Huml, K. Brož*

CFD Code AMEM and the 2nd Law of Thermodynamics ..... 656
*O. Vítek, M. Polášek, K. Kozel*

A Network Thermodynamic Analysis of the Heat Pipe ..... 658
*J. Procházka*

Measurement of Tensile Stiffness of Cross Wound Tubes ..... 660
*Jiang Sun, M. Růžička, O. Uher*

Analysis of the Load Capacity of an Electron Beam Welded Worm Wheel ..... 662
*M. Vorel*

Application of Thermodynamic Stability Condition to the Modelling of Turbulent Channel Flow ..... 664
*T. Hyhlík*

Turntable for Multi-purpose Windtunnel ..... 666
*P. Antoš*

The Effect of Fiber Tow Undulation on the Axial Stiffness of Filament Wound Composite Tubes ..... 668
*Jiang Sun, M. Růžička, O. Uher*

Numerical Solution of Transonic Flow in Turbine Cascades ..... 670
*J. Halama, J. Dobeš, J. Fořt, J. Fürst, K. Kozel*

Variational Principles in Mechanics III (Audio-Visual Educational Program) ..... 672
*M. Španiel, M. Draxler*

Passenger‘s Seat Meets Criteria of FAR23 (JAR23) Recommendation ..... 674
*M. Španiel, D. Šimek*

Research of the Dynamics of Water Reservoirs ..... 676
*J. Nožička*

Direct Method for Measuring Deformations on Structures ..... 678
*S. Holý, J. Zeman*

Joint Teaching of Experimental Mechanics Methods in FME and FNSPE CTU and Their Impact on Product Quality ..... 680
*S. Holý, N. Ganev, I. Kraus, K. Vítek*

Secondary Flow in Curved Cylindrical Channels ..... 682
*D. Hanus, P. Anderle, T. Čenský, J. Nožička, J. Adamec*

Influence of the Inlet Flow Structure on the Energy Loss within Curved Channel ..... 684
*D. Hanus, L. Janko, T. Čenský*

Data Management for FE-calculation Based Fatigue Analysis ..... 686
*J. Papuga, M. Španiel, M. Růžička*

The Hole Drilling Method Data Evalution by means of the Integral Method ..... 688
*K. Doubrava, S. Holý, Z. Kuliš, O. Weinberg, K. Vítek*

Tube to Elbow Processing Simulation ..... 690
*K. Vítek, M. Španiel, M. Přibyl*

The Efect Methods of Elastic Constant Optimization ..... 692
*K. Vítek*

Damage Localization of Structures Based on Modal Characteristics Changes ..... 694
*M. Polák, T. Plachý*

Coal Seam Loading before and after Bump Initiation ..... 696
*J. Vacek*

Thin-Walled Shell Collapse - Experiment and FE Solution ..... 698
*M. Španiel, J. Dvořák, S. Holý*

Optimization of Guiding Properties of Rail Vehicle Trucks ..... 700
*J. Dvořák*

Application of Semiconductive Strain Gages for Hole Drilling Method ..... 702
*K. Vítek, S. Holý, K. Doubrava*

## 7. MECHANICAL ENGINEERING

Parameter Measurements of Experimental Mobile Aerating Equipment ..... 706
*J. Melichar, J. Andreovský*

Deformation Measurement of Structural Parts in Industry Using Gradient of Wave Field ..... 708
*J. Novák*

Experimental Verification Technology of Ultra Light Rotor ..... 710
*P. Růžička*

Nonconvex Mathematical Programming in Evaluation of Experimental Data ..... 712
*T. Mareš*

Digital Optoelectronic Techniques for Tophography of Industrial Surfaces ..... 714
*A. Mikš, J. Novák*

Mixing of Suspensions ..... 716
*T. Jirout, F. Rieger*

Stance for Measuring Couplings and Gears ..... 718
*P. Pospíchal, L. Jančík*

Investigation of Acceleration Fatigue in the Category of Ultralight Airplanes ..... 720
*T. Marczi, M. Růžička, Z. Maléř, S. Slavík*

Experimental Evaluation of Precise Gearboxes ..... 722
*V. Dynybyl, L. Jančík*

Correlation Investigation between the Operational Load Factor and Structure Load of UL Airplane for the Purpose of Structure Fatigue Prediction ..... 724
*T. Marczi, M. Růžička, Z. Maléř, S. Slavík*

Investigation of Latent Thermal Energy Storage Use in Solar Heat Pump Systems ..... 726
*V. Slašťanová*

Hydraulic Circuits for Controlled Loading of Driveś Elements ..... 728
*J. Heller, M. Bulínová*

Static Check of Countershaft by Using Matlab ..... 730
*J. Křička, J. Bečka*

Contribution to Methodology for Determination of Elastic Constants of Engineering Materials ..... 732
*I. Kraus, N. Ganev, H. Lauschmann*

Development of an Optimised Control System for a Multi-temperature Refrigeration Systems ..... 734
*L. Vaclavek, J. Lohan, A. Ryan*

Optimalization of Parametres of Emergency Brake ..... 736
*J. Sojka*

Working Accuracy of Numerically Controlled Machine Tools ..... 738
*M. Janda, J. Rybín*

Batch Heating of Liquids ..... 740
*M. Dostál, K. Petera*

Equipment for Simulation of Rotating Loading Using Frequency Converter for Controlling Induction Motors ..... 742
*J. Chyský, A. Kubačák*

Determination of Residual Stresses in Bulky Forgings of Different Heat Treatments ..... 744
*S. Holý, O. Weinberg, J. Václavík, K. Doubrava, K. Vítek*

EMAS Program and Waste Heat Utilisation in the Industry ..... 746
*J. Petrák, P. Novák, R. Kunčar, M. Petrák, K. Čáp*

Mixing of Suspensions in Tall Vessels with a Draught Tube ..... 748
*J. Brož, F. Rieger*

Research of the Construction Molded Panels with Hybrid Material Structure ..... 750
*J. Pohl, J. Talácko*

Design and Check of Air Heating and Ventilation of Film Studio ..... 752
*T. Špirek, J. Schwarzer*

Dynamic Stability of Machine Tools and Cutting Process ..... 754
*P. Bach*

The Test Stand with High Dynamic Motion Axis Driven by Linear Motor ..... 756
*A. Bubák, M. Ondráček, J. Smolík, O. Novotný*

## 8. PRODUCTION SYSTEMS AND TECHNOLOGY

Diagnostics of Large-Area Solar Cell Homogenity by Local Irradiation ..... 760
*Assefa Lemma Asresahegn, V. Benda, P. Hrzina*

Diagnostics of Recombination Centres in Silicon Solar Cells ..... 762
*Quan Tran Hung, V. Benda*

Influence of Configuration Air-Technology Elements on Velocity Fields in Cleanrooms ..... 764
*J. Kužel, J. Hemerka*

Volumetric Accuracy of Machine Tools ..... 766
*O. Svoboda*

New Conception of Milling Centers For High Speed Cutting ..... 768
*J. Smolík, J. Houša, M. Ondráček, O. Novotný, P. Kolář, P. Sedláček, A. Přiklopil*

The Returnability of Investment to Simulation Software and Monitoring of Costs for Foundry Al Alloy ..... 770
*A. Herman*

## 9. ENERGETICS AND POWER ENGINEERING

Load Regulation System for Micro Electric Energy Generators ..... 774
*P. Mindl*

Forecast of Primary Energy Resource Consumption by IAEA's Software Tool „Message" ..... 776
*M. Honzík, J. Pejter*

DFT Spectrum Analysis in Power-Line Systems - Uncertainty by Non-Coherent Sampling ..... 778
*M. Sedláček*

Using Computer Simulation for Estimation of Uncertainty of RMS Value of Digitized Signal ..... 780
*M. Sedláček, M. Novotný*

Errors Measurement Analysis of Piston Engine Running Roughness ..... 782
*M. Čambál, L. Novák, I. Uhlíř, K. Miffek*

International Comparison of AC Voltage Ratio Standards ..... 784
*K. Draxler*

Internet Teaching and Modernization of on Safety Problems Oriented Subjects at Faculty of Electrical Engineering ..... 786
*V. Kůla, M. Cipra, P. Kočárník*

Power Electronics in Automotive Hybrid Drives ..... 788
*Z. Čeřovský, Z. Halámka, P. Mindl, V. Pavelka*

Design and Realization of Active Magnetic Combined Bearing ..... 790
*J. Pavelka, L. Synek*

Diagnostics of Rotating Electric Machines by Using of Expert System ..... 792
*K. Záliš*

Partial Discharge Measurement in Conditions of Disturbances ..... 794
*K. Záliš, L. Beranová*

Propagation of Partial Discharge Impulses in Windings ..... 796
*K. Záliš, R. Kosek*

Development of Neural Network for Recognition of Partial Discharge Patterns ..... 798
*K. Záliš, J. Chmelenský*

Power Supply of Deep-Sea Mining Machine ..... 800
*P. Voženílek, P. Tušla, J. Janoušek, K. Buhr*

Renewable Energy Sources Support Policy in the Condition of Power Market Creation ..... 802
*J. Knápek, J. Vašíček*

Measurement of Space Characteristics of Illumination ..... 804
*J. Šilhán, J. Habel, T. Veselka*

Mathematic Description of model of Light Reflection ..... 806
*J. Málek, J. Habel*

Seasonal Storage of Solar Energy and its Long-Term Monitoring ..... 808
*K. Brož, B. Šourek*

Computer Support of Measurement the Induction Motors - Omega 2002 ..... 810
*V. Hlinovský*

## 10. NUCLEAR ENGINEERING

Time Behaviour of Reactor with Liquid Fuel ..... 814
*J. Křepel*

Influence of Selected Scavengers on Radiation Degradation of 1,2-Dichloroethane ..... 816
*R. Silber, V. Múčka, M. Pospíšil, V. Kliský*

Biomonitoring in the Neighbourhood of NPP Temelin in the Years 2000-2002 ..... 818
*L. Thinová, T. Čechák, J. Klusoň, T. Trojek*

Methodology Preparation of Radon in Caves Continuous Monitoring ..... 820
*L. Thinová, Z. Berka, T. Čechák, D. Milka, E. Brandejsová*

Complex Preparation of Specialisation Extension from Nuclear Reactor Theory and Engineering into Nuclear Installations Theory and Engineering on FNSPE ..... 822
*K. Matějka, J. Zeman, D. Kobylka, M. Kropík, Ľ. Sklenka, J. Bouda*

Microtron Beam Position Control in the Electron Transmission System ..... 824
*Č. Šimáně, M. Vognar, D. Chvátil, V. Němec*

New Trends in Nuclear Reactors Development ..... 826
*K. Matějka, J. Zeman, D. Kobylka, A. Zíb*

MCNP Calculation of Segmented Gamma-scanner Calibration Factors ..... 828
*J. Klusoň, K. Svoboda, T. Čechák*

Nuclear Data for Target and Blanket Neutronic Calculation of Accelerator Driven Transmutation Technology Systems ..... 830
*K. Katovský*

Experimental Study of Subcritical Blanket Blažka with External Neutron Source NG2 at Nuclear Physics Institute in Řež ..... 832
*K. Matějka, J. Rataj, P. Bém*

Training Reactor VR-1 On-line on the Internet ..... 834
*Ľ. Sklenka, K. Matějka, M. Kropík*

Basic Critical Experiment with Core B5 on Training Reactor VR-1 ..... 836
*K. Matějka, J. Rataj, M. Dostál, J. Dufek, M. Kříž, L. Milisdörfer, V. Klupák, S. Dostálová*

Monte Carlo Simulation of Linear Accelerator Electron and Photon Beams for Radiotherapy - Geant4 ..... 838
*M. Soukup*

Quality Assurance of PLA Design for Nuclear Devices ..... 840
*M. Kropík, M. Pech, V. Svátek*

Training Reactor VR-1 Control Rod Drives and Safety Circuits Upgrade ..... 842
*M. Kropík, K. Matějka, V. Cháb*

Determination of Iodine by the Short-term INAA on Training Reactor VR-1 Sparrow ..... 844
*A. Kolros, M. Vobecký*

Sensibility of the Fluoride Salts Flow Computations to the Selected Numerical Parameters ..... 846
*D. Kobylka*

Innovation of Dosimetric System on Reactor VR-1 Sparrow ..... 848
*A. Kolros, R. Starý*

## 11. CHEMISTRY

Utilization of Ionizing Radiation for Removal of Some Toxic Heavy Metals from Aqueous Solutions ..... 852
*M. Pospíšil, V. Múčka, P. Hejnová, R. Silber, J. Dolanský*

Reaction Order of Radiation Dechlorination of Some Aliphatic Hydrocarbons in Aqueous Solutions ..... 854
*V. Múčka, M. Pospíšil, B. Lízalová, D. Poláková, R. Silber*

Remediation of Cs-137 Contaminated Soils ..... 856
*M. Němec, J. John, J. Rezbárik, M. Pražská, P. Skřehot*

Study of Cobalt and Europium Interaction with Humic Acid by Gel Chromatography ..... 858
*M. Cabalka, B. Drtinová, D. Vopálka, J. Dolanský*

Using XRFA for Analysis of Corroded Bronze Objects ..... 860
*T. Trojek*

Role of Kinetic Processes for Sorption Dynamics ..... 862
*D. Vopálka, M. Bozenhard, K. Štamberg*

Elemental Composition of Aerosol in the Region of Příbram Mines ..... 864
*J. Král, J. Voltr, J. Proška, J. Němeček*

Analysis of Trace Elements in Wood-rotting Fungi by PIXE Method ..... 866
*O. Hanzálek*

## 12. BIOMEDICAL ENGINEERING

The Creation of Models of Biocybernetics Systems for Education ..... 870
*M. Šorf, V. Eck, L. Janků, M. Fejtová, D. Novák*

College Licence of Matlab for CTU in Prague, MU in Brno and UWB in Plzeň ..... 872
*J. Hozman*

Gas Exchange Modelling During Artificial Lung Ventilation with Tracheal Gas Insufflation ..... 874
*V. Kopelent, K. Roubík, V. Zábrodský*

Three-Dimensional Dosimetry Using Gel Dosimeters ..... 876
*P. Dvořák, V. Spěváček, J. Hrbáček, J. Novotný Jr., T. Čechák*

Dependence of Opening Angle on Position in Aortic Tree ..... 878
*L. Horný, T. Adámek, O. Kittnar*

Estimation of Age Based on Ossification Ratio Male Thyroid Cartilage ..... 880
*L. Horný, T. Adámek*

Influence of Anthropometric Parametrs on Maximum Aerobical Output ..... 882
*L. Horný, L. Příbaňová, J. Heller*

Oncology and Microwave Applicators ..... 884
*J. Cvek*

Motion Analysis of Human Lower Jaw in 3D ..... 886
*T. Goldmann, L. Himmlová*

Accreditation of Mechanical Testing Laboratory in Accordance with the Standard ČSN EN ISO/IEC 17025:2001 ..... 888
*J. Rosenkrancová, R. Sedláček, S. Konvičková*

The Modelling of Interaction of Biomaterials ..... 890
*M. Vilímek, A. Donát, F. Valenta*

Modelling of the Respiratory System with Respect to its Anatomical Structure Using Electro-Acoustical Analogy ..... 892
*M. Rožánek, K. Roubík*

Mechanical Properties of Mitral Annuloplasty Rings ..... 894
*R. Sedláček, S. Konvičková*

Tubular Microsensor for Stress State Analysis in Living Bone ..... 896
*S. Holý, J. Volf, K. Vítek, M. Bláhová*

Estimation of Aortic Aneurysm Behaviour using Artificial Neuronal Network ..... 898
*L. Horný, J. Vtípil*

Methods of Microwave Applicator Evaluation ..... 900
*J. Herza*

The Possibilities of Tooth Bleaching with Laser Radiation ..... 902
*H. Jelínková, P. Koranda, J. Šulc, M. Němec, T. Dostálová, D. Houšová*

Planar Shape Description by Means of Wavelet Transform ..... 904
*R. Šmíd*

Methodology of Evaluation of Phonocardiograms in Measurement of Pulse Wave Velocity ..... 906
*M. Jelínek, J. Dobeš, L. Poušek*

Excentric Photorefraction in Clinical Practice ..... 908
*J. Dušek, M. Dostálek*

Influence of Mechanical Loading on the Rise and Development of Osteoarthrosis in the Hip Joint ..... 910
*Z. Horák, M. Sochor*

Intelligent Medical Data Analysis ..... 912
*L. Lhotská, J. Kléma, J. Kubalík, J. Palouš, P. Kokol*

Transducer for Pressure Distribution Measurement and Its Use in Biomechanics ..... 914
*J. Volf, J. Vlček, S. Papežová, S. Holý, P. Novák, J. Otáhal*

Carbon Dioxide Laser Thermokeratoplasty ..... 916
*A. Jančárek, G. Kuhnová, M. Vrbová, M. Janek*

Bone Structure Analysis Using X-ray Computer Tomography and Development of a New Diagnostic Method for Osteoporosis ..... 918
*R. Mokso*

## 13. CIVIL ENGINEERING

Experiments with Connections at High Temperature ..... 922
*M. Beneš, F. Wald, Z. Sokol*

Welded Joints in Aluminium Structures ..... 924
*F. Jandejsek, F. Wald*

Protection of Buildings against Ground Moisture - Efficiency and Reliability of Selected Remediation Means ..... 926
*E. Burgetová, D. Bedlovičová*

Relaxation Qualities of Asphalt Mixes ..... 928
*P. Mondschein*

Assesment of Stream Ecological Status in Urban Watershed ..... 930
*D. Komínková, G. Šťastná, J. Nábělková, Z. Handová*

Inverse Modeling of Heat and Moisture Transport Processes in a Building Envelope with Interior Thermal Insulation System ..... 932
*Z. Pavlík, J. Maděra, R. Černý*

Semi-Scale Testing of Interior Thermal Insulation System on Mineral Wool Basis ..... 934
*Z. Pavlík, R. Černý*

Risk Assessment of Urban Drainage Impact on Small Streams ..... 936
*G. Šťastná, D. Komínková*

Test House for Validation of Hygrothermal Performance of Interior Thermal Insulation System on Mineral Wool Basis ..... 938
*J. Pavlík, J. Toman, R. Černý*

Experimental Research of Structural Materials and Technologies ..... 940
*F. Luxemburk, B. Novotný, P. Bouška, P. Mondschein*

The Effect of Extreme Rainfall on the Fuction of Overflows ..... 942
*D. Hánková, P. Štefanová*

Research into Non-force Effects and Aggressive Environment Affecting the Ageing of Historical Structures with Special Emphasis on Charles Bridge in Prague ..... 944
*J. Witzany, M. Gregerová, P. Pospíšil, A. Materna, T. Klečka, P. Bouška, R. Wasserbauer, D. Bedlovičová, E. Burgetová, J. Pašek, T. Čejka, V. Mencl, P. Cikrle*

Functional Qualification and Optimization of Building Structures ..... 946
*J. Witzany, J. Šejnoha, J. Procházka, J. Studnička, J. Jettmar, F. Lehovec, H. Krejčiříková, D. Jarušková, V. Vorel*

Non-parametric Statistic Methods for Motorway Inspection Measurement ..... 948
*V. Vorel, O. Král*

Horizontally Curved Composite Steel and Concrete Bridges ..... 950
*P. Ryjáček*

Prediction of Temperature and Velocity Fields in Glazed Entrance Hall ..... 952
*J. Schwarzer, T. Navrkal*

Fatigue of Asphalt Mixes ..... 954
*F. Luxemburk, B. Novotný, J. Valentin, P. Mondschein*

Measurement of Temperature during Deformation Monitoring of Historical Buildings ..... 956
*P. Vobořilová*

Sustainability through Optimised Structures using Recycled Waste ..... 958
*P. Hájek, R. Wasserbauer*

Fatigue of Girders With Undulating Web ..... 960
*M. Tůma*

Simulations of Erosion Effect of Extreme Precipitation Events by the Help of EROSION 3D Model – Validation of Model Input Parameters ..... 962
*H. Nováková, T. Dostál, J. Veselá*

Determination of Morphological Characteristics of Natural Stream Channels as Basic Data for Revitalization of Watercourses Design ..... 964
*P. Koudelka, K. Vrána, T. Dostál*

Impact of Landscape Retention Capacity on Rainfall-Runoff Regime and Transport Processes ..... 966
*J. Váška, K. Vrána, T. Dostál, P. Paříková*

Models of Wind Actions on Civil Engineering Structures and Their Applications ..... 968
*J. Král, M. Jirsák, S. Pospíšil*

Field Measurement of Soil Hydraulic Conductivity ..... 970
*S. Zemánek, T. Vogel, M. Císlerová, T. Kvítek*

Equivalent Constant Amplitude of Stress Range ..... 972
*L. Tovarová, T. Rotter*

Equalizaton of Students´Knowledge of Process of Construction by Internet Teaching ..... 974
*Z. Jeřichová, J. Ladra*

Applicability of Evaporative Cooling Techniques in the Czech Republic ..... 976
*M. Lain, M. Duška*

Optimization of Reinforced Concrete Structures ..... 978
*M. Lepš*

Optimization of RC Structures ..... 980
*M. Lepš, J. Zeman, Z. Bittnar*

Determination of Soil Erosion by Rainfall Simulator ..... 982
*P. Paříková, J. Koláčková, J. Alexandrová*

Evaluation of Measurement Methods and Results According to Standard CSN ISO 5725 ..... 984
*L. Línková*

Basis for Probabilistic Design of Structural Elements in Accordance with Eurocodes.....986
*M. Sýkora*

Bending Capacity of Thin-Walled Steel Z - Purlins .....988
*M. Rosmanit, T. Vraný*

Hydraulic Model of Drinking Water Distribution System.....990
*K. Slavíčková, R. Kasal, A. Grünwald, M. Slavíček*

Environmentally Optimised Design of the South Façade of a Low Energy Building.....992
*J. Novák, J. Tywoniak*

Geotechnical Engineering II .....994
*J. Jettmar*

Aplication of Tensor Computation in Geodetic Networks.....996
*M. Seidl*

River Basin Management Plan.....998
*Moudar Ahmad*

Water Management in Reservoirs with Increased Safety-Ecological Requirements of Reservoirs Relese .....1000
*P. Chvojková*

Distributed Parameters Usage in Network Simulation Models .....1002
*D. Vytlačil*

Verification of Principles of Sustainable Construction in Two Housing Designs.....1004
*P. Hájek, J. Růžička, J. Novák, R. Začal, J. Kalousek, M. Pavlíková, J. Tywoniak, E. Zezulová, K. Kabele, S. Frolík, J. Mukařovský*

A Case Study of Environmental Assessment of Housing Buildings.....1006
*P. Hájek, M. Vonka, J. Novák, J. Tywoniak*

Concept of Guidelines for Sustainable Construction of Buildings.....1008
*M. Pavlíková, P. Hájek, M. Pavlík, J. Tywoniak*

Technologies of Roof Extensions on Prefabs .....1010
*J. Kovalský, M. Popenková*

Cleaning of Facades with a View to Graffiti Removing.....1012
*M. Hlava, P. Svoboda*

Control of the Water Treatment Process with Neural Networks.....1014
*A. Grünwald, P. Fošumpaur*

Data Mining Methods in the Field of Waste Water Treatment .....1016
*A. Grünwald, P. Fošumpaur*

Hydrodynamics and Water Quality Modelling in a Reservoir.....1018
*P. Fošumpaurová, P. Fošumpaur*

Risk Modified Dynamic Model Creation.....1020
*V. Beran, P. Dlask*

Temperature Fields Measurement in Road Bridge Barikádníků in Prague ..... 1022
*J. Římal, V. Jelínek, J. Chod, H. Horká, K. Maleček, A. Kovářová, F. Vodák, O. Kapičková, J. Zaoralová, B. Klobouček, B. Sopko, S. Kasíková*

Temperature Fields Measurement in Railway Bridge in Královské Poříčí ..... 1024
*J. Římal*

Risk in Tunnels Assessed using Bayesian Networks ..... 1026
*M. Holický, J. Marková*

Probabilistic Modelling of Carbonation Depth ..... 1028
*M. Holický, J. Marková*

Study of Earth Heat Exchanger ..... 1030
*M. Kabrhel*

The Application of Revised Universal Soil Loss Equation (RUSLE) for the Estimation of Erosion Risks in the Kamenice River Watershed ..... 1032
*A. Jakubíková, J. Váška*

Compression Tests of Masonry from Unburned Bricks, Mechanical Physical Properties of Unburned Bricks ..... 1034
*J. Růžička*

Ecological Study in Water Reservoir Flaje Catchment ..... 1036
*M. Slavíček, A. Grünwald, B. Šťastný, K. Slavíčková*

Automated Measurements of Hydraulic Parameters of the Soils in Presence of the Preferential Flow Close to Saturation ..... 1038
*M. Sněhota, M. Císlerová*

Influence of Factors on Function of Excavator Working Tool ..... 1040
*K. Jeřábek, V. Voštová, J. Jurman*

Opimalization of Maintenance Management of Housing Found ..... 1042
*M. Párová*

Technical Solution of Draining Shaft Manufacturing Using Special Concrete and Concreting Design including a New Mould ..... 1044
*J. Ladra, P. Svoboda*

Accuracy Evaluation of LVDTs and Strain Gages for Dynamic Measurement of Engineering Structures ..... 1046
*M. Černý*

Floods Analysis and Mitigation on the Orlice River (FLAMOR) ..... 1048
*P. Valenta, J. Valentová, A. Patera*

Computer Support of Practices of Engineering Surveying Objects ..... 1050
*P. Hánek, F. Bubeník, P. Hánek Jr.*

The Analysis of the Unsteady Thermal Behaviour of the Building ..... 1052
*K. Aubrechtová, J. Tywoniak, Z. Svoboda*

Corrosion Control in a Distribution Network of Drinking Water ..... 1054
*A. Grünwald, M. Šaršeová, B. Šťastný, K. Slavíčková, M. Slavíček, K. Vlčková, J. Zeithammerová*

Effect of Chlorination and Sonication on Removal of Humic Compounds from Water ..... 1056
*A. Grünwald, V. Přikrylová, K. Slavíčková, B. Šťastný, M. Slavíček, K. Vlčková, J. Zeithammerová*

Characteristics of Organic Precursors and Their Relationship with Disinfection By-products ..... 1058
*A. Grünwald, B. Šťastný, K. Slavíčková, M. Slavíček*

Research of Co-operation of Soil and Geotextile Like Basis for Static Proposition of Bank ..... 1060
*S. Sedláčková*

Measuring Methods and Equipments Applied at the Model Plant of Roll-Belt-Conveyer ..... 1062
*J. Polnický, K. Jeřábek*

Mechanical Properties of Composites and Adhesives for Strengthening of RC Structures ..... 1064
*M. Černý*

Investigation into Strength of Thin-Walled Girders ..... 1066
*P. Brož*

## 14. ARCHITECTURE AND TOWN PLANNING

Optimum Laser Systems in Industrial Metrology (part 4) ..... 1070
*M. Kašpar, R. Blažek, P. Hánek, J. Pospíšil*

Sustainable Growth and Life Cycle Management of Buildings and Towns - Economy and Development of Czech Towns in the Past ..... 1072
*K. Maier, M. Hůla, P. Nacu, D. Němeček, A. Jurkovič*

Architecture - Environment, City planning, Construction, Space Arrangement, Technology for Sustainable Development ..... 1074
*D. Koišová, G. Kucejová, T. Podlešáková*

Effective Disconnexion of Thin-Walled Structures Using the Blasting Technique ..... 1076
*T. Pokorný*

Research of Historical and Contemporary Architecture - 4th Phase (year 2002) ..... 1078
*P. Urlich*

Central Archives of Historical Building Surveys ..... 1080
*M. Ebel*

The Central Europe Metadatabase of Geographical Data ..... 1082
*J. Vorel*

Digital Methods within the Design and Presentation of Architecture ..... 1084
*M. Fischer, P. Vaněk*

Planners´Formation for Sustainable Urban and Regional Development ..... 1086
*I. Horký, A. Mansfeldová*

Transformation of Urbanisme ..... 1088
*J. Mužík, J. Sýkora, M. Baše, K. Maier, M. Hexner, I. Kaplan, I. Oberstein, I. Vorel, J. Mejsnarová, K. Vepřek, J. Zajíc*

Spatial Models of Historical Buildings - Possible Areas of Utilization ..... 1090
*J. Hodač*

Relationship Between Digital and Physical Models Used in Teaching Processes in Ateliers of Architectural Creation ..... 1092
*P. Mezera, V. Dvořák, L. Dufek, J. Křemen*

Real and Digital Models in Architecture ..... 1094
*L. Dufek*

Computer Models of Buildings. Practices, Teaching, Relationships, Perspectives ..... 1096
*J. Křemen, V. Hamata*

Architectural and Historical Field Research as a Base for Creation of Digital Models of Architecture ..... 1098
*M. Nesměrák*

Model Methods of Design, Model and Presentation Techniques in Architecture ..... 1100
*J. Pospíšil*

Influence of Strategic Investments on the Regional Development and Its Consequences ..... 1102
*D. Němeček*

PROLAB – Changes of Real and Virtual Space ..... 1104
*P. Bednář, O. Vinař, M. Pelešková, D. Branderský*

PROLAB – Virtual Exhibition Design – New Effective Tool of Marketing and Communication ..... 1106
*P. Bednář, O. Vinař, M. Pelešková, P. Slavík, P. Vašenda*

The Influence of Strategic Investments on the Territorial Development of Regions and its Consequences ..... 1108
*P. Nacu*

## 15. TRANSPORTATION, LOGISTICS, ECONOMY, MANAGEMENT

Sociological Analysis of the Production Process ..... 1112
*M. Kavan*

Advanced Methods of Flexible Pavement Design and Rehabilitation Enhancement ..... 1114
*B. Novotný, F. Luxemburk*

The Role of SMEs in the Regional Development of the Czech Republic ..... 1116
*V. Beran, P. Dlask, J. Frková*

Internet Information Sources for Development of Product Strategies of Small and Medium-sized Industrial Enterprises ..... 1118
*J. Procházka, V. Dolanský*

The Life Cycle Costs Application on an Equipment Renewal ..... 1120
*V. Šajner*

Ecological Aspects of Transportation ..... 1122
*K. Neubergová, B. Kubát*

Application Wireless Technologies in Transportation ..... 1124
*J. Bláha*

Risky Alternatives Decision Making Under Incomplete Information
On Scenarios Probability ..... 1126
*L. Vaniš*

The Channels via Which the Foreign Direct Investment Affects
the Domestic Economy ..... 1128
*H. Pačesová*

SW Tools for Engineering Support ..... 1130
*V. Beran, J. Frková, V. Berka, P. Dlask, L. Hačkajlová, L. Jilemnická, J. Tománková*

Sustainable Development in Regions ..... 1132
*V. Beran, J. Frková, P. Dlask, L. Jilemnická, J. Tománková*

IT (Information technology), support to HR (Human Resource Management) ..... 1134
*R. Kyptová*

Evaluation of Investments in Information Technology Projets ..... 1136
*P. Kuře*

The Planning and Management of Lifelong Education ..... 1138
*T. Macák*

Methods of Strategic Management in Transnational Companies ..... 1140
*Majed Ayoubi*

The Effective Organization ..... 1142
*P. Mareš*

Expert System for Tendering of Public Construction Orders ..... 1144
*L. Hačkajlová, T. Hlaváček, V. Tatýrek*

Distribution of Overhead Costs in an Engineering Enterprise ..... 1146
*D. Mádlová*

Complex Assessment of the Benefits of Road Infrastructure Development ..... 1148
*F. Lehovec, P. Karlický*

Marketing Strategy in Integrated Engineering ..... 1150
*M. Prajer*

Innovation of the Road Pavement Catalogue TP 78 ..... 1152
*L. Vébr, F. Luxemburk, B. Novotný*

Design of Field Thoroughfares ..... 1154
*L. Vébr*

Strategy of Preventive Protection in Construction Industry ..... 1156
*L. Jilemnická*

Enterprise Selection ..... 1158
*P. Malát*

Acoustic Emission of Grass-covered Tram Track ..... 1160
*H. Špačková*

Sustainable Growth of Building Capacities Owing to the Preparation of the Czech Companies for the Access to the EU Building Market ..... 1162
*V. Hájek, J. Novák, J. Vokálová, V. Jelen, B. Horáková, J. Jakubše, Z. Prostějovská*

The Role of Human Resource Management in Employees' Development ..... 1164
*K. Horáková*

FDI and the Internationalisation of R&D ..... 1166
*J. Zahradník*

Findigs from Research on Development of Technically Oriented Managers ..... 1168
*R. Kreim*

Decision Aspects of Quality, Ecology and Safety of Products in Integrated Engineering ..... 1170
*J. Zahradník*

Various Possibilities How to Repair Wooden Elements by Means of Filling ..... 1172
*P. Neumann, P. Svoboda*

Specification of the Standard Cost Model of New Products ..... 1174
*K. Macík*

Managerial Support of the Product Development Process ..... 1176
*F. Freiberg*

Specific Methods and Seven New Tools of Quality Management ..... 1178
*J. Kožíšek*

Implementation of the Europe Flight Regulations in Flight Training Organisation of C.T.U. ..... 1180
*M. Kameník, L. Capoušek, B. Hřebejk, B. Stavovčík, J. Sobota*

Development of Product Strategies Supported by Information Systems ..... 1182
*V. Dolanský, P. Žemlička*

Market Capitalization Optimizing ..... 1184
*J. Vodička*

Management Processes in Technical-economic Design, Decision-making, Fractals and Market Bubbles ..... 1186
*V. Beran*

Project Management of Public Construction Contracts ..... 1188
*V. Tatýrek, T. Hlaváček*

Units Throughput in the Area of Non-linear Processes ..... 1190
*V. Svoboda, M. Kortanová*

Product Costing: Starting Target of Development Process or Result of Development?..... 1192
*M. Zralý*

Planning in the Project Management ..... 1194
*J. Tománková*

System Dynamics in Project Management ..... 1196
*D. Vytlačil*

The ITS Applications Using the GNSS System..... 1198
*M. Svítek*

Transport of Dangerous and Oversized Goods ..... 1200
*F. Kopecký, M. Svítek*

Evaluation of the State in the Public Space of the Cities after Overflow ..... 1202
*P. Šrytr, P. Havelka*

Section 6

# MECHANICS
# &
# THERMODYNAMICS

# Dynamic Performance of a Single-pipe Heating System

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This project inquires into dynamic performance of a single-pipe horizontal heating system (hereafter SHHS) with the riding connection of radiators. The measurement experimentally ascertained the optimal velocity in the basic pipe and assessed the influence of the natural uplift on leakage into the radiators, which were connected from the both sides from up - downwards and from down - downwards.

This project inquires into dynamic performance of a single-pipe horizontal heating system (hereafter SHHS) with the riding connection of radiators. The measurement was carried out on the SHHS, installed in the hall laboratories of the Environment Engineering Institute, Faculty of Engineering, Czech Technical University, Prague.

The measurement experimentally ascertained the optimal velocity in the basic pipe and assessed the influence of the natural uplift on leakage into the radiators, which were connected from the both sides from up - downwards and from down - downwards. The measurement also ascertained how closing of one of the radiators influence heat-technical performance of the SHHS.

The heating system has five radiators with the riding connection and the measurement itself was carried out during three different flows of the heating water through the system, i.e. at different velocities in the basic pipe. The measurement was carried out at velocity of 0,9 m/s in the basic pipe, and further at velocities of 0,7 and 0,4 m/s. All the values, ascertained during the experiment, were processed and interpreted in a graphic form, in order to remain well-arranged.

The experiment confirmed our presumption of optimal velocity of 0,9 m/s in the basic pipe. The whole system performed very steadily at the above stated velocity and the output of all radiators was spread out uniformly. In contrast, at velocity of 0,4 m/s the system performed very unsteadily and the heat-output was spread out very uneven in the SHHS. The results ascertained at velocity of 0,7 m/s differed just slightly from those at velocity of 0,9 m/s.

The measurement confirmed the presumption of better leakage into the radiators, connected from down - downwards. This connection takes advantage of the natural uplift in the radiator, which enables faster and more perfect flush of the radiator with the heating water. The radiators connected from up - downwards had slower start of the maximum output and smaller utilization of the natural uplift, as opposed to the radiators connected from down - downwards.

The measurement carried out at velocity of 0,9 m/s of heating water in the basic pipe showed, that closing of the first radiator leads to a considerable rise in the output of the second radiator (by 564 per cent!) in the hydraulic line. The output of the other radiators remains almost uneffected at the above stated velocity. When we closed the third radiator, it

resulted in a rise in the outputs of the previous (i. e. the second) radiator and the following (i. e. the fourth) radiator. The rise in the second radiator makes 36 per cent and in the fourth radiator 127 per cent. Closure of the last (i. e. the fifth) radiator had practically no effect on the outputs in the previous radiators in the SHHS.

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# Starting up of Radiators in By-pass

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The research documents appropriately and unambiguously the dynamic behavior of panel radiators and compares the following types of connection: two-sided, from above downwards and from below downwards. However the results of experiment need not have strong ties only to by-pass connection with single-tube horizontal heating system (JHOS), but it can concern even the vertical or horizontal two-tube systems only with regard to inlet and outlet tubes connection to radiator.

The experiment was intended on a rate of starting up of radiator in by-pass connection with single-tube horizontal heating system. There was watched uniformity of temperature field after attaining 93% energy output too. Two different connection of the radiator was used: two-sided, from above downwards and from below downwards.

The two camera shooting radiators were cut-off till the JHOS was warmed up to performance temperature. The start of camera shooting radiators was corresponding with full opening of the radiators valves. Shooting time interval was setup at 5 seconds till attaining 93% energy output and then modified to 30 seconds. Comprehensive set of picture for evaluation was obtained for both radiators this way.

In the first case (from above downwards - diagonally), after 30 seconds, left upper part of the radiator is warmed up. Remaining heat exchanging area has still ambient temperature. Upper distributing chamber is warmed up after 1 minute 20 second and the rest of radiator is warmed against buoyancy. The right part of radiator is warmed up faster due to more expressive buoyancy effect in left part and diagonal connection. There is still uneven temperature field, after 6 minute 20 second. Full energy output of the radiator is reached slowly in next 5 minutes.

In the second case (from below downwards), there is obvious faster warming up than in the first case after 20 seconds (after full opening of the radiator valve). The buoyancy effect helps warm up the upper distributing chamber and upper third of the radiator is warmed up to performance temperature after 40 second. The temperature field is more uniform than in the first case, except first two vertical channels which are slightly warmer than remaining part of the radiator due to buoyancy effect from the hot water inlet.

The rise time is about 1 minute shorter in the second case than in the first case.

In the first case (from above downwards), the buoyancy effect acting against pump forced flow. The temperature field is developed slowly and unevenly. There is possible to suppose that both convection heat transfer and radiation heat transfer are unbalanced during a heating season due to control interference.

In the second case (from below downwards), the buoyancy effect helps warm up the radiator. It causes faster flow in to upper distributing chamber, especially by first two vertical channels. Starting up of radiator is faster and temperature field is stabilized faster at well-balanced values.

Connection from below downwards could be recommended for radiators connecting in by-pass to single-tube horizontal heating system. Control response is faster and control of the single-tube horizontal heating system with radiators in by-pass is more effective.

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# Steady State Heat Analysis of Diesel Engine Cylinder Head

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Cylinder heads of diesel engines experience severe thermal and mechanical loading under engine operation as they are directly exposed to high combustion pressures and temperatures. In addition, they need to house intake and exhaust valve ports, fuel injector and complex cooling passages. Compliance of all these requirements leads to many compromises in design. As a result, cylinder heads often fail in operation (deformations, cracks) due to overheating in regions of limited coolling. In this work we put the emphasis on the problematic regions around the valve seats and narrow bridges between valves. The main portion of heat accumulated in valve is rejected through the contact surface of the valve seat. Therefore, deformations of these parts accompanied with improper contact and occurrence of leakage dramatically increase thermal loading of valves and promote their destruction.

A three-dimensional numerical analysis based on the finite element method (FEM) has been used to predict the detailed steady-state temperature distributions within the cylinder head. This analysis was conducted by using the solver ABAQUS/Standard, which provides a comprehensive, general-purpose finite element analysis tool that includes a variety of time- and frequency-domain analysis procedures and ABAQUS CAE was used for modeling and visualization, which performs using ABAQUS/Standard and creating geometry of model and finite element models using advanced meshing and easy-to-use procedures for defining loads and materials properties.

The FE model was created for the cylinder head of a big direct-injection diesel engine commonly used in power generation units. The main parameters of the engine are: bore 275 mm, stroke 330 mm, mean effective pressure 1.96 MPa and nominal speed 750 rpm.

The cylinder head is made of casted iron. It contains two intake and two exhaust valves made from forged alloy steel. The valve guides as well as valve seats are pressed into the head. The seats of exhaust valves are cooled by cooling water which flows through the annular cavities around the seats. The fuel-injector is situated into the axis of the cylinder. The developed FE model includes all these components. The real design of the cylinder head was slightly simplified in details to make meshing easier. The model of the cylinder head block was created by using 3D product development software Pro/Engineer and imported as a CAD model, unlike the models of other components (valves, seats, valve guides and fuel-injector) were developed directly in ABAQUS CAE. In case of valves and fuel-injector, some parts of these components which were considered having negligible influence on results were significantly simplified or completely left out. The interaction between components of the FE model is described using the mechanical and thermal contacts.

Thermal loading involves the heat fluxes from burning in-cylinder gases and the convection from the burned gases exhaust around the surface of valve stems, inner surface of valve seats and along exhaust-port walls. Although all these parameters are due to cyclic nature of engine operation periodically varying in time, the computation are performed assuming steady-state loading using the averaged (mean) values. Considering the speed of the periodical changes with comparison of thermal inertia of all the components of cylinder head, this simplification is acceptable. Boundary conditions - the in-cylinder gas-to-wall as well as intake and exhaust port heat transfer coefficient and bulk gas temperature were obtained from the detailed thermodynamic analysis of the engine using the 0-D thermodynamic model OBEH [4] based on Eichelberg's empiric equation. The coolant side boundary conditions were based on values reported in the literature. The possibility of exceeding the boiling point of cooling water and associated steep changes in heat transfer coefficient were at the current stage of model development neglected. Remaining free surfaces are desribed using heat transfer coefficient and bulk air temperature. Mechanical boundary condition are as follows: the head is placed on the sealing and using six bolts fastened to the rigid block, which substitutes engine cylinder.
A total of 220,311 node points and 121,658 elements were employed to describe the FEM model.
Results of the first calculations provide some interesting information on the temperature distribution in components of cylinder head. First, a positive influence of cooled seats of exhaust valves is apparent as the temperature within the exhaust valves exceed just slightly those in intake valves experiencing significantly lower thermal loading. Region between the hole for engine starting and adjacent intake valve seat appears as the most problematic region from the point of view of thermal loading. In this region the cooling passages otherwise created through the whole gas-side wall of the cylinder head are missing because of the situation of the mentioned hole enabling the engine starting by means of supply pressurised air.
FE model of very complex cylinder head assembly was developed and used to simulate quasistatic thermal analysis. Following mechanical computations including thermal and pressure loading and assembling prestress.

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# Models of Dynamical Mechanical Systems with the Possibility of Simulation of Operating Behavior Solved by MATLAB and SIMULINK and Present on the Web Pages

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The contribution presents the numerical solution and simulation of operating model's behavior of mechanical and hydro mechanical systems with MATLAB and SIMULINK. Systems parameters, driving and loading forces or moments, elasticity, damping and unbalances mechanical parts, clearances, friction, etc. have influence on the behavior of system. The model of mechanical system, which is mostly system with more degree of freedom, is usually compiled with a driving asynchronous or direct current motor, gearbox, mechanisms, kinematics bonds, control parts and driven machine.
The mathematical model of this system's model is compiled with the equations of motion based on the second Lagrange equation, Newton`s second law or d`Alembert`s principle. The equations of motions are system of non-linear differential equations. The numerical solution was performing using computer programs MATLAB or SIMULINK.
The knowledge of dynamical characteristics of these systems is inherent part of engineering. It is important for the construction and design of machines and for the regulation and control of different process. Therefore the part of the Bachelors studies at the Faculty of Electrical Engineering CTU is also courses in technical mechanics and especially in the field of Electrical Power Engineering and Control Engineering. The objects of the engineering course are mandatory, voluntary as well as optional. The courses proceeded at a basis, which the students have received in physics in the first two years of their studies. These courses widen their technical and practical knowledge. The students get to know methods of vector and analytic static systems, kinematics of planar mechanisms and especially dynamical systems with one and n-degree of freedom.
For the compilation equation of motion Newton's second law or Lagrangian equations of the second order is being used. The equations of motion of these mechanical systems are in most cases systems of non-linear algebraic-differential equations. The reason for non-linear equations is non-linearity of kinematical bonds, passive resistances, dampers or elastic elements. Their analytic solution is limited to few exceptional incidents. In research description of non-linear systems it is necessary using numerical methods in connection with computer systems. Compared to other possible software products MATLAB appeared to be the most successful for teaching.

A method of solution for the characterization of a physical model of real machine system has been developed including non-linear elements with dissipation of energy and conditional bonds. The computational system MATLAB and SIMULINK uses a numerical solution in order to solve the mathematical model, i.e. the system of non-linear differential equations of the second order. The modeling, numerical solution and dynamical simulation of operating duty of system, make possible the design of parameters of those system.

The construction of physical and mathematical models of non-linear machine systems and the use of MATLAB and SIMULINK will be illustrated in paper by practical example.

For an independent study of student was compiled collection models examples both mechanical and hydro mechanical system including in introduction methods explanation of compiled equation of motion and also the examples both models of mechanical and hydro mechanical systems. First models are easy models with one degree of freedom and following models are models with more degree of freedom. Every example includes the figure of system, method of compilation of equations of motion, numerically solution and graphical output demanded parameters.

The numerical solution is realized with MATLAB m-files or SIMULINK scheme. Web pages are to the disposition of the students.

The contents of the Web Pages is:

1.Introduction to MATLAB
- 1.1 User Environment
- 1.2 Elementary Function
- 1.3 Matrix and Operation with Matrix
- 1.4 Form of Function
- 1.5 Visualization
- 1.6 Simulink

2.Methods of Compilation of Equations of Motion

3.Models of Mechanical and Hydro Mechanical Systems
- 3.1 Mechanical System with Unbalanced Rotor installed on an Elastic Frame (review of the influence of centrifugal force, elastic and damping coefficient of an elastic frame)
- 3.2 Mechanical System with Unbalanced Rotor installed on two Elastic Frames (review of the influence of centrifugal force, elastic and damping coefficient of an elastic frame)
- 3.3 Mechanical System with Elastic Coupling Driving with an Asynchronous Motor
- 3.4 Mechanical System with Elastic Coupling and Gearbox Driving with Direct Current motor (solution with using MATLAB)
- 3.5 Machine with Elastic Shaft Driving with Asynchronous and Direct Current Motor (solution with using SIMULINK)
- 3.6 Mechanical System With Elastic Shaft and Rack Driving with Asynchronous Motor
- 3.7 Model of Manipulator with Two Degrees of Freedom
- 3.8 Model of a Hydro Mechanical System with Two Tanks
- 3.9 Mechanical System with Two Moments of Load Driving with Asynchronous Motor
- 3.10 Model of Manipulator with Three Degrees of Freedom
- 3.11 Model of the Winch with Four Degrees of Freedom with Elastic Coupling and Elastic Frame
- 3.12 Model of Machine System with Gearboxes and Three Degrees of Freedom

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# Ductile Crack Growth Modelling Using GTN Model

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Ductile crack propagation in notched tensile specimens machined from A508 pressure vessel steel was numerically modelled using the Gurson-Tvergaard-Needleman model, Eq. (1), described elsewhere (e.g. [1-4]). A user-material subroutine [2] incorporating the modified Gurson-Tvergaard-Needleman model of porous metal plasticity was introduced into the ABAQUS™ software package.
The yield condition is given by:

$$\Phi = \frac{\sigma_{eq}^2}{\sigma_*^2} + 2q_1 f^* \cosh\left(\frac{3}{2} q_2 \frac{\sigma_m}{\sigma_*}\right) - (1 + q_1^2 f^{*2}) = 0 \qquad (1)$$

where $\sigma_{eq}$ is the macroscopic von Mises stress, $\sigma_*$ is the current flow stress of the matrix, $\sigma_m$ is the hydrostatic stress, $q_1$ and $q_2$ are parameters, $f^*$ is the equivalent void volume fraction taken as:

$$f^* = f \qquad \text{for} \qquad f \le f_c$$
$$f^* = f_c + \delta f \qquad \text{for} \qquad f > f_c$$

where $f_c$ is the critical void volume fraction inducing void coalescence.

It can be shown easily that $\sigma_{eq}$ is zero for $f^* = 1/q_1$. The ductile crack extension is, therefore, numerically represented by the local increase of void volume fraction.
The evolution of the void volume fraction is given by the differential equation:

$$\dot{f} = (1 - f)\,tr(\dot{\underline{\underline{\varepsilon}}}^p) + \frac{f_N}{s_N\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{\varepsilon_M^{pl} - \varepsilon_N}{s_N}\right)^2\right] \dot{\varepsilon}_M^{pl} \qquad (2)$$

with initial condition $f(t=0) = f_o$. The first term in Eq. (2) represents existing void growth, the second term the nucleation of new voids.

For the finite element simulations, the matrix was represented by an elastic-plastic material obeying the Hollomon stress-strain law given by Eq. (3). The flow stress is assumed to vary linearly with temperature (first order approximation).

$$\sigma_* = \sigma_o = K\varepsilon_{pl}^{\,n}(1 - \beta T) \qquad (3)$$

where $T$ is the absolute temperature (in the 183-373 K temperature range), and $n$, $K$, $\beta$ are parameters ($n$=0.14, $K$=1278 MPa, $\beta$=0.001 $K^{-1}$).

Parameters of Hollomon law were identified from compressive tests on an INSTRON hydraulic testing machine in previous research [2].

Linear axisymmetric elements with selective integration were employed in the finite element analysis. The mesh size in the ligament was (100 x 100) $\mu m^2$. The computations were performed in the framework of finite strains, with an updated-Lagrangian formulation.

The parameters of model were chosen in order to fulfil the load drop in the load vs. reduction of diameter diagram of notched tensile specimens NT2, NT4 and NT10 tested at 0 °C. The parameters are assumed not to vary with temperature or with strain rate, which seems to be fulfilled in the temperature range where ductile crack occurred (from -60 °C to 0 °C). The resulting set of parameters allows modelling of ductile crack growth at different stress triaxialities and can therefore be used to account for other specimen geometries such as compact tension (CT) or central notch (MT) specimens.

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# Optimizing of Laminate Plate Elastic Behavior

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Problems of structural optimization and analysis of stress and strain lead often to function optimization problem to minimize a given functional subject to system of differential equations and inequalities with some boundary conditions, and system of integral equations and inequalities. This class of structural optimization problems is called function structural optimization. The branch of mathematics that deals with this problem is called the Variational Calculus. Difficulty of solving this problem is the motivation that brought to the idea of transforming given function optimization problem with Galerkin method (with basis according to finite element method) to a problem of parameter optimization. This paper deals with both the function optimization and parameter optimization of laminate plate stiffness.

The paper is specialised in expressing the relation of a measure of laminate plate stiffness with respect to fibre orientation of its plies. The inverse of scalar product of lateral displacement of plate central plane and lateral loading is the mentioned measure of laminate plate stiffness. In the case of simply supported rectangular laminate plate this measure of stiffness is maximized and optimum orientation of its plies is searched.

We contemplate the problem of rectangular laminate plate with common but fixed given dimensions, number of plies, thickness of plies, mechanical properties of orthotropic plies and lateral loading that is simply supported on its boundary with the aim to specify an orientation of its plies that maximize the measure of stiffness that is inverse of measure of compliance. The measure of compliance is given by scalar product of the deflection function describing deformed middle plane of the plate and the lateral loading over the projection of the plate into middle plane.

We must search an actual deformed state with respect to the common plies orientation. This solution is used in the above expressed measure of compliance and minimum of this expression is searched.

It is not worthwhile to present the way of constructing of this relation. It is also not worthwhile to present the way of resolving of this. Therefore, we only introduce the result.

First example: a square plate with six plies that are laid symmetric whit respect to the middle plane of the plate. This plate is continuous loaded with value increasing as the co-ordinates are increasing.

There are three variants of solution that have the same value of our measure of stiffness. This value of measure of stiffness is the maximum from all ones. The optimal plies orientation is 45° for all plies, the only difference is an orientation (plus, minus). It is interesting that the first variant is balanced and therefore not twisted.

Second example: a rectangular plate with side ratio 1:2 with six plies that are laid symmetric whit respect to the middle plane of the plate. This plate is also continuous loaded with value increasing as the co-ordinates are increasing. The same remark as for the previous example holds also for this one. The only contrast is the optimal plies orientation. At this example it is 75°.

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# A Fan Duct Design of a Very Light Aircraft Power-Plant and Its Experimental Aerodynamic Investigation

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So-called „cold jet" power plants of very light aircraft composed of a piston engine, a blower and a necessary air duct realized up to now have been unsuccessful. Analysis has shown that the difficulty mainly was the deformation of the flow fields at the entry of the blowers.

A CFD method analysis of the originally designed channel has revealed substantial nonuniformity of the flow field at the blower disk cross section (up to 40% of the mean velocity). Instead of classic design with inlet diffuser, a plenum chamber and an inlet nozzle into the blower a new sedately convergent one has been designed. The aim of the design was to keep laminar boundary layer along the all channel within all service conditions.

Elementary dimensions of the channel have been calculated from engine parameters and fuselage structure layload. To prove the new ways to the design of an inlet channel comparison has been realized at three variantsof the new inlet channel with the classic one. To check these types of inlet channel numerical calculations of the velocity distribution the entry of the blower has been performed using commercially available Fluent 6 CFD software.

As entry at the Fluent 6 program a 3D model of the channel in the CAD system Unigraphics has been used. Altogether 12 variants of the inlet channel have been considered with different shapes at the leading entry and relative position of axis of the blower.

The 3D computation grid has been generated using the Gambit preprocessor into which the model of the channel has been imported using IGES format from the Unigraphics system. The grid of the classic channel had $470.10^3$ elements the new channels used about $100.10^3$ elements, since their shapes were less complicated. In all cases similar boundary conditions were applied. At entry a "Velocity Inlet"condition has been applied with uniformdistribution of velocity, at the outlet a "Pressure Outlet" has been used. At the plane of symetry a boundary condition "Symetry" has been applied. In all cases $w_1$=50m/s was used. Numerical calculations have been performed with the segregated solver steady and incompressible flow has been computed. Turbulence model "Realizable k-ε model has been applied and intensity of turbulence 0,2% proposed.

At the entry of blower the lowest velocity has been about 70m/s and the highest one about 120m/s for the classic type of the inlet channel. The velocity at the entry of the blower of the new inlet type varies in a zone of 6% of the mean velocity only.

For the verification by aerodynamic experiments the variant with the smallest nonuniformity of the flow field at the blower area has been choosen. The CAD system Unigraphics has been used again to create a positive mold (mock up) of the choosen inlet channel variant in scale 1: 1,934. A handmade technology of the mold made of playwood ribs and urethane foam core has been intended and prepared. In the end to provide higher shape precision of the mold the CAM technology based on UG model has been used. A sample of the inlet channel made of composite sandwich (reinforced glass fiber laminate and urethane foam core) has been manufactured by the company Comlet in Litomyšl.

An aerodynamic experiment methodology for investigation of the outlet velocity field has been prepared. An actual experimental device – a wind tunnel in laboratory of the Ú207.1 dept. – had to be modified. A new inlet nozzle of the investigated channel fixed to the plenum chamber flange was manufactured. In the plane of the channel outlet a traversing device with the five holls probe has been installed. Two stages of the aerodynamic mesurement have been considered.

The first stage consisted of manual setting of the probe possition and total pressures recording. The outlet velocity field (axial component of the velocity vector only) of the channel has been mapped at the 250 measured points. At the present time the measurement is being evaluated. The first results signalize that the outlet velocity varies less 4% of the mean velocity.

In the second stage the semiautomatic procedure of the measurement is being supposed. The special software for such assignment, the pressure scanner by Pressure Systems, Ltd. and an electrical driven device of the traverser have been provided.

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# Air Flow Patterns in Cleanroom with Personnel Protection Zone

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This project is concerned with development of airflow patterns visualization and measuring in cleanrooms with low velocities of flow. Project is supported by FRVŠ grant No. FRVS2096/G1: Influence of air ventilation elements to flow field in cleanrooms.

Cleanroom is a room, in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation and retention of particles inside the room and in which other relevant parameters e.g. temperature, humidity and pressure are controlled as necessary. It is definition in ISO standard 14644-1.

Cleanroom airflow patterns can be categorized as either unidirectional or non-unidirectional. When a combination of the two is used it is frequently called mixed airflow. Airflow patterns for cleanroom class ISO Class 1-5 is unidirectional while non-unidirectional and mixed flow is typical for cleanroom ISO Class 6 and less clean. In cleanrooms of lower classification where unidirectional air is not required, it is sometimes desirable to maintain zones of higher airflow to segregate process cores within the cleanroom, a modified unidirectional airflow system is used which may be called directed airflow.

Unidirectional airflow may be either vertical or horizontal. Both types of unidirectional airflow have air return inlets, which are nearly opposite one another in order to maintain the airstream in as straight a flow patterns as possible. In both designs, the important design feature is the ability to ensure that the airflow patterns are disrupted as little as possible at the process core.

As part of the testing procedure to ensure that a cleanroom is making correctly, the air movement within the room should be checked. It is necessary to check that there is sufficient air movement within the room to either diluted, or remove, airborne contamination and hence prevent a build-up of contamination.

In turbulently ventilated cleanrooms, air is supplied and mixed in a turbulent may. Good mixing should be demonstrated in all parts of this type of cleanroom to ensure that the contaminants will be removed. However, it is particularly important in critical areas, where the product is exposed to the risk of contamination, to demonstrate that good mixing is obtained. In unidirectional flow, to ensure the cleanest conditions, critical areas should be supplied with air coming directly from the high efficiency filters. However, problems may be encountered because of:

- heat rising from the machinery and disrupting the airflow
- obstructions preventing the supply air getting to the critical area
- obstructions, or the machinery shape, turning the unidirectional flow into turbulent flow
- contamination being entrained into the clean air

Visualization the airflow will demonstrate whether or not any of these problems exist and whether they are likely to cause an increase in contamination.

For experimental verification of elimination of mentioned above problems in the unidirectional airflow cleanrooms and investigation the influence of airflow inlets and outlets arrangement to flow field in cleanrooms, a modular experimental chamber was built in the laboratory of

Department of environmental engineering. The experimental chamber has the parameters: height 2,8 m, length 2,7 m and width 1,2 m and serves as the two – dimensional model of the cleanroom with a source of contaminants and a personnel safety zone. The chamber is adjustable and enables to build the variety of air inlet arrangements and velocities in the ceiling and variety of air outlet arrangements and outlet velocities in the contamination zone and in the personnel zone. One wall of this chamber is made from Plexiglas due to visualization air movement and for measuring velocity field by streaming method. The chamber is designed as the under – pressure chamber. Two fans are used for air ventilation in the contamination and personnel protection zones and are controlled by frequency converters.

There are a number of methods that can be used to visualize the flow of the air in a cleanroom. These can be grouped under the following headings:

- streamers
- smoke or particle streams
- air velocity and direction measurement

Streamers – the types of streamers that are used to visualize airflow are threads or tapes. The best types are those which have a high surface area to weight ratio and can be easily seen. A useful way of using streamers is to attach it onto the end of an anemometer; it can then be used to ascertain the direction of air when the velocity is being measured at a particular spot. A permanent record of the airflow within the cleanroom can be obtained be measurement of the velocity and direction over a section of the room. Setting up a guide in the room helps with this. Stands the height of the room should be used and strong thread strung across the stands. The thread is marked at given intervals, so that points are available for measuring air velocity and direction. Streamers are useful to indicate the direction of airflow, but do not give an exact representation; because of their weight streamers do not flow with the air stream. This is a problem, which increases as the air velocity decreases.

Smoke or particle streams – there are a number of methods suitable for generating smoke ao particle streams that are used to show the flow of air in cleanrooms. However, the use of oil smoke may not be acceptable in some cleanrooms, as oil left on surfaces can be contamination hazard. Water vapour is a contamination – free alternative and can be produced by different techniques such as from solid $CO_2$ (dry ice) or by nebulizing water. Another technique for observing airflow is what is often known as a puffer and smoke tube.

Air velocity and direction – Measurements can be done using a multidirectional anemometer that will give the air velocity either in the X and Y-axis, or in the X, Y and Z-axis. There anemometer can be expensive and a simple anemometer with a streamer attached to give the air direction will give reasonable results, as especially if the airflow is unidirectional and reasonably represented in two dimensions.

Further possibility of flow identification is flow simulation. CFD programme can help to investigate air movement in the cleanrooms. It is possible to create a variety of cleanroom models and simulate the flow in CFD programme. Flow direction and flow velocities are seen from the results of CFD simulation.

All these methods will be used in research of airflow patterns in cleanroom with personnel protection zone, built in our laboratory.

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# Heat Storage in the Ground

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Ground massif could be something like alternative source of heat. It belongs to group of renewable sources of energy. Nowadays it is not possible to predict when the drawing of this source of energy will be completed. Originator of geothermal energy in ground is, if you like was sun rises together with nucleus conversion inside the Earth. The potential of geothermal energy is fairly low (the available temperature of the massif is low and it is not possible to use them right). It means that for using this energy for heating for example, some energy transformer is needed. Heat pump is used as the transformer for almost all cases.
Geothermal energy is really low potential. Ground temperature rises almost constantly from just about 5 meters of depth, where the temperature gradient is from 1,5 to 3 degrees of Kelvin per 100 meters of depth (it depends on frequency of ground water, possible eruptions in the region etc.). The temperature gradient up to 6 K/m occurs in extreme in our region, especially in mountains in the North Bohemia.

The temperature of massif is changed owing to forecast and periods to depth approximately 2-3 meters from surface. That is why we can point out that ground massif is a constant source of heat.

From the other point of view we recognise that ground massif could be used as an accumulator of the heat. It is opposite case when we do not want to get the heat out of the ground but again we want to charge the heat into the ground. We are getting source of cold and also we can saturate ground massif by this way. This is an alternative of classical heat accumulator (most often water accumulators). The ground massif has several advantages against classical accumulators. The first is incomparable amount of heat, which we can bank into the massif (and the same amount of cold we can “draw”), the second is that this kind of accumulating is long term process which means during the summer the ground is charged and during the winter is drained. And the third advantage is next: If we use massif only as a source of heat it could gradually chill out. That is why bidirectional using of the massif (draw the heat out of the massif and also recharge it by the same amount) is beneficial.

If we are in a situation that we need to use geothermal ground energy as a source of heat is in place to concern in this problem. Then we can use the ground not only as a source of heat but also as a source of cold. The same unit is needed for this (heat pump, pumps, bore in ground), be enough to use right connection and right regulation of these two systems.

This kind of unit was realised in U216 Dept. of Environmental Engineering at Faculty of Mechanical Engineering of CTU. The base consists of 100 m deep bore (diameter is 144 mm) placed on faculty court. Two U-pipes are placed inside the bore and these pipes are full of liquid, which conduct the heat. The bore occurs 5 meter from the building where the laboratory with the heat pump and other equipment is placed. The measuring bore is hollowed out 7 meters from the first bore. Measuring bore find out the temperature gradient in the area of drawing and accumulating of heat and also temperature responses are measured. Secondary

part of the equipment is designed for heating and for air conditioning of laboratories and adjacent offices.

Nowadays the simulation of accumulation of the heat into the ground massif has been preparing. Simulation will be completed by software TRNSYS with program unit DST.

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# CFD Code AMEM and the 2nd Law of Thermodynamics

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The article deals with multidimensional modeling of the internal combustion engine (ICE) in-cylinder phenomena. The specific problems of ICE have to be taken account – non-stationary viscous (turbulent) compressible flow, low Mach numbers, movable boundaries, chemical reactions (chemical kinetics), liquid-gaseous phase interaction (for direct liquid fuel injection engines), etc. The main target of the work is to develop a code which is capable of dealing with the above mention features.

The code was named AMEM which means Advanced Multizone Eulerian Model. It is the CFD program primarily developed to solve velocity and important thermodynamic parameter (e.g., pressure, temperature, etc.) fields in the ICE cylinder. Currently, there are 2 versions available – AMEM2D which is a 2-D (planar symmetry) variant and 2.5-D (axisymetrical case) version called AMEM. Only compression and expansion strokes are computed.

The mathematical model is based on Leibnitz integral balancing equation (it is also called Reynolds theorem) which is formulated for arbitrary movable boundaries of a control volume. When applied to basic conservation laws, the continuity, momentum and energy integral equations are obtained. To close the equation set, additional relations (e.g., equation of state, viscous fluid model, etc.), initial and boundary conditions are needed. At the moment, perfect gas model is used however, specific isobaric heat capacity is a function of temperature. More detailed description can be found in [2]. Local entropy is computed applying well-known Gibbs equation (there is enough information available to compute it) and averaging over the entire fluid volume is performed. The system as the whole domain is isolated in terms of mass transfer therefore, in-cylinder averaged specific entropy can be used.

Concerning applied numerical method, the well-known Runge-Kutta multistage method (see [3]) is used. The convective terms are approximated using either $1^{st}$ order of spatial accuracy (upwind) or $2^{nd}$ order while viscous terms are always $2^{nd}$ order. The artificial viscosity of the Jameson type (see again [3]) is used to damp non-physical oscillations.

A lot of cases (different mesh corsenesses, different numerical schemes – $1^{st}$ and $2^{nd}$ order, different physical models – non-viscous, viscous fluid, turbulent flow) were computed to test the numerical method, to find out suitable coefficients for artificial viscosity, etc. The results were also used to test the solution in terms of the $2^{nd}$ law of thermodynamics. In the case of no heat transfer to the combustion chamber walls, the law strictly says that entropy of the whole computed domain must be non-decreasing function when plotting entropy versus time. It is useful to use well-known T-s diagram in which the entropy curve should not decrease regardless of temperature changes.

It was confirmed that the numerical results (for the cases without heat transfer) violate the $2^{nd}$ law of thermodynamics. There is decrease in entropy for the most of the computed cycle. This is in conflict with the law. Different numerical parameters were tested (mesh coarseness, space accuracy, time accuracy, coefficients for the Jameson type artificial viscosity – even different model to stabilize the solution was employed) without any success. The shape of the curve in

T-s diagram remains the same. Clausius integral was computed as well to confirm the conclusion. For the finer mesh, the entropy decrease is smaller. Even different physical models were tested (non-viscous and viscous gas, turbulent flow with prescribed turbulent viscosity in the whole domain). This phenomenon seems to be the property of the whole numerical solution.

Although it is clear now that the numerical solution given by the code violates the 2nd law of thermodynamics (which is the fundamental base of the science), the interpretation of the fact is rather difficult. It is not clear whether the results are completely wrong or if there is only a small deviation from the physically correct solution. When studying the detailed entropy, velocity and other important thermodynamic parameter fields, the results seems to be correct (at least qualitatively) and they correspond with the knowledge obtained from literature and experiments.

The code is being modified for turbulence models (2 equation ones) and 3-D version is being prepared. Long computations (very fine mesh is adopted) are being carried out to see if the T-s diagram curve can change its shape. At the moment, no clear solution of the problem is known and further research seems to be necessary. Different numerical schemes (e.g., PISO algorithm) are being taken into consideration.

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# A Network Thermodynamic Analysis of the Heat Pipe

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A heat pipe is a self-contained device which transfers heat by the process of boiling in an evaporator, vapor flow, condensation in the condenser and condensate return.

This work provides a view into the physics behind the heat pipe operation which was considered a thermal network of various components. Transient heat pipe behavior is described by first–order, linear, ordinary differential equations. The heat pipe consists of a number of components with different thermal resistances and dynamic responses and the heat pipe consists of eight processes which can be classified into two categories:

A. Pure heat transfer (or heat conduction) processes:

1) Radial heat conduction through the evaporator wall
2) Radial heat conduction through the evaporator liquid – wick
3) Axial heat conduction through the adiabatic section wall
4) Axial heat conduction through the adiabatic section liquid - wick
5) Radial heat conduction through the condenser liquid – wick
6) Radial heat conduction through the condenser wall

B. Heat and mass transfer (or heat convection) processes:

7) Vapor flow (heat convection)
8) Liquid flow (heat convection)

Processes 7) and 8) form a working fluid circulation which plays an essential role in the heat pipe operation.

There is a thermal resistance associated with each of the eight heat transfer processes. Once the thermal resistance of each component (or processes) is calculated, the heat pipe temperature at any location and heat flux in any process can be readily obtained.

This work provides a numerical model including a transient wall heat conduction and a quasi – steady – state vapor flow. The results showed a little difference compared to a fully transient model. Furthermore, the vapor flow thermal resistance is considerably smaller than those of other processes. Therefore, the vapor flow can be neglected from the thermal network without causing significant errors.

The above argument implies that transient temperature behavior of the heat pipe mainly depends on the wall and wick heat conduction. It must be emphasized that although the working fluid presents little resistance to heat transfer, it does affect the heat pipe operation in another important way by maintaining a wetted evaporator surface so as to continue the heat transfer process.

Since the heat pipe is viewed as a network system of heat conductors, system analysis theories can be used for transient heat pipe analysis. Components of heat pipe are a one – dimensional heat conductor with a cross – sectional area of $A_i$ and a thickness of $\lambda_i$. Two ends of the heat conductor are exposed to temperatures of $T_{i,1}$ and $T_{i,2}$, respectively. Assuming the

temperature at the middle of the heat conductor is Ti, the following energy balance equations can be obtained:

$$\rho_i A_i \lambda_i c_{p,i} \frac{dT_i}{dt} = Q_{i,1} - Q_{i,2} \tag{1}$$

$$Q_{i,1} = k_i \frac{T_{i,1} - T_i}{\lambda_i / 2} A_i, \qquad Q_{i,2} = k_i \frac{T_i - T_{i,2}}{\lambda_i / 2} A_i \tag{2}$$

Rearranging eqns (1) and (2) gives:

$$\frac{dT_i}{dt} = \frac{2\alpha}{\lambda_i^2}(T_{i,1} + T_{i,2} - 2T_i) \tag{3}$$

It should be noted that the input and output heat fluxes have been linearly approximated using Fourier´s Law. Equation (3) is the governing equation of each component (or process) in the heat pipe network, except for the vapor and liquid flows which have been assumed to have negligible effects on the heat pipe heat transfer. The heat transfer rate into the system ($Q_e$) and the convective cooling conditions are given. If other heating and cooling conditions apply, corresponding changes must be made in the calculation.

Based on fundamental heat transfer principles, the system must obey the following two rules:

1) at any vertex, the summation of input heat flows equals the summation of output heat flows

2) the components (heat conductors) with a common vertex experience the same temperature at the corresponding ends.

The heat pipe working fluid functions as a thermal energy carrier which cycles between the evaporator and condenser. Since its transient response is almost spontaneous and its thermal resistance is negligible, the working fluid presents negligible effect on transient temperature distribution in the heat pipe. However, it is very important for the working fluid to continuously circulate in the heat pipe.

The working fluid undergoes a thermodynamic cycle which was analyzed by T-s diagram.

# Measurement of Tensile Stiffness of Cross Wound Tubes

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The response of fibrous composite materials can exhibit an exceptionally wide range of behaviors depending on the properties of the fiber and matrix constituents, the fiber orientation of the layers in a laminate, and the loading. Therefore, it attracts the increasing researches.

**Experiments**

Because of the anisotropic nature of composite, measurements can be very sensitive to fiber orientation and gauge alignment. Considering this fact, we chose symmetric lay-up tubes as specimens. The Specimens (tubes) were wound on mandrel (diameter 26 mm) with carbon fiber (T700) tows wetted with epoxy resin (p418). The fiber orientations of our specimens are positive and negative7-, 10-, 14-, 17-, 20-, 26-, 31-, 36-, 46-, and 59-degree. The layer thickness is about 1 mm. Our measurements focus on the axial and transverse strains and break loads. Strains are measured through two approaches, one is through cross strain gauges which give us axial and transverse strains, the other is through extensometer which provides a measurement of the average strain over 30mm length and only measures the axial strains.

The results (see Table 1) of tensile stiffness of cross filament wound tubes showed that smaller winding angle tubes (7-, 10-, 14-, 17- and 20-degree) exhibited linear response and larger winding angle tubes (26-, 31-, 36, 36-, 46-, 59-degree) exhibited nonlinear, inelastic response prior to failure. The inelastic strains are associated with inelastic response of the matrix, shear deformation of fiber, as well as damage development. About the nonlinearity of cross filament wound tubes, we will do more research.

**Calculation of Axial Stiffness and Poisson's Ratio of Cross Filament Wound Tubes**

According to classical laminate theory, the relationships of mid-plane strains, curvatures, in-plane forces and moments per unit length, and considering the characteristics of the fixing of tested tubes and the symmetric layers $[+\theta, -\theta]$, the curvature vector $\{\kappa\}$ is zero. When loading in axial direction, we can calculate the axial stiffness and Poisson's ratio.

Calculation results and experimental axial stiffness in elastic range are present in Table 1 and 2. Average break loads are listed in Table 3. As indicated in the Table 1 and 2, the correlation between theoretical and experimental stiffness is very good, but the correlation between theoretical and experimental Poisson's ratio is not good as the stiffness. The discrepancies are due mainly to factors associated with experimental accuracy.

Table 1. Calculation and Experimental Results of Axial Stiffness

| | | Winding Angle [degree] | | | | |
|---|---|---|---|---|---|---|
| | | 7 | 10 | 14 | 17 | 20 |
| $E_x$ [Gpa] | Experiment | 112.55 | 109.63 | 100.97 | 83.69 | 76.74 |
| | Calculation | 119.41 | 113.77 | 105.28 | 84.4 | 81.07 |
| | | Winding Angle [degree] | | | | |
| | | 26 | 31 | 36 | 46 | 59 |
| $E_x$ [Gpa] | Experiment | 55.31 | 40.27 | 30.00 | 19.91 | 14.90 |
| | Calculation | 56.51 | 38.11 | 27.03 | 18.16 | 14.57 |

Table 2. Calculation and Experimental Results of Poisson's Ratio

| | | Winding Angle [degree] | | | | |
|---|---|---|---|---|---|---|
| | | 7 | 10 | 14 | 17 | 20 |
| $\nu_{xy}$ | Experiment | 0.40 | 0.65 | 0.77 | 0.92 | 1.12 |
| | Calculation | 0.59 | 0.84 | 1.1318 | 1.39 | 1.59 |
| | | Winding Angle [degree] | | | | |
| | | 26 | 31 | 36 | 46 | 59 |
| $\nu_{xy}$ | Experiment | 1.41 | 1.28 | 1.17 | 0.81 | 0.38 |
| | Calculation | 1.69 | 1.53 | 1.28 | 0.79 | 0.34 |

Table3. Break Loads

| | Winding Angle [degree] | | | | |
|---|---|---|---|---|---|
| | 7 | 10 | 14 | 17 | 20 |
| Break Load[kN] | 125.406 | 126.98 | 130.5387 | 126.8921 | 112.2073 |
| | Winding Angle [degree] | | | | |
| | 26 | 31 | 36 | 46 | 59 |
| Break Load[kN] | 76.05214 | 58.05067 | 47.368 | 21.586 | 11.835 |

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# Analysis of the Load Capacity of an Electron Beam Welded Worm Wheel

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This research work deals with finding the maximum load capacity of the weld of an electron beam welded worm wheel with regard to low production costs. Because of advantageous wear features of bronze, worm wheels ($d_m > 120$ mm) are often made of a steel hub and a bronze rim, which are welded together by electron beam technology. The weld normally reaches only up to 66% of the wheel width. This allows large cost saving providing the bronze rim is enough thick. Nevertheless, the unconnected part of the wheel width acts always as a notch, which may get dangerous with thin rims. The original objective of the presented research activity was to find an optimum weld depth for a thin bronze rim, which would offer minimum production costs on the one hand and safe long-lasting operation on the other. However, it turned out later that the crack growth is far more related to residual stresses and not to the notch.

Apart from the notch in the wheels with the weld depth reduced to 66%, numerous radial cuts gave also evidence of cracks completely embedded in the weld. To find out the real crack distribution ultrasonic tests were performed on several wheels, which delivered C-snapshots of the whole cylindrical steel-bronze interface. They showed large scale embedded cracks often extending over 120 degrees along the circumference. This implies that the critical cracks are in no way initiated through the unwelded part of the wheel width. Wheels that were tested after operation exhibited similar crack distribution with cracks extended due to fatigue growth. To estimate other possible influences on the crack initiation, two small pieces of the same steel a bronze were welded up under the same conditions as the worm wheels. After cutting the new weldment no cracks were found. Therefore, the cracks in the worm wheel must be initiated exclusively by residual stresses. In order to investigate them numerically, tensile tests with mini flat specimens as well as hardness measurments were done to find out mechanical properties of the base materials, weld metal and of the heat affected zones of the electron beam weld.

To explain the mechanism of crack initiation on the basis of residual stresses extensive numerical analyses were done. This objective, i.e. the determination of residual stresses as a result of the welding process, was achieved by an uncoupled thermal and structural analysis. To reach reasonable computational costs geometric and mesh optimization of the models were carried out. The worm wheels were analyzed in three variations of the weld depth (100%, 80%, 66%). As a result, a full residual stress field can be presented. Finding the highest stress peaks, loci of crack initiation can be determined. The calculated residual stresses did not prove to depend on the weld depth. Based on principal stress directions it can be followed that the crack growth depends predominantly on tangential stressing and not on the radial stressing as was originally assumed. Redistribution of stresses after teeth milling and loading was also examined. Teeth milling has a positive influence on making the cracks stable and that the external loading changes the existing stresses very little. The results of the numerical analyses were verified with booth hole drilling method and X-ray tests in the vicinity of the weld bead.

To possibly reduce residual stresses, the influence of pre-heating was considered. However, bronze parts can be pre-heated only up to a limited measure, so that its special features would not get lost. Therefore, through the analysis of time development of the residual stress field during the welding period an improved welding procedure was proposed to reduce high residual stresses considerably or to avoid them at all. This is based on eliminating the effect of high concentrated heat input during the electron beam welding using more electron beams aligned closely after each other.

In order to consider the fracture properties of the weld, experimental work was performed with CTS- and SENB-Probes. Whereas the fracture toughness of the weld is similar to the one of bronze, its threshold toughness for the fatigue crack growth is closer to the one of steel. Using these values numerical analyses of stability of the cracks in the weld were done under consideration of the residual stresses and operation loads. To this point special routines had to be programmed. It proved, that the cracks that grow in the weld metal do not cause a wheel failure immediately. They weaken the bronze rim considerably which in turn leads to less stiff toothing. As a result, the teeth roots have to experience greater deformation and soon develope fatigue cracks, which cause the final separation of the bronze rim. Therefore, either the maximum operation loads must be diminished so that cracks in the weld remain small and stable or at best a crack free weld with low residual stresses should be produced. Based on this, new recommendations for production and operation will be defined.

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# Application of Thermodynamic Stability Condition to the Modelling of Turbulent Channel Flow

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The traditional approach to the modelling of turbulent flows is based on the Reynolds Averaged Navier-Stokes Equations (RANS). Additional terms, representing the transport of momentum between turbulent fluctuations and the averaged flow field, i.e. fictious turbulent stresses, appear in the RANS. This statistical approach leads to the problem with closure of the system of equations describing the flow field. For the closure of this system of equations, it is necessary to model the additional terms in the averaged equations (RANS). It is carried out using asumptions and hypothesis based on experimental laws of turbulence, but their applicability is limited to the given domain of application. There is no general way to the modelling of turbulent flows.

At the beginning of the development of a new turbulence model, it is necessary to focus on simple shear flows, i.e. free shear flows, and wall bounded shear flows. It is possible to use the eddy viscosity hypothesis, because there exists only one component of the Reynolds stress tensor. Moreover, in the case of wall bounded flows it is necessary to overcome the problems near the wall. In technical practice, the two-equation models of turbulence are widely used for specifying the eddy viscosity. Each model uses the first equation for turbulent kinetic energy which is based on physics. There is only one limitation in the term representing turbulent diffusion, but the gradient diffusion hypotesis is used. The second equation is a serious problem, e.g. the equation for rate of dissipation of turbulent kinetic energy is semi-empirical, that is the hidden crucial error of these two-equation models of turbulence. In our model, the thermodynamic stability theory is used for the derivation of the second equation leading to the equation based on physics.

A modification of Ljapunov stability theory is used for the derivation of thermodynamic stability condition. The modified theory is looking for the stability function depending on the difference from the reference state [1]. During the derivation of the thermodynamic stability condition, the second law of thermodynamic splits into two axioms. They are the axiom of maximum probability and the axiom of time irreversibility. The axiom of maximum probability is equivalent to the statement that entropy come to its maxima in every material point for locally equilibrium state. The extremal condition can be interpreted as the stability condition with respect to small fluctuations. For the fluid with convection the total enthalpy is used. The total enthalpy reaches it's minimum in every material point in local equilibrium state. The thermodynamic stability condition can be understood as an expression of the Braun-Le Chatelier principle: Fluctuations from the reference state induce dissipative proceses reducing these fluctuations. In the case of fluid with convection, it can be shown that the second differential of the total entalpy is the Ljapunov stability function. After the neglection of the influence of the temperature and external volume forces it can be shown that the material derivative of turbulent kinetic energy must be non-possitive [1].

The measured balances of kinetic energy are used for the verification of the non-positivity condition of the material derivative of kinetic energy. The kinetic energy balances are evaluated from the measurement by the hot-wire anemometry. The results of measurements in the boundary layer near separation were published in [2], [3]. From these results, is is obvious that our thermodynamic stability condition is satisfied in the wall region of the boundary layer, but not in the peripheral region. The experimental results considering jets were published in [4], numerical results were published in [5]. In the later case the thermodynamic stability condition is satisfied in the region near the centre of the jet, but not in the peripheral region. These differences in the peripheral regions are probably caused by intermitency. In future, this problem has to be investigated thoroughly.

The condition of the non-positivity of the material derivative of the kinetic energy is satisfied in the developed channel and pipe flows due to definition of these flows. Two new approches to the modelling of turbulent developed channel flows were derived and published in [6], [7]. The numerical method for the solution of this problem was discussed in [6]. Numerical results of the solution of developed channel flow by means of finite difference method will be presented.

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# Turntable for Multi-purpose Windtunnel

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Flow around car-body causes not only drag, but also aerodynamic forces and moments, which influence ride comfort and vehicle stability. At higher velocities the field of aerodynamic forces acting on the car-body is non-negligible, in the extreme case even safety aspects of the vehicle may be endangered.

When driving in the straight direction, next to the drag also lift force and pitching moment is generated. Thus loading of wheels and consequently tyre adhesion is changed. Road holding and vehicle behaviour when changing the driving direction or by overtaking manoeuvre, for example, is influenced by the interaction between those forces and moments.

In the nature wind-silence comes only rarely. Crosswind causes unsymmetrical flow around the vehicle and thus side-force, yawing and rolling moments are generated. At the same time, drag, lift and pitching moments are significantly changed. As a result of it, changes to the cruising direction occur, which have to be compensated by the driver.

Impact of aerodynamic forces on the vehicle stability is particularly strong in the case of gusty crosswind conditions. The same character of the flow around vehicle arise also by sudden overtaking manoeuvre or when parts of the road are alternately hidden in the leeward shadow of buildings and trees, for example, and opened to the ambient environment. Relation between aerodynamic- and mass forces determines the behaviour of vehicle in such extreme situations.

The task of aerodynamic development of vehicle includes next to the optimisation of aerodynamic drag also the question of low sensitivity to crosswind effects. Thus, unsymmetrical flow around vehicle has to be simulated also in the windtunnel. The model of vehicle measured is in the test-section of windtunnel connected with aerodynamic balance, which can be generally placed below or above the base-plate of the test-section. If the aerodynamic balance is placed above, which means that the model is hanged over the base--plate (either with the help of strings or more recently on the beam if the balance is tensiometric and placed inside of the model), then there is no need to design special turning construction of the test-section table. In the latter case, the model is placed on supports going through the table. This means, if the model is to be directionally adjustable around its vertical axis, also the table of the test-section has to be turning.

Windtunnel of the Department of Fluid Dynamics and Thermodynamics U207.1 of the Faculty of Mechanical Engineering of CTU is of close-circuit type with opened test-section. It is power by a 32 kW asynchronous electromotor, which enables a maximum flow speed in the test-section of cca 20 m/s. The test-section is for measurements of aerodynamic forces and moments equipped either with one- or multicomponent aerodynamic tensiometric balance placed under the table of test-section. Until now, the table of the test-section simulating non-moving road didn't allow measurements of directional dependency of aerodynamic forces acting on the vehicle. Present engagement of the department U207.1 in the development of aerodynamic modifications of heavy trucks and trailers showed significantly, that in order to evaluate in all the complexity the aerodynamic properties of such vehicles (but not only of

them, of course), it is needed to perform also measurements of directional dependency of their aerodynamic properties.

Within the solution of this grant project a new test-section table with turning middle part has been designed and built. The turntable is constructed as an independent unit, which can be easily transported away from the test-section. The body of the table has the dimensions of cca 900x900x950mm and fits for both the one- and mutlicomponent aerodynamic balance. On the base-part there is another one which is withdrawable and enables height adjusting in the range of 400 mm. This part is bearing the turning unit, turning smoothly in the range of 360°. Turning unit is driven by an electromotor with high gear ratio. The plate of the table representing road is made of alu-sheet with the overall size of 1000x1490mm. A circle with the diameter of 900mm represents the turning part of the plate.

The new turntable opens further field of aerodynamic research in the laboratory of the department U207.1 aiming at complex evaluation of aerodynamic properties of vehicles. Now, it is possible to get the field of aerodynamic force- and moment coefficients and their gradients as a function of angle of approaching flow and to put them to the equations of vehicle-motion in order to study numerically ride comfort and road holding of vehicles.

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# The Effect of Fiber Tow Undulation on the Axial Stiffness of Filament Wound Composite Tubes

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Filament winding is an automated process used in the fabrication of components of structures made with flexible fibers. Individual fiber tows wetted with liquid resin are "wound" on a mandrel which has the shape of the final structure. This manufacturing process often produces fiber crossovers in the architecture of the parts, although these structures are often modeled as laminated $[+\beta, -\beta]_n$ lay-ups. The purpose of our work is to evaluate the real influence of these crossover (so called undulation) regions on the axial stiffness of tubes.

Specimens (tubes) we measured were wound on mandrel (diameter 26 mm) with carbon fiber (T700) tows wetted with epoxy resin (p418). The layer thickness is about 1 mm. We made two batches of tubes, one batch with undulation, the other one without undulation. Each batch of tubes is divided into ten groups according to winding angles ranged from 7° to 59°. Two batches of tubes at one kind of winding angles have the same materials, the same mandrel diameter, and the same wall thickness respectively. The axial stiffness of tubes was measured. For example, at winding angle 17, the average axial stiffness of tubes without undulation is 83.69 Gpa and the average stiffness of tubes with undulation is 76.34Gpa. There is a little loss of stiffness for undulated tubes and this loss is due to the fiber undulation when fiber goes from one layer to another layer. Therefore, the stiffness calculation of tubes should consider this fact.

We developed the fiber undulation calculation model in order to consider the continuity and undulation of fibers in cross filament wound tubes. Our brief calculation procedure is present below.

-Determine the undulation ratio $R_u$.

Calculate the area of the representative unit cell which depends on the winding pattern and the area of undulated part in the cell. Then

$$R_u = \frac{\text{undulation area}}{\text{unit cell area}}$$

-Calculate the stiffness matrix for non-undulation part according to classical laminate theory.

-Calculate the stiffness matrix for undulation part.

- First, calculate undulation height and undulation angle which change in the whole undulation length $L_u$.
- Second, calculate stiffness of undulation part by using undulation angle transform matrix to modify the stiffness matrix.

-Calculate the whole stiffness of unit cell which is the combination of undulation part and non-undulation part including the ratio $R_u$.

In order to apply the calculation method mentioned above, the undulation length should be obtained first. This undulation length can be measured or estimated as about 6-10 times layer thickness [3]. In our research, we measured the undulation length $L_u$ of 17-degree winding angle tube. For this measuring, a small strip of laminate tube was cut and then fixed in resin in order to make a measuring sample. Through microscopic technology, we can find the undulation part and measure the undulation length. For example, the length of 17-degree winding angle tube, $L_u$ , is 3.8 mm. The stiffness of this winding angle tube without undulation and the stiffness of the same winding angle tube with undulation from our measurement and from calculation are listed in Table 1.

Calculation shows that the undulation part really softens the axial stiffness. With the number of layers, layer thickness and undulation ratio increasing, the undulation effect on the stiffness will be more obvious.

Table 1. Stiffness Comparison

| | Experiment | Calculation |
|---|---|---|
| With undulation | 76.34 | 74.00 |
| Without undulation | 83.69 | 84.4 |

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# Numerical Solution of Transonic Flow in Turbine Cascades

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This contribution presents numerical results of 2D and 3D transonic flow in turbine cascades. We solve numericaly the integral form of the system of Euler equations (inviscid flow) or by the system of Navier-Stokes equations (viscous flow). Turbulence is modeled by a proper algebraic model. We use following numerical methods developed at our department:

1. a method based on the simplified TVD MacCormack scheme published by Causon
2. a method based on the full TVD MacCormack scheme
3. a method based on the cell-vertex Ron-Ho-Ni scheme
4. an explicit method based on modified Roe's Riemann solver
5. an implicit method based on Osher's Riemann solver

The first three methods have been developed for quadrilateral or hexahedral structured and the last two for unstructured triangular or hybrid meshes. The first three methods use central discretization of convective terms, therefore a kind of artificial viscosity terms has to be included - the first two use TVD form of damping terms, the third one uses Jameson's type of artificial viscosity. The last two methods are upwind methods. The fourth method, explicit Roe's methods, is based on 1D approximated Roe's Riemann solver with entropy correction (Harten, Hyman) applied on each cell interface. Higher order of method is accomplished by MUSCL type of interpolation, Van Leer limiter and three stage Runge-Kutta scheme in time direction. The fifth method, Osher's implicit method, uses first order approximation in implicit part and higher order approximation on right hand side (piecewice linear reconstruction by weighted ENO). Linear system of equations is solved by restarted GMRES with ILU preconditioning.

The inviscid flow model (Euler equations) is apropriate for the validation of convective term discretization, for the evaluation of influence of computational grid etc. It can be also used for simulations of flow in turbine cascades close to design conditions. The laminar viscous flow model (Navier-Stokes equations) is an intermediate step towards turbulent flow model. It helps to validate discretization of viscous terms. The effect of turbulence is medelled by the Baldwin-Lomax model in inner region and by the Rostand model in the outer region and in the wake. Numerical tests shown the key role of the onset and the offset of transition.

Achieved numerical results show a good agreement with experiments and/or with results of other numerical simulations. Numerical results for several radial and axial geometries include 2D radial and axial stator and rotor cascades, 3D axial low-pressure high-power steam stator and rotor turbine, ...

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# Variational Principles in Mechanics III (Audio-Visual Educational Program)

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This paper deals with educational computer course "Variational principles in mechanics" produced by Audiovisual and Technical Centre of CTU in Prague. Course is divided onto four parts, the first two of which were finished in 2000 and 2001(displacement and force approach in classical vector mechanics and virtual displacements/forces principles), the third one – object of our interest (supported by IG CTU) was created during 2002 (principles of minima of potential/complementar energy and classical Ritz's method) and the last part (FEM) is to be done in 2003. It is conceived as a FEA lectures in FME CTU in Prague supplement.
While the lectures introduce basic variational principles briefly as facts, without derivation, in our computer course full derivation of virtual displacements and forces principles in static is given.

The principles derivation for case of simple plane truss system (discrete system), thick-walled pressure vessel (1D continuum) and extetension onto 3D continuum may be found in parts 1 a 2. Both principles are outlined step by step from vector (Newton) description using forces, up to scalar (analytical) one using virtual works. Basic terms as interface, kinematic and force boundary conditions, virtual displacement and force/stress are introduced, explained and discussed during the derivation.

Explanation of potential/complementar energy minima principles using single rod under tension loading is done in the first chapter of part 3. Then the 3D extension is outlined via analogy by splitting potential energy onto deformation one and external forces work.

Reminding or simple explanation of vector spaces theory is the goal of second chapter. Properties of functions spaces as $L^2_\Omega$ (terms like dimensions, base, distance, metric …) are discussed using analogy with algebraic vector spaces.

Basic idea of Ritz method is the next topic. Subspace satisfying homogenous kinematic boundary conditions is introduced and extended to satisfy any conditions by adding single base vector satisfying it. Then variational problem to find displacement minimizing potential energy is converted onto looking for minimum of function using a subspace of displacements fields given as linear combination of base vectors.

Ritz's method is demonstraded by simple example of rod under gravity loading using goniometric and piecewise linear base functions.

The program is produced using multimedia creator “Scala” and is based on common reading and listening of the text, graphic representations of matices, graphs, and figures on screen. Although, the program may be viewed continuously, user is allowed to jump forward or back, stop and release single pages and turn on/off the sound. There are pages invoked by labels in text giving more detailed explanations.

The program is distributed on CD and we plan to distribute commonly all parts after finishing the last one in 2003.

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# Passenger's Seat Meets Criteria of FAR23 (JAR23) Recommendation

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Following new aircraft industry and transportation FAR23 instruction, Ministry of Industry and Trade of the Czech Republic initiates development of new passenger's seat meets criteria of above-mentioned FAR23. Newly outlined methodology of passenger's seat design should be used in small personnel aircrafts produced by Czech companies. Holder of the grant supporting this research has been established Aeronautical Research and Test Institute, which cooperate with our team on field of numerical solutions and simulations of mechanical stress analysis.

This short abstract is focused to explanation and description of our main ideas used at numerical solution of mechanical stress analysis of dynamically loaded seat's structure by reason of horizontal and vertical impact. Those impacts simulate mechanical conditions in time of rescue landing of the aircraft. Main objective of our research is to observe influence of dynamic load to seat's structure and passenger's body too. This text maps first part of our research and development work.

First phase of our work was detailed understanding to structure of seat from obtained designs. This phase consists of properly identification of all construction elements of seat's structure, boundary conditions, initial conditions and outer load.

Special attention has been paid to understanding of construction solution and function of deformable element. Real deformable element is implemented as riveted joint but use of this joint is nonstandard. In case of vertical impact exceeding initial value, rivets will break through material of the shell.

Main seat's structure consists of number of the rotary and spherical joints, number of rods and some plain shells and some more complicated parts. Rods assemble main seat's frame and plain shells lying between rods makes seat's squab and seat's back.

Boundary conditions are given by fixed and sliding restraints represented by attachments of the seat to the aircraft's body. Aircraft's body is not important in our analysis and we will assume that is ground with defined global coordinate system.

Outer load consists of the parts come up from negative acceleration during the impact and come up from interaction between seat and passenger's body, which defines contact problem.

Second phase is building of FEA model of whole mechanical system seat – passenger. FEA model of the rod is mesh of the 3D beam elements. This kind of FEA model requires to be provided lengths of prismatic parts, profile's geometrical characteristics of those parts, position of the central axis of the profile, eccentricity of the places of the loads and material properties. Geometrical characteristics are area and moments of inertia of the profile. Most of the rods have material properties of aluminium alloy. Some of rods have material properties of steel. Two besides laying rods are connected using rotary or spherical joint.

FEA model of the real shell consists of the mesh of shell elements laying at the central surface of the real shell. This kind of elements requires to be provided thickness and material properties. Both shell surfaces have material properties of the steel.

Whole FEA model contains two side forms. They will be represented by mesh of the 3D solid brick elements with material properties of the steel.

FEA model of the deformable element is the most important part of the whole FEA model. Maximal fidelity to behaviour of the real deformable element is required. Here are two ways to model deformable element. First way is to create model with rivets and let them to break through the shell. This model is relatively simple but computation takes too much time and movement of the rivets is discontinuous. Have been made tests of this approach and our expectations be confirmed. Second way is to create model without rivets and process of breaking real rivets through real shell replace by friction process with properly set friction characteristic. This approach requires knowing real force-displacement characteristic, without its knowledge this model can not be used. Number of the experiments has been made by reason of obtaining this very important characteristic.

Boundary conditions are very simple. Fixed restraints have no degree of freedom. Sliding restraints allow only horizontal movement so they have only one degree of freedom.

No breakable part of whole FEA model is FEA model of the passenger's body. There exist a lot of human's body models in the world and it was difficult to choose the right one. HYBRID II seems to be the best model for our needs. It is $50^{th}$ percentile adult male test dummy and is specified in the Federal Motor Vehicle Safety Standard 208 of the United States of America. This instruction provides all parameters of the dummy and according to this instruction has been created FEA model of the HYBRID II dummy. From point of view of mechanics is HYBRID II kinematical system of bodies. In FEA model are all bodies represented by ellipsoids with defined geometrical and mass properties and joints. Joints are defined as Cardan or flexion-torsion restraints with friction, dumping and movement limits. Ellipsoids are built as mesh of the rigid shell elements. FEA model of dummy HYBRID II has been several times tested with good results.

Following dynamic character of the loading process during of the impact will be used numerical explicit computational algorithm. Real computations of FEA are made with software tool set Abaqus 6.2 provided by Hibbit, Karlsson & Sorensen, Inc.

At presented time development and research work are in progress.

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# Research of the Dynamics of Water Reservoirs

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Up until the nineties, the knowledge of the dynamics of water reservoirs, both isothermal and non-isothermal, was very limited. The impact of discharging warmed or otherwise contamined water was measured by means of inadequate mathematical models, physical models applicable with difficulties or with hypotheses that were far too simplified. The results often misinformed the general public, and the impact of the energy management upon the hydrosphere looked worse than it actually was. Collected within the monitoring of changing temperatures and from float measuring, the reservoir dynamics data were incomplete. Another reason why the mathematical modeling results were wrong was the fact that it was virtually impossible to get a sufficient number of the input data.

The situation got better in the nineties, when the Water Management Research Institute acquired sublevel automatic apparatuses (RCM-7) measuring speed, horizontal flow direction, temperature, pressure and time. These data are recorded onto a magnetic medium in an optional interval. However, the work is very expensive and proceeds very slowly, because it is necessary to anchor the apparatus to the ground and let it float in a selected place. The results are only available when a sufficient number of data is recorded, the apparatus taken out and the data evaluated by means of special software.

The objective of research described was to improve the methodology of investigation of the dynamics of water reservoirs and to establish the effects of energy generation works (hydroelectric, thermal and nuclear power plants), both within the displacement of large volumes of water (peak hours, pumping) and within the cooling water diversion and discharging of warmed or contamined wastewater.

To achieve expected results it was necessary to build a mobile workstation allowing to carry out the measurement and to process the data in real time. For the measurement of water speed profiles, the NORTEK ADP 1,5 MHz apparatus has been purchased. The measuring with ADP is done from the water level; the apparatus immediately establishes 3D distribution of water speed, flow direction and the depth up to 60 m. It gives an immediate feedback that can be recorded into a notebook. By changing the location on the water level, it is possible to get data on the movement of the water during natural reservoir regimes as well as during regimes affected by water management actions. Based on this data, it is possible to establish the flows affecting the mixing of warmed water or wastewater, identify diffusion processes, specify delays and properly react to the results of possible accidents, all this with significant cost reduction, measuring time reduction and more data from the entire volume of the reservoir.

During the measurement the apparatus is located on a floating pontoon, which was designed and built as a part of project described. The pontoon is equipped with a drive unit and remote control system with an independent stabilizing system (so called piezo-electric gyroscope), that allows exact measurement in such locations, where the Earth coordinate system cannot be used.

The communication between the NORTEK ADP and the computer is wireless (433 MHz radio communication within of 400 m). The pontoon contains a power supply unit

allowing the continuous operation of NORTEK ADP apparatus and the communication system for at least 7 hours, the second power unit supplies the drive unit and remote control system. This allows the research staff to stay ashore, accidental movements of any person being aboard do thus not affect the stability of the pontoon.

The system has been verified by comparative experiments using both NORTEK ADP and RCM-7 apparatus in the early 2001. Several other measurements (water power plant Slapy, water reservoir Kořensko close to a nuclear power plant Temelín) on water reservoirs has been done during 2001 and 2002, see [1] and [2].

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# Direct Method for Measuring Deformations on Structures

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A method for measuring permanent length deformations in materials includes determining a change of an initial distance between two measuring points – measuring base - on the material surface according to he basic relation of the theory [1]. A first pair of impressions is formed on a portable impression body that corresponds to these two measuring points prior to the expected deformation and a second pair of impressions is formed after a critical loading of the material. The distances between the first and the second pair of impressions are then compared. A portable impression body is made of ceramic composite obtaining very low thermal expansion coefficient that enables for most applications to omit the changes of temperature of the impression body in the moment of impression and in he moment of measuring. A device for carrying out the method uses a fixed portion arranged on the material being measured and a portable impression body. The fixed portion of the device is provided with a pair of measuring elements which correspond to the measuring points disposed at a mutual distance from each other, and the portable impression body of the device has an impression face adapted for receiving the impressions that are created by the measuring elements.

An extremely precise, fast, simple, cost effective way to take direct measurements of microscopic elongation of a variety of materials for use on finished structures, without interrupting the structure's operation. The method involves using a gauge to permanently fix two extremely hard posts onto the examined areas of structure to be measured. These two posts have raised edges that are perfectly parallel to one another. After the posts are attached, the edges exactly reflect the elongation of the structure being measured.

These edges are used to make a physical impression a on a specialized impression body that withstands extreme temperatures and creates a permanent record of the length between the two edges on the gauge. This impression body can be taken to a lab to measure the length between the two impressions, using a standard industrial measuring microscope. Measurement can be taken as frequently as desired and compared to build a profile of structure changes and to know when or if the structure has exceeded its safe limit.

There are four main items to the method:

a) the gauge;
b) the impression body;
c) the hammer (Fig. 3) used to create the impact between the gage and the impression body;
d) the measuring microscope for assessment of length relations and for parallel configuration of industrial minerals.

The form of the gauge depends upon the particular application, more specifically, it depends on whether welding is or is not permitted. An example of each type follows.

On a pipeline, where welding is permitted, the gauge consists of two parts: a base, made of the same material as the pipeline, and two posts, made of extremely hard cemented carbide (industrial minerals may also be used). The base (with the two posts shaped into two

parallel edges attached and spaced apart) is strategically welded to the pipeline and split between the posts so that it perfectly reflects the movements of the pipeline.

When welding is not permitted, in airplane applications for example or is not possible as in civil structures, the gauge is fixed to the surface to be measured by special temperature resistant glue. In this case, the base of the gauge acts as a template and is removed after the edges are secured, leaving only the industrial mineral edges on the surface . In both cases (welding or gluing), the fixed edges never need to be replaced and can be used to make measurements as frequently as desired.

The impression body is made of an extreme temperature resistant ceramic (a standard material with other industrial uses such as housing fuses) with one surface (the impact surface) coated with a specialized man-made material (the coating also has other industrial uses). This specialized material allows for perfectly precise impressions (two lines) to be made by impact with the two edges on the gauge. The two lines are permanent so measurements can be made from them at any time in the future. Ceramic body enables data notation in a very easy way.

The hamme is a simple, easily modifiable, hand-held tool that holds the impression body so that the user can align it with the two posts on the gauge. The hammer has a button that when pressed rapidly pushes the impression body forward (powered by a compressed spring) creating sufficient impact to create the intended lines for measurement. The hammer can easily be attached to an extension arm or pole that makes it more convenient to reach extended distances. Likewise, it can be fitted with a swivel head for use in more cumbersome applications. As the hammer never comes into contact with the gauge or the structure being measured, its heat resistant properties are not so important. It is made from standard metals and can be used as often as desired. A person would need to wear protective, heat-resistant clothing when taking measurements in very high temperature areas, but the hammer's construction would be sufficient to withstand such conditions. The entire process takes only a moment and is as simple as lining up the hammer (holding the impression body) with the gauge and pressing the hammer's button. Therefore, each measurement only takes a few seconds.

For civil applications (monitoring of cracks after seismic incidents, etc.) a modified gauge is to be used in the form of two ceramic rods with applied two parallel edges. These two rods are connected one to the other by a breakable layer with very low strength and this twin is applied to the civil structure by means of a stiffened frame .

The described gauge presents a simple, cost effective as to instrumentation and gauges and powerful mean for monitoring and determining deformation of structure under very severe loading conditions (high temperature and long time). Some samples were tested under severe conditions (one gage under temperature from –112$^{o}$C to + 1050 $^{o}$C).

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# Joint Teaching of Experimental Mechanics Methods in FME and FNSPE CTU and Their Impact on Product Quality

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At present, in the time of implementation of methods and means of numerical simulation, one, either in universities or in practice, sometimes meets misbelieve about usefulness of experiment. The position of experiment in the education in technical universities has been and still is discussed [1,2]. It is without dispute that experiment lost its position as a mean solution, but it has a dominant position in some areas of mechanics and material sciences as for example determination of residual stresses is.

Origin of residual stresses is in technology. Character of this kind of stresses is in self equilibrium state in the whole body or area. That is why is not possible to determine them form outer loadings, either mechanical or given by temperature fields. There are two ways how to determine them. One chance is to break this equilibrium [3] and the released deformations to measure by means of mechanical or electrical gages or optically. This belongs to so called destructive or semi-destructive methods. Another way is to use changes of structural ordering of the stressed material what develops changes in magnetic qualities or atomic grating. The last mentioned phenomenon can be measured by means of X-ray or measuring elastic waves velocity.

As the residual stresses are of increasing importance all students of particularly mechanical or civil engineering . The residual stresses are superimposed to stresses from outer loadings. In case of inconvenient quality (in tension) and residual stress value in the surface layer the stress state can induce to brittle or fatigue break and in this way have impact on the service life of the structure.

That is why problems of residual stresses should be read during lectures in the FME,FCE,FNSPE and FT of CTU in Prague. Since beginnings of $90^{th}$ lectures are given for student of Applied mechanics in FEM and physics of solids in FNSPE in the joint form. Professors from FME are reading lectures to students of FNSPE and on the contrary. This covers problems of destructive methods (fully or semi) by means of mechanical and electrical gages and nondestructive by means of X-ray difractography. During last three years there was involved nonuniversity workplace – Institute of Thermomechanics of the CAS – for lecturing of determinig residual stresses by means of measiring wave velocity of surface acoustic waves.

Joint activities of professors and assistents working in different institutes and faculties help effective teaching. Mutual exchange of readers and possibilities for presentation of methods and instrumentation aims to higher efficiency of using laboratories and

instrumentation and brings broader and better knowledge of students of magister degree. In the collaboration of the Dept. of Mechanics of FME and Dept. of Physics of Solid of FNSPE of CTU in Prague some experiments for PhD thesis were done [3].

For the future this joint teaching of experimental mechanics methods is expected in FCE CTU in Prague and participation of further collaborators of CAS.

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# Secondary Flow in Curved Cylindrical Channels

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In the flow in curved channels (both stationary and rotating ones) which are used as basic working elements of turbomachines and jet engines important energy transformations proceed. The internal flow energy transformations in the curved tubes are accompanied by energy dissipation. The energy dissipation mechanism is in principle due to the friction forces caused by the viscosity and the turbulence of the flow with important transversal gradients of velocity within the channels. The energy loss is represented basically by the increase in entropy of the flow and demonstrated in general by loss of total pressure and by non-uniformity of the velocity and pressure fields. An important role in the total energy loss in the channels is played by the out-flowing vortex tubes generated in the flow by the action of the transverse pressure gradient arising as a result of centrifugal forces accompanying curved flow in the stationary channels or due to Coriolis forces in the case of rotating channels. A systematic experimental and theoretical investigation of the phenomena concerning the 3-D complex subsonic low speed flows within the channels, casings and curved tubes of jet engines and turbomachines were performed with special interest in the relationship between the value of the total losses and the geometry parameters of the curved channels.

In order to study, both experimentally and theoretically, flow mechanisms in curved channels, particularly with respect to the formation of the streamwise vortices [1] that contribute significantly to the well-known flow pattern of the secondary flows with a pair of counter-rotating vortex tubes, a simple experimental model of the curved tube was chosen. The tube is represented by an elbow of a circular cross-section with a bend of 90°. The biggest possible diameter of the tube was chosen to ensure detailed measurements within the channel by pneumatic and hot wire probes. The diameter of 300 mm is sufficiently large for this purpose and the energy requirements for creating the airflow of sufficient speed by the blower are met by the installed laboratory electrical supply. The chosen diameter allows further to test the channel with a naturally fully developed turbulent inlet flow modeled by a tube of a length of 60 diameters, that means the length of the pipe is 18 meters, which is the maximum allowed by the dimensions of the laboratory. The elbow consists of 7 segments.

In order to study the influence of the geometrical shape of the elbow of the given Dean number, which is composed by the Reynolds Number and by the square root of the ratio of the cross-section diameter of the elbow and the radius of the bend of its center line, a number of various experimental studies have been carried out with the turbulent flow at the inlet section of the elbow simulated by a short straight tube with a standardized measuring diaphragm [2].

The results of this investigation led to an improved design method of the inlet and outlet channels of jet engines. It was applied on the outlet channel of the two shaft Walter M601F turboprop engine of a max cruise power of 500 KW driving for example Let L 410 and Let L 420 light commuters. The new outlet channel with an energy loss of about one half of the original one provides the engine with another 18 kW of power without any rise in total fuel consumption. The same research led also to the design of a new inlet for the other, larger three-shaft Walter M 602 turboprop engine developed for the new L 610 commuter. Both

newly designed and manufactured channels have met all airworthiness requirements and the inlet channel assured a very homogenous flow field in the inlet section of the first stage of the compressor.

As a tested model an arrangement of the described curved segmented channel and two short straight tubes has been chosen. The tested model consists of the assembly of the circular elbow,of the short pipe of 300 mm in the front and of the longer pipe of 1000 mm in the rear. The outlet section of the second pipe leads to the atmosphere. The design of the arrangement allows fit the measuring traversing apparatus to the flanges connecting the parts of the tested model in three principal positions. The first position at the inlet section of the elbow defines the measuring plane A. The position at the outlet section of the elbow defines the measuring plane B. The third position at the outlet of the channel defines the measuring plane C. The measuring traversing apparatus is a semi-automatic device that is half manually and half computer operated to move and adjust the measuring probe in the measuring plane. A manually operated and adjustable rotating flange allows circumferential turns of the radial beam of the linear traversing bar holding the probe. As the first step of the evaluation of the 3-D flow fields the measuring of mean velocity within the tested model of a curved tube was chosen. For the measuring of the mean velocity vector field in the measuring plane a five-hole micro-probe with each sensor orifice outer diameter of 0.8 mm has been designed, manufactured and calibrated.

The first stage of the measurements of turbulent 3-D mean flow fields in the tested model of a curved duct [3] enables to preliminary quantify the influence of two tested inlet flow structures on the formation of secondary flow and in particular on the process of the forming of the two counter-rotating vortices which create the well-known horse-shoe vortex in the form of two vortex tubes connected and anchored in the elbow with their open ends flowing away with the flow from the curved duct. According to the theoretical assumptions the area of secondary flow at the outlet section C and the intensity of the vortexes are tied with the boundary layers thickness on the walls in the inlet and curved part of the tube. In the case with thin boundary layer this area is very small, also the size of vortexes is very small, thus they dissipate before they reach the measuring C plane. But on the other hand, in the case where the in-coming flow has a boundary layer fully penetrating as far as the tube axis, a significant secondary flow with flowing away vortexes is formed where the vortexes are indicated in the measuring C plane.

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# Influence of the Inlet Flow Structure on the Energy Loss within Curved Channel

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To simulate the inflow conditions a new open type low turbulence wind tunnel has been designed using the CFD methods for the aerodynamic design [1] and overall design, manufactured and tested [2]. The tunnel is equipped with a very fine air filter allowing the use of thermo-anemometry methods for the measuring of the velocity fields in the un-stationary and turbulent flows. The controlled and adjustable flow volumes of the air represented by the velocity at the outlet section of the accelerating nozzle are in the range from 10 to 60 meters per second. At the exit section of the nozzle the flow is laminar and rather homogenous with a very thin boundary layer of the thickness less than 1 mm. The measured streamwise component of intensity of turbulence at the exit section of the nozzle did not exceed 0.25%.

As the first step of the evaluation of the 3-D flow fields the measuring of mean velocity within the tested model of a curved tube was chosen. For the measuring of the mean velocity vector field in the measuring plane a five-hole micro-probe with each sensor orifice outer diameter of 0.8 mm has been designed, manufactured and calibrated.. The measured five pressures are conducted by short tubes of a small diameter to a Pressure Systems Inc. pressure micro-scanner with a pneumatically controlled and computer operated switch and then transduced and converted to a digital signal and processed by computer. The mass flow is detected by the pressure difference between static pressures measured in the plenum chamber of the wind tunnel and at the exit section of the accelerating nozzle.

The acquisition and sampling of the measured data is made by the National Instruments Data Acquisition System consisting of the AT-MIO-1 measuring card and the Lab View software. The system operates the traversing device in radial direction automatically. To increase the accuracy of the measured data the system acquires 50 data items for every position of the five-hole probe with the sampling frequency of 10 Hz.

The main measured quantity detected by the pneumatic probe is the main velocity vector and its components to the axes of the Cartesian system. The values and angles of the mean velocity vector are calculated by means of measured individual aerodynamic and directional characteristics of the used probe. From the defined position of the probe and measured pressures in five orifices of the probe and the total temperature of the flow, the static and total pressures of the flow and two angles defining the direction of the velocity vector are calculated.

The measurements have been performed at the aerodynamic laboratory of the Department of Fluid Dynamics and Thermodynamics of the Faculty of Mechanical Engineering of the Czech Technical University in Prague [3] using the described low turbulence wind tunnel.

Two different cases of the inflow structure and turbulence at the inlet section of the tested aerodynamic model have been examined.

The first case marked as Case 1 was realized by connecting of the tested model directly to the outlet section of the accelerating nozzle of the wind tunnel. In this case the inlet flow to the tested model is very homogenous with a very uniform measured velocity distribution. The intensity of turbulence of the flow and its distribution measured by a hot wire probe was also low with maximum value of 0.25% at the used mean velocity of 40 m/s. The mass flow of the

air at the atmospheric conditions has been maintained constant during the measurements. For every adjusted and controlled to the same value.

The second case marked as Case 2 was realized by inserting a smooth straight circular pipe of a length of 18 meters between the accelerating nozzle of the wind tunnel and the tested model. In this case the inlet flow conditions at the tested model correspond to the fully developed turbulent pipe flow of the standard characteristics that are assured by the straight, smooth circular pipe of the length of 60 diameters. The mean velocity distribution as well as the turbulence characteristics have been measured and verified by the hot wire probe with oblique oriented wire. The experiments have been performed at the same mass flow as those in Case 1. Mean velocity distributions in three measuring planes A, B and C were measured at the tested model. The experiments were performed for the same mass flow $Q$ and the same Reynolds and Dean numbers with two different inlet flow structure conditions noted as Case 1 for a homogenous low turbulence inflow and as Case 2 for a fully developed turbulent velocity profile. The mean velocity vectors were measured using a micro-pneumatic five-hole probe. The flow fields were traversed in 1369 points and in every point five pressure values were sampled for 5 seconds with a sampling frequency of 10 Hz. The acquired data were stored in the computer and then evaluated. For the inlet flow conditions as described above the Reynolds and Dean numbers of the experiments were: $M = 0.12$, $R_e =$ 818000 and $D_e =$ 808000.

The first stage of our carried-out measurement proves the influence of the inlet flow structure and turbulence on the total flow field in the elbow and on the development of a secondary flow which is characterized by the formation of two counter-rotating flowing away vortices. While in the case of a homogenous inlet velocity field with low turbulence intensity the whirling movement was not indicated in the outlet cross-section of the measured model, in the case with the fully developed inlet turbulent velocity profile the whirling movement was considerable though of comparatively smaller importance from the energy point of view.

Measured values of the loss coefficients:

| Loss coefficient | $\varsigma$ | $\varsigma_{kinu}$ | $\varsigma_{tot}$ |
|---|---|---|---|
| Case 1 | 0.235 | 0.0003 | 0.235 |
| Case 2 | 0.273 | 0.0090 | 0.282 |

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# Data Management for FE-calculation Based Fatigue Analysis

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The fatigue damage analysis represents highly complex task, where even some parts of analysis can be based on estimates and presuppositions. A nominal stress approach is a usual method for such analysis at present. A S-N curve (Woehler curve) of smooth specimen is utilized here as a prime material property and another parameters (roughness of the construction parts, potential notches, size effects, etc.) are included. Unfortunately, it was obvious from late sixties, that the basis of this method is not sufficient for complex types of loading, where even some load channel can act in different phases, frequencies, etc. The problem stated here is not the utilization of the S-N curve itself, but the inability to propose a satisfactory way how to describe the changes of straining not in one stress/strain component, but in the whole tensor.

As stated, the problem consists in the description of complex states of stress/strain on the construction part and in the way, how to analyze their changes. Since the precise description of loading in particular places of the construction can be vary difficult, it is characteristic that the development of new methods for fatigue analysis is joined with the development of hardware and software techniques. Thus, the finite element analysis can be considered as one part of fatigue analysis - or better - its preprocessor. The stress/strain states are computed by FE-analysis on the whole construction part. Precisely - the solution in elastic range only and usually on part's surface are appropriate for fatigue damage analysis. It is not possible to calculate the strain reaction of long load histories in whole elasto-plastic region till now. The second premise given above stems from the fact, that the surface of specimens is the place where the maximum values of straining can be found and where the surface itself creates the biggest material non-homogenity.

Even if we consider the parts of component only, where the loading is the roughest, the solution of fatigue analysis expects relatively broad excerption of values computed by the FE-analysis. Moreover, advanced fatigue computation techniques operate with the stress/strain state on the specimen's surface directly. Thus, the normal line to particular place of surface should be computed (see [1]). Knowing also the fact, that modern fatigue analysis of welds expects stress/strain input data in particular distances from the weld root, we decided to build a FE-calculation results' data manager.

The goals of the project were to build an own way how to efficiently store raw data from the FE-analysis, how to manage them and how to work with them (i.e. to allow further fatigue analysis, submodelling, etc.). The inputs for this data field should be commercial FE-processors ANSYS, ABAQUS and COSMOS, since the teams cooperating on this project dispose of these various softwares.

The basic data storage is designed as a bunch of separate binary files provided with headers, where the descriptions of stored data are given. In order to have minimum file size and fast access to such data, the data items in each file are homogenous - i.e. data items have the same size. It can go complicated, since e.g. element description consists of element header (its number, number of nodes, etc.) and included nodes' numbers are given. The solution in our data structure is to separate these two information. In one file are given the element headers,

together with pointers to another file, where nodes' number appropriate for the particular element are saved.

As explained, the data storage is solved as a multitude of separate files. Functions should be defined on each file (i.e. on each data item), which allows to access the particular item, to add or delete another item. Since the utilization of this data structure is expected also on systems, where are more users than one, a separate memory pool is allocated, where all processed data are stored, when needed. Thus, another procedure for data acquisition from the hard disc to the memory is necessary, together with solving the way back.

The bunch of files must be joint together by a special manager, which gives overview of data in current project and allows access to desired files. Again, functions for file addition to the project and its deletion from project should be defined.

The FE-model is relatively a highly specialized data structure. Each data item type should have its specific functions - e.g. a set of element headers, element table of incidences and nodes are needed to set up the normal to a concrete point on the model's surface. Nevertheless, it can be expected, that also data without any direct connection to the FE-data can be stored in the project (various temporary data). As stated before, it is necessary to define also the data convertors from softwares given above.

Described requirements were successfully solved during last months. The data convertors are set up in current time, together with further specification of particular data types involved in the FE-model.

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# The Hole Drilling Method Data Evalution by means of the Integral Method

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Knowledge of residual stresses is very important for designers of constructions. One of the most used methods for determination of residual stresses is hole drilling method. Principle of this method is drilling small blind hole into centre of strain gauge rosette. Drilling of the blind hole is processed step by step. This procedure relaxes residual strains that can be measured by the strain gauge rosette after finishing of the each step. Evolution of residual strains dependence on depth is obtained. Main problem of determination of residual stresses is using correct equation between function of relaxed strain and residual stresses as function of depth. There were developed many methods such as incremental strain method, average stress method, power series method, integral method, etc. Integral method can be considered as the most fundamental one from the four above mentioned methods.

In the integral method, the contributions to the total measured strain relaxation of the stresses at all depths are considered simultaneously. The measured strain relaxation $\varepsilon(h)$ due to drilling a hole of depth $h$ is the integral of the infinitesimal strain relaxation components from stresses at all depth in the range $0 \le H \le h$. For the case of the equal biaxial stress field can be formulate

$$\varepsilon(h) = \frac{1+\mu}{E}\int_0^h \hat{A}(H,h)\sigma(H)dH$$

where $\hat{A}(H,h)$ is the strain relaxation per unit depth caused by a unit stress at depth $H$. Hole depth is $h$. Determination of the strain relaxation function $\hat{A}(H,h)$ could be done experimentally from sufficiently large number of strain gauge measurement with gradually increasing hole depths. However, it is very difficult if not almost impossible to determine strain relaxation function $\hat{A}(H,h)$ experimentally. That is why $\hat{A}(H,h)$ is determined by means of the finite element calculation..

Strain relaxation response $\varepsilon(h)$ is not determined continuously but only at $n$ discrete points corresponding to $n$ increments of hole depth. Relation between relaxed strain and residual stress is changed in discrete form, where integral changes into sum of coefficients and stresses.

$$\bar{a}\,\sigma = E\varepsilon/(1+\mu)$$

Matrix of coefficient $\bar{a}$ is equal integral of $\hat{A}(H,h)$ during the depth and it is computed by means of FEM. Finite element model must describe variation of the depth hole and

dimension of the strain gauge rosettes. For plane stress state must be computed matrix of coefficients $\overline{b}$ also. Matrix $\overline{b}$ corresponds to load state of shear stress field.

Coefficients $\overline{a}$ and $\overline{b}$ were published only for small range of the hole depth. Coefficient computing for wider range of depth is main aim of present work. Program ANSYS 6.1 is used for finite element calculation. Finite element model is used in the form of two dimensional axis-symmetric. Element PLANE 83 is used. with 8 nodes elements with three degree of freedom in each node. Hole depth changes are made by assigning zero elastic properties to the element within desired hole boundaries. Separate calculations are made for loadings in each increment with a given hole depth.

The integral method is accepted method for determination residual stresses by means of hole drilling method. Computing of coefficients $\overline{a}$ and $\overline{b}$ allows higher accuracy of determination residual stresses in the case of gradient filed..

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# Tube to Elbow Processing Simulation

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A tube bending, when using a process of winding the tube on a formative segment without a supporting thorn (including the tube unloading), was simulated within a subject of "Tube elbows processing simulation". The bent tube is deformed (thus loaded) by a bender translation made by a prescribed rotation of an arm joining the bender with the segment. The tube unloading is due to deactivation of the mutual contact of the tube and the bender.
Two 3D FEM models of the tube bending simulation, when applying the winding formative segment without a supporting thorn , was created in the ABAQUS 63/CAE program. The models differ from each other only in applied benders: the first is a roller, the other is a slider. While the roller, joined with the arm, can rotate about its axis, the slider is coupled with the arm by a fixed binding which makes a mutual motion impossible.

Beside an absolutely rigid bender, the bending assembly is created also by an absolutely rigid segment and a flexible arm, which is modeled as an annular profile beam. As a flexible body, the arm is modeled only to define its coupling with the bender by means of the mechanical bindings and not using a connector element. Consequently, the steel arm is defined as an isotropic linear-elastic material.

The bent tube is modeled as a shell with a various wall thickness. Elastic plastic material of the steel cold bent tube is modeled according to the Prandtl-Reuss plastic flow theory obeying the Mises plastic criterion and the isotropic hardening. The elastic part of the tube material model is linear-isotropic. The plastic part of the metal cold formed material has to be set into the ABAQUS 63/CAE program by the data table $\lfloor \sigma ; \varepsilon_{\mathrm{pl}} \rfloor$ where $\sigma$ designates a real stress in the cross section of the tensile test bar and $\varepsilon_{\mathrm{pl}}$ designates the plastic part of logarithmic strain $\varepsilon$ of the bar. The data table $\lfloor \sigma ; \varepsilon_{\mathrm{pl}} \rfloor$ in the solved example was obtained by approximating the plastic part of the tensile test diagram $\sigma = \sigma(\varepsilon)$ of the modeled material with a spline through the points $[\varepsilon_{\mathrm{E}} ; \sigma_{\mathrm{E}}]$, $[\varepsilon_{\mathrm{Kt}} ; \sigma_{\mathrm{Kt}}], [\varepsilon_{\mathrm{neck}} ; \sigma_{\mathrm{neck}}]$ in the solved example. The plastic relative strain magnitude $(e_{\mathrm{pl}})_{\mathrm{krč}}$ of the tensile test bar at the moment of the neck forming in this bar does not differ much from the value of ductility *a*. In practice, the elastic-plastic stresses in a formed material should be much smaller than the real strength limit $\sigma_{\mathrm{Ut}}$ of this material. That is why, a relation $(e_{\mathrm{pl}})_{\mathrm{krč}} = a$ can be written. For each spline, tangents in its initial and end points have to be defined. The tangent in the initial point $[\varepsilon_{\mathrm{E}} ; \sigma_{\mathrm{E}}]$, corresponding to the elasticity limit of the modeled material, can be a connecting line of this point with the coordinate system origin having the axes $\varepsilon$, $\sigma$. A graph slope of the function $\sigma = \sigma(\varepsilon)$ in the endpoint $[\varepsilon_{\mathrm{neck}} ; \sigma_{\mathrm{neck}}]$, corresponding to the moment of the neck forming in this test bar, is determined from a condition stating that the increment of the tensile test bar loading is equal zero at this moment (the relation $\sigma_{neck} = \sigma_{\mathrm{Ut}}$ holds too).

The two FEM models contain definitions of contacts between the tube outer face and surfaces of the segment and the bender. The two contacts are of a master-slave type with a finite sliding of the contact surfaces. The tube outer face is a slave surface all the time. The two

contacts are defined as hard contacts in the normal direction. The contact surfaces behavior in the tangential direction is described, at both the contacts, by the Coulomb friction model, that is characterized, in both the cases, with the same value of the friction coefficient.

Although the results obtained in this paper mostly coincide with the tube bending behavior known as far, they have to be taken cautiously, basically for next two reasons. The first reason is the fact that the plastic part region of the tube material model is based only on three standard values of the chosen material tensile diagram, being published in engineering tables, and on an estimated material elasticity limit. Thus in fact, the tube material model is therefore merely a fictional one. The second reason is that the results obtained have not been experimentally verified.

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# The Efect Methods of Elastic Constant Optimization

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Any classic tensile experiment can introduce significant uncertainty, regarding the boundary condition definition, into the elastic constants' definition. Moreover, necessity to measure small strains by strain-gages arises. Thus the identification of material properties by the help of tensile experiments is time demanding and quite high-priced. In contrast, a simply shaped bar body, variously loaded, can be manufactured easily and prepared fast for the experimental use. It can be modeled quickly in the frame of any relevant computational system. The possibility to measure experimentally displacements on such simple bar construction is attractive, together with the fact that the strain sensitivity can be adjusted by means of proper choice of bar's dimensions. The sensitivity of a measuring instrumentation is then adapted. The measuring instrumentation should be purely mechanical and no extra investments into strain-gages are necessary.

The bending diagram of dependency of displacement **v** on the force **F**, which is obtained from the linear regression analysis in the form: $\mathbf{v = a * F}$ in the validity range of the Hooke's law. Generally, the slope of regression line $\mathbf{a(E, \mu)}$ is a function of Young's modulus **E**, Poisson's ratio $\mu$ and of constant dimensions of expected bar specimen. When the specimen is shaped as a circle with mean radius **R** and with a constant rectangular cross-section (height in radial direction **h** and width **b**), by the FE-analysis concerning the Poisson's ratio $\mu$ and displacement $\mathbf{v(E, \mu)}$ for the chosen unit force **F** is adapted by polynomial regression thus, the displacement **v** is a week function of $\mu$ and dominant function of **E**.

The elastic modulus' identification can be done according to Fig. 3, where the inverse proportion of $\mathbf{v(E, \mu)}$ displacement to elastic modulus **E** is documented (prepared via power function regression on calculated variants). Since the slope **a** of the regression line on experimental data corresponds to displacement **v** for given unit force **F**, the elasticity modulus **E** can be determined as an intersection of the regression line from the experiment and of the regression hyperbole set from calculations, i.e. from the equality: $\mathbf{v = a*F = a*1 = c*E^{-1}}$. The elasticity modulus is then given in accordance with the previous equation from the ratio: $\mathbf{E = c/a}$.

The determination of Poisson's ratio is based on the hypothesis of "simple functional dependency of bar's displacement under a dominant combination of torsion and bending on Poisson's ratio $\mu$". The circle is loaded by a force perpendicular to the bar's plane and the displacement **u** in the direction of **F** is measured, leading to the linear regression line $\mathbf{u(F) = p*F}$. The calculations of the displacement $\mathbf{u(\mu)}$ are performed with the use of unit loading force **F** and constant elasticity modulus **E**. They are characterized by a regression line, which is a strongly linear function of $\mu$ in the form: $\mathbf{u(\mu, E) = g*\mu+h}$ The constant **h** is a function of elasticity modulus **E** only, which is already set from the previous analysis of the first displacement **v**.

Thus the **h** constant can be determined from the calculation of displacement $\mathbf{u(\mu, E)}$ of the bar's model loaded by unit force **F** and with material constants in the form: **E =** previous

analysis**, μ = 0**. Thanks to the second suitable combination of constants (**E =** previous analysis**, μ = 1**) the constant **g** of the regression line stems from calculated deformation **u** as: **g = u-h**. The Poisson's ratio can be found as an intersection of the linear regression of experimental data and of the linear regression of calculations: **u(μ,E) = (g*μ +h)*F** = **p*F**. This leads to: **μ = (p-h)/g .**

At last can be concluded, that only two relatively simple experimental measurements of two displacements on bar specimen and linear regression of these data are sufficient for identification of basic material constants by the here presented method. Then, only three easy calculations of the corresponding bar loaded by the unit force and with properly chosen material constants, which are performed on given computational system, are sufficient. Thus these 2+3 results directly lead to both E, μ constants.

We have determined the elastic constants for steel, duraluminium and cooper flat beam specimens using special device which allows pure four-point bending. Strain gauges were mounted at the locations of the highest bending stress. Results of measurements were compared to the results obtained by the ultrasound method. According to our results ultrasound method seem to be more accurate. However, the ultrasound method requires complicated technical devices which are not in common available in the technical practice.

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# Damage Localization of Structures Based on Modal Characteristics Changes

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This paper summarizes pieces of knowledge, which authors obtained from solution of problems with utilization of experimentally obtained modal characteristics (frequencies, natural modes and damping) for analysis of structural state of structures and simple structural elements, especially for damage localization of structures.

Methods and procedures, which use results of an experimental modal analysis for estimation of a degradation degree of a structure, is suitable to verify on simple structural elements, when we know their damage state. Three experimental studies were carried out. The influence of damage increase of simple reinforced concrete beams on change of their modal characteristics was monitored in these studies. The state deterioration of beams was done by static loading and dynamic fatigue loading.

Modal characteristics of the beams, which were measured after each loading step, were mutually compared. There were computed changes of natural frequencies and changes of damping frequencies of the beams. For the comparison of natural modes there were used modal assurance coefficients MAC, coordinate modal assurance criterions COMAC, changes of a mode surface curvature CAMOSUC, changes of a modal flexibility matrix and curvatures of changes of a modal flexibility matrix defined by authors.

Conclusions of the first study, in which three reinforced concrete T-beams were investigated, are written in [1]. Partial results of the second study, in which three square section RC – beams were investigated, are published in [1], [2], [3] and [4]. Experimental part of the third study, in which three RC – slabs has been examined, hasn't been finished yet and obtained data are still processed.

Problems of damage localization based on modal characteristic changes were investigated not only experimentally but also theoretically. A finite element model was created for the square section RC – beam, which were observed during the second study. Its material was defined not only by Young modulus but also by ultimate stress, ultimate strength and softening modulus. The parametric study of chosen characteristics was done with the model of the beam. The main aim of this study was to achieve the best agreement between static and dynamic behavior of the model and the real beam. The model identified by this study was loaded in steps, which corresponded with loading steps used during experimental study. Modal characteristics computed for each loading step were mutually compared as in experiment.

Pieces of knowledge obtained on simple structural elements were used for an analysis of a development of the state of three road pre-stressed concrete bridges in Czech Republic (slab bridge across the Radbuza river in Pilsen, box section bridge on D1 km 62.5 across the valley of Sedlice creek and box section bridge near Koberovice on D1 km 82.5). These analyses were done based on results of periodic experimental monitoring of changes of their modal characteristics.

Determination of degradation degree of structures has become a very important problem today. Many scientists not only in Czech Republic but also abroad are interested in damage detection of structures based on changes of their experimentally determined modal characteristics. Many interesting pieces of information about the deterioration of reinforced

concrete structures can be obtained based on analysis of changes of experimentally obtained modal characteristics of these structures. It's suitable to use mainly changes of natural frequencies. For localization of places with crazing induced by load increase during experimental and theoretical studies there prove good the use of COMAC, change of CAMOSUC, change of a modal flexibility matrix and especially a curvature of change of a modal flexibility matrix defined by authors.

For acquisition of reliable data for appreciation of monitored structure based on COMAC, change of a modal flexibility matrix and a curvature of modal flexibility matrix there is very important to consider carefully character and number of natural modes, which should be used in their computation. For determination of CAMOSUC there is most suitable to use a basic natural mode (the 1st vertical bending mode of natural vibration), for higher natural modes CAMOSUC doesn't give as good results as for the 1st one. For reliable analysis there is important to obtain reference data about dynamic properties of investigated structure in undamaged virgin state. It's the best before starting its operation.

The usage of changes of damping frequencies of natural vibration is unsuitable for estimation of a degradation degree of a structure. It hasn't been found out dependence between a damping frequency and a damage degree of a structure yet.

Also the usage of coefficient MAC is problematic for this purpose. It can't be used for localization of a damage. The change of coefficient MAC is very often small when comparing natural modes in virgin state and in damaged state of a structure. Many times there happens that values of MAC are higher for comparison between virgin state and less damaged state than for comparison between virgin state and more damaged state. This effect could by explained. Mass is constant along the beam, so shapes of natural modes depend only on the ratio between stiffness in each cross-section. This ratio is constant on the undamaged beam, after first crazing in single cross-section it decreases locally but after crack initiation in other cross-sections along whole beam the ratio becomes relatively constant again. This is why the agreement described by MAC is better for more damaged state of the structure then for less damaged one.

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# Coal Seam Loading Before and After Bump Initiation

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This paper deals with to the behavior of open rock that occurs, for example, during longwall mining in coal mines, in deep tunnel, or shaft excavation.

Longwall instability leads to extrusion of rock mass into an open space. This effect is mostly referred to as a bump, or a rock burst. When bumps occur, the rock has to possess certain particular rock burst properties leading to accumulation of energy and the potential to release this energy. Such materials may be brittle, or the bumps may arise at the interfacial zones of two parts of the rock, that have principally different material properties.

The solution is based on experimental and mathematical modeling.

These two methods have to allow study the problem on the basis of three presumptions:

- The solution must be time dependent
- The solution must allow the creation of crack in the rock mass
- The solution must allow an extrusion of rock into an open space (bump effect)

This three presumption is necessary in the study of bumps problem. It is known, that if the progress of mining is very slow only, and rock mass has time to create sufficient amount of cracks near the surface of rock wall, bump does not occur. If rock mass has not this time, the bump occurs.

Experimentally was this problem studied in the special loading cell. It consists of the lower steel tank, which is designed for the horizontal forces caused by the vertical load in araldite specimens. The loading cell is equipped with plexiglass on its sides which allows the samples to be observed during the tests. This loading cell models (simulates) the rock mass in the vicinity of the seam. In the loading cell we placed two araldite specimens (with dimensions of 160/400/40 mm), which model a real seam. The gap between them corresponds to the width of a working gallery in a mine. We observed the mechanism and the history of coal bumps. The araldite specimen was covered with a soft dural sheet, and a force meters were placed on it in the following manner: 5 comparatively thick force meters were placed near its outer edge and another 15 thinner force meters were placed next to them. A 300 mm high block of duraluminium was placed over this sheet. This block simulates the handing wall. This arrangement make it sure, that loading of coal seam will be the same, as in reality.

. The sizes of the force meters were 160/ 68/16 or 32 mm. There are 4 strain gauges on each strain gage. These allow us to measure the deformation along its full length. The strain gauges are connected in series in order to be able to gauge each force meter separately and to increase gauging sensitivity simultaneously. Force meters indicated by numbers 1, 2 ... 30 (width 16 mm), 31, 32 ... 40 (width 32 mm) were calibrated within the expected range of forces, that is 0 to 250 kN .

The stability of measuring system in unloaded state was verified for approximately 26 hours. The value of the readings in unloaded force meters was measured in 5 minutes intervals.

Random error of the measuring system is characterized by floating deviation (derived also from 480 values); it equals approximately 0,50 kN. The errors of the gauging electronic system are only small, they reach a smaller value than approximately 0.3 % of the maximal gauged range.

Results of experiments. The first bumps were recorded at forces 1100-1700 kN. The lack of bumps for VW 01-03 is probably due to we failed to recognize them until we had gained some experience. The best way to recognize a bump is noticing the drop in force at the press or the changes in the stress registered by the force meters

*PFC* $^{2D}$ (Particle Flow Code in Two Dimensions) was used for the numerical modeling part of the project. A physical problem concerning the movement and interaction of circular particles may be modeled directly by *PFC*$^{2D}$ .

Particles of arbitrary shape can be created by bonding two or more particles together: these groups of particles act as autonomous objects, provided that their bond strength is high. As a limiting case, each particle may be bonded to its neighbour: the resulting assembly can be regarded as a "solid" that has elastic properties and is capable of "fracturing" when the bonds break in a progressive manner. *PFC* $^{2D}$ contains extensive logic to facilitate the modeling of solids as close-packed assemblies of bonded particles; the solid may be homogeneous, or it may be divided into a number of discrete regions of blocks.

Each particle has its own axial and shear stiffness, and own size. Particles are jointed by axial and shear strength. All this quantities is possible to subject to Gaus statistical dispersion. Each particle is possible to fix against moving or rotation.

The calculation method is a time stepping, explicit scheme. At each step, Newton's second law (force = mass x acceleration) is integrated twice for each particle to provide updated velocities and new positions, given a set of contact forces acting on the particle. Based on these new particle positions, contact forces are derived from the relative displacements for pairs of particles: a linear or non-linear force/displacement law at contacts may be used.

Iteration is finished, when unbalanced force drops under prescribed force.

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# Thin-Walled Shell Collapse - Experiment and FE Solution

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Application of light-weight structures leads up to structures made of either composite materials or metal materials, but in form of thin-walled structures. In the second case of structures loaded in pressure we meet problem of stability as one of the limit state of the structure.

Experimental research gives very often much lower critical loading in comparison with theoretical one. Reasons for it we can find in deviations from ideal geometry taken in account into the theoretical solution.

The paper deals with stability loss critical force assessment of thin walled cylindrical shell (ratio of radius and thickness was 300) axially loaded. Both end were perfectly fixed. Loading was applied symmetrically in axial direction until collapse was done. The difference in the values of this critical loading received by experiment on one side and on the other one by "Eulerian" solution or by FEM.

Improving the results by computing the critical loss force is only possible if we take beside ideal geometry also deviations from it – imperfections.

For implementation of these imperfections (change of thickness, radius, material quantities, etc) we have no realistic data. Imperfections were implemented as a linear combination selected natural shapes at the stability loss according to the following rules:

1) every natural vector of radial displacement has the maximum = 1;
2) if the critical force is multiple (what is typical for rotational symmetry of the examines structure – cylinder) both deflection vectors are combined so that the maximal one has to be situated in the axis of the cylindrical system and this result is used as one natural vector;
3) Coefficients of particular natural vectors were modified so that the maximal radial imperfection value reaches predefined value (in our case one half of the thickness).

The program has as input N natural vectors received from the stability loss of the model with perfect geometry and output are coordinate-changes for all nodes.

Loss simulation was realized as static analysis without inertial forces. Control of the solution may be under condition of either force loading when the force increase is defined and the response is its displacement or deformation control when the displacement is defined and response is loading force. In the first case there were some problems with convergence, n the other approach was substantially effective, especially by application of small artificial damping.

Loading of the model under the condition of deformation control was applied step by step until the ratio of radius and deflection reaches 13.

FEM post buckling analysis of thin-walled cylindrical shell with shape (radial) imperfections, if we use deformation control of loading and small artificial damping, seems to result in acceptable correspondence between experiment and numerical simulation.

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# Optimization of Guiding Properties of Rail Vehicle Trucks

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The term 'guiding properties' embodies a set of different parameters that are used to describe the quality of behaviour of a vehicle running on a straight part of track, along an easement curve and/or in a curve. Among the most significant ones, we rank the grade of riding quality, which gives account of the reaction of a human organism to the running of a particular vehicle on a given track. An important parameter, especially from the economical point of view, is also the absolute magnitude of forces at the points of interaction of the vehicle with the track. Another significant one, considering the safety of the running, is the stability of a vehicle running at high speed and the directly related concept of critical speed.

However, all the above-mentioned parameters of behaviour are very hard to determine during a standard testing on a track. The two ones named last are even impossible to establish for the reasons of operation safety. Therefore, the best solution is to conduct an experiment under laboratory conditions, i.e. mathematic modelling.

When describing a vehicle mathematically, very important and most complicated is the description of forces acting between the wheels of a wheel set and the rails. For this purpose, the most commonly used is the Kalker's linear model of creep forces without saturation.

This model is described by the following equations (see research reports mentioned under references 1 and 2):

$$\begin{bmatrix} F_{tx} \\ F_{ty} \\ M_{nz} \end{bmatrix} = -\begin{bmatrix} C_{11} & 0 & 0 \\ 0 & C_{22} & C_{23} \\ 0 & -C_{23} & C_{33} \end{bmatrix} \begin{bmatrix} \nu_{tx} \\ \nu_{ty} \\ \nu_{nz} \end{bmatrix},$$

$$C_{11} = abGc_{11},\ C_{22} = abGc_{22},$$

$$C_{23} = (ab)^{\frac{2}{3}} Gc_{23},\ C_{33} = (ab)^2 Gc_{33},$$

where:

- $F_{tx}$,$F_{ty}$ tangential forces at the point of contact between a wheel and a rail,
- $M_{nz}$ normal moment at the point of contact between a wheel and a rail,
- $\nu_{tx}$, $\nu_{ty}$, $\nu_{nz}$ are relative creep speeds in tangent plane,
- a, b major and minor half-axis of contact ellipse respectively,
- G shear modulus,
- $c_{11}$, $c_{22}$, $c_{23}$, $c_{33}$ relative Kalker's coefficients.

The latter describes the individual components of these forces in a local coordinate system of the contact between the wheel and the rail as 'linearly' dependent on the relative creep speeds that occur just at the point of contact between the said parts of the vehicle and the rail.

A very important step in the calculation is to determine Kalker's coefficients ($C_{11}$, $C_{22}$, $C_{23}$, $C_{33}$) creating the 'linear' dependence on the relative creeps. The creeps, however, are

constant only for a given geometrical arrangement and loading of wheels and rails. Therefore, a program was developed, based on the algorithm created by Ing. Tomáš Heptner (see research report mentioned under reference 3), in order to be able to determine all the geometrical parameters necessary to calculate Kalker's coefficients depending on the transverse shift of the wheel set in the rail. The new program was drawn up as universal with respect to a possibility of combining different profiles of wheel and rail treads.

The result of the calculation carried out by this program is the dependence of Kalker's coefficients and geometrical parameters of the wheel-rail contact on the transverse shift of the wheel set; for the present moment only for the combination of profiles UIC-ORE and UIC-60 with superelevation 1/40. The behaviour of the resultant dependences proved that the value of Kalker's coefficients is almost constant at small deviations that occur when a vehicle is running on a straight part of a track. A significant change of values and their variability results from bigger deviations that may occur when a vehicle is running in a curve or when it exceeds the critical speed, i.e. in a very dangerous case.

Another possibility of investigation and optimization of guiding properties of vehicles with wheel-set bogies is to conduct an experiment on testing equipment. In this particular case, it concerns a model to scale of a wheel-set bogie located in the heavy laboratories of the CTU (Czech Technical University, Prague). The model has been supplemented with a pneumatic part, which enables precise and independent regulation of air-pressure in individual branches of the system, thus simulating the transverse loading and the distribution of vertical load caused by the centrifugal force resulting from the running of a vehicle in a curve.

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# Application of Semiconductive Strain Gages for Hole Drilling Method

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Stability and accuracy of resultant stresses using drilling method depends also on geometrical relations between center of the drilled hole and positioning the strain-gages [1]. Next problem is due to plastification near the hole if the value of residual stresses are high as near the hole. Theoretical peak value can reach of three times value of the distributed stress and in this way even to exceed material proportional limit. And in this area there are situated also measuring strain gages. In this area there is also steep course of the determined stresses.

All these unfavourable circumstances is going down when the position of strain gages increases. But simultaneously the measured changes of the released strain is going down. Foil strain gages which are in preference used by the residual stress determination have low deformation sensitivity in spite of the fact that they have many advantages as temperature self-compensation, suitable geometry and sophisticated methodology.

At positioning the strain gages forth from the drilled hole it is necessary to use more sensitive strain gage – semiconductive strain gage. This advantage [2] is partially degraded by high sensitivity to temperature. This is coved by multiple connection with semiconductive temperature sensor.

On the flat rot there were applied 7 pieces of seminconductive strain gages AP 120-3-12 made of silicon and 7 silicon resistance temperature sensors T 240 connected into couples. Onto the surface strain gages are applied by means of the epoxy cement PC-6 produced by the Japanese company KYOWA.

During last year this approach was tested on a sample. Actual results are promising. Simultaneously to experiments numerical modeling of stress state and relevant constants for calculation of stresses form strains in the area used in experiment and that are missing by normal strain gage application have been done [3,4].

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Section 7

# MECHANICAL ENGINEERING

# Parameter Measurements of Experimental Mobile Aerating Equipment

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The mobile aerating equipment is an alternative solution of systems used for surface and waste water aerating. The equipment (aerator) uses an axial impeller wheel that causes hydrodynamic impact of fluid stream and air is pumped into admission of air medium. One box unit conception of aerator consists of these main parts: drive electromotor, gap of shaft and hollow shaft with impeller wheel. Effectiveness of equipment is done by an intensification of atmospheric oxygen absorption by mixed fluid with relatively low investment and operational costs. A relatively simple design enables easy servicing and handling. It possible to set an example of utilisation; pools, freshwater fish culture ponds, pools of fishery equipment and pools of sewage disposal plants.

The main part of aerator is an axial impeller wheel. This wheel is placed at the end of hollow shaft used as an inlet of air under fluid level in pool. The starting variant was three-wheels design with straight blades (not curved in a space). The simplicity of production technology was preferred by producers in this case. Unfortunately the action performance of aerator with the wheel was insufficient.

The design and production of laboratory experimental equipment was carried out in link with done model tests [1], [2].

The equipment enables to carry out measurements with different variants of impeller wheel under different revolutions in range 2 300 - 4 000 $min^{-1}$ and an optional shaft declination. Electromotor's energy input was measured under constant revolutions. A main observed parameter was air volume that was pumped into fluid stream. The shape and size of aerated zone in water and a predisposition to create funnel vortex of liquid in front of an impeller wheel was observed as well. A flow characterisation through the impeller wheel was evaluated by visually coloured flow. The equipment has enabled even the operations with a developed cavitation on the impeller wheel.

Parameter measurements were carried out with two variants of impeller wheel blading (with 80 mm diameter). Wheels were produced from plastic materials at investigator's working place.

Observed parameters of equipment were measured as with sooner produced impeller wheel [1], [2] as with newly produced impeller wheel with spatially curved blades often used at impeller wheels of axial pumps. Both variants of impeller wheel were compared under the same working conditions.

Energy consumption advantage of carried out changes of the initial shape of blading was proved by experiments. Necessary data were obtained to choose the optimal variant of impeller wheel's design under existing operation conditions.

Quantitative parameter values were found out. These values has not been published yet in accessible literature sources.

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# Deformation measurement of structural parts in industry using gradient of wave field

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It is often needed to measure very accurately either static or dynamic shape deformation of various types of surfaces in industry. Several different measuring techniques can be used according to the size of the test surface, the microstructure of the surface and the required accuracy of the measurement. The presented work deals with modern techniques for non-contact measurments of the shape deformation of surfaces in engineering practice, especially in optical industry, experimental mechanics, etc. Two most important types of non-contact methods for evaluation of shape deformations are used nowadays in practice: moiré and interferometric methods. These methods enable to carry out a non-destructive inspection of various types of engineering surfaces with a high accuracy and subsequent automatic analysis of measurement. Moiré is the phenomenon, which originates from incoherent superposition of two periodic structures, mostly by gratings. The resulting pattern is characterized by fringes of a specific direction according to a position of superposed gratings. Moiré methods use incoherent sources of light and the shape deformation of the test surface is determined on the basis of the shape of the moiré fringes. These measurement techniques enable to measure deformations of relatively large surfaces in the range from several microns to centimeters. The resulting accuracy of such techniques is within microns. Other noncontact methods are modern interferometric measurement techniques, which enable to carry out measurements with the accuracy in the range of nanometers. The reflected or transmitted wavefront is deformed according to the change of the geometrical shape of the test surface. The object wave field then interfere with the appropriate reference wave field and the intensity of the interference field is recorded by a suitable photodetector. From the distribution of the intensity in the detector plane one can determine the phase change of the object wave field, which is proportional to the shape deformation of the test surface.

The described techniques also have several drawbacks. The interferometric methods need relatively difficult optoelectronic system to obtain the required measurement accuracy, e.g. a very precise mechanics and a coherent source of light. These measurement systems are very expensive. They also often cannot be simply used in industrial practice according to their sensitivity to mechanical vibrations. One is limited to measure only small displacements, i.e. in the range of micrometers. In case of measurement of extended objects it is necessary to use a high power laser as a source of light. Described moiré methods cannot be easily used in non-laboratory measurement conditions with respect to light losses and their accuracy is lower than the accuracy of the interferometric methods. Mentioned drawbacks lead to the development of new methods, which enable to quantitatively measure the shape deformation of surfaces with nearly the same accuracy and sensitivity as common interferometric methods. On the other hand, the costs of such systems should be rapidly decreased. These methods also should be less sensitive to negative influences during the practical measurement process, e.g. mechanical vibrations.

The research project deals with the design and analysis of such measurement and evaluation techniques. In this work the optical methods suitable for deformation measurement, which are based on an approximation of wave fields in geometrical optics, were thoroughly investigated.

The geodetic methods, which are used for static measurement of large and remote objects in civil engineering, can be included into this category. However, these techniques are not very accurate in comparison with the interferometric methods and cannot measure dynamic deformations. Our work is focused on other type of geometrical optical methods, which evaluate the components of the gradient of the wave field that is deformed by the change of the shape of the test object surface.

The basic concept behind these methods is that the test surface can be sampled at a number of points across it in a predetermined fashion, and then the change of the surface shape can be reconstructed from the first derivatives of the wavefront, which is reflected or transmitted by the object. If the surface of the test object is sampled by a number of rays (in fact by beams of the specific physical properties), the ray deviations at some desired detector plane location can be obtained. With modern solid-state array detectors, e.g. CCDs, the intersections of the reflected beams can be determined with a subpixel accuracy. From intersections of the beams with the detector plane and the location of this plane it is possible to determine the displacement of sample points on the test surface. Using suitable numerical methods the deformation of the test surface can be approximated. The accuracy and sensitivity of these methods depends on the design of the measurement system, the number of rays and the evaluation methods, which are used for measurement. A great advantage of these methods is their high accuracy, insensitivity to mechnical vibrations, simplicity in comparison with complicated laser systems, which are used at present, and the fact that these methods may use a simpler incoherent source of light.

An implementation of these non-contact and non-destructive methods for deformation measurements in industry was investigated in this research project. In the world, there is paid a significant attention to these high sensitive non-contact techniques, because the described techniques may replace current laser interferometric methods. The proposed solution contains of several original techniques, which extend the solved problems both in the theoretical and practical aspects. In the primary stage of the project there was put the accent on the theoretical analysis and the numerical simulation of the proposed method. A smaller part of this stage was also devoted to necessary support experiments, which were focused on the design and calibration of the proposed parts of the measurement system. Further work will be focused on experimental verification of the method and elaboration of the software for an automatic evaluation.

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# Experimental Verification Technology of Ultra Light Rotor

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At present time, a sporty flying is more and more popular. Sporty aircrafts with ultra light construction are in great demand. Great many small companies are specialized to produce small series of ultra light aircrafts and make effort to obtain important part of market. We can talk about a pioneering age of new branch of air industry today, about an ultra light air industry. Nowadays, the ultra light air industry assumes know–how from well-developed civil air industry, but not all of the technical solutions are possible to simply extract. There are new restrictive conditions, not exceeding boundaries of physical laws and different priorities. The ways, haw to overcome the problems, are seeking and no traditional solutions are discovered. They can to be useful for classical air industry, as well.

Dreams and desires of aeronautical fans, amateur pilots and sporting pilots have a serious place in this new branch. The firms, which produce ultra light aircrafts, immediately exert to fulfill them. We can see an evident analogy with the evolution of classical aviation. The interest of ultra light aircraft pilots move from the gliders and the propeller planes through the scale downed replicas World War I and World War II combat aircrafts to the jet planes.

So we face the problem to solve qualitatively new task, haw to construct the ultra light jet aircraft and what propulsion use for that aircraft. Obviously, we can use real jet engine, but there is also an alternative way. The way is using the classical piston engine joined with the “cold propulsion” – “ducted fan”. This construction has an obvious advantages and some disadvantages as well. The disadvantage is namely necessary distance between the piston engine and fan. It is important reason to have a collected engine mass nearly a center of gravity of the whole of aircraft. The duct, where the fan is placed, must be also correctly aerodynamically shaped. We continue to solve primary problem. That is a construction of the main rotor part – ultra light transmission shaft.

The ultra light transmission shaft is a critical part of this ducted fan design. The shaft must relay a needed power, withstand torsion vibration and torque peaks. Any torsion and flexion vibrations are not allowed in an operational range of revolutions. This construction is moreover limited by the cardinal requirement. The mass of the ultra light aircraft must not exceed 450 kg.

All construction requirements for ultra light rotor stated above produce technological problems. The Solution of those problems is no less important. We have an extremely long hollow shaft (37.52 in), which has a relatively big diameter (4.567 in) and extremely thin shell (0.039 in). This ultra light shaft must be manufactured very precisely, but we cannot to use common techniques, for example honing cannot be use for aluminum alloy. In addition, we cannot use high technology like a chemical and electrochemical machining, because they are expensive for the manufacturers of the ultra light aircrafts.

The ultra light rotor for that torque transmission to the fan of the ultra light jet aircraft with piston engine was designed in this project. The construction material was selected as a high strength aircraft alloy D16. According to criterions discussed above was preferential choose traditional technology lathe machining with special spike. This suggested technique of ultra light shaft manufacturing was tested on section equal one third of total shaft length. The technique is: 1) to prepare and to fix the D16 alloy solid material in the lathe. 2) to drill the shaft hole diameter is 2.362 inch. 3) gradual accretion this hole by using double knife, final diameter is 3.937 inch. 4) to turn the precise hole by using solid knife to the diameter 4.496 inch. 5) to warm and to join precisely manufactured steel special spike. 6) to fix the shaft and the special spike to the lathe and rough-turn surface to diameter of flanges. 7) to turn the material between flanges to diameter 4.921 inch 8) to machine the blend of flange on the support side. 9) to machine the blend of flange on the spindle side. 10) to turn the material between flanges to specifies diameter of rings. 11) to turn the material between rings to diameter 4.675 inch. 12) to warm and to detach the ultra light shaft from precisely manufactured steel special spike by using different thermal stretch both materials.

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# Nonconvex Mathematical Programming in Evaluation of Experimental Data

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Evaluating of experimental data leads to a lot of problems. Determining of parameters of material models is one of such problems. In fact, it is a problem of finding such value of model parameters for them the sum of squares of diference of measured quantities and quantities of searched model was at its minimum. This is a problem to find a minimum of known function that is often in a form of sum of products of powers of design variables and known coefficients. The considered problem is called geometric programming problem.

Geometric programming method is method of solving the parameter optimization problem of this form. To treat this problem, geometric programming method employs the geometric inequality to transform the minimization of function that is nonconvex to the problem of maximization of dual function that is concave and subject to linear constraints.

Geometric inequality states that the weighted arithmetic mean is at least as great as the weighted geometric mean. It is known that positive weights satisfy the normality condition (theirs sum equals to one). The geometric inequality becomes an equality if, and only if, the averaged quantities are equal each other.

The problem of maximization of dual function that is concave and subject to linear constraints can be readily solved. Moreover, if the number of primal variables is equal to number of terms of primal problem minus one, the constraints of this concave problem have one solution and the maximization problem is reduced to solving of system of linear equations.

This optimization method always produces a global minimum, not only a relative minimum, of problems of this form that generally involve functions that are both nonlinear and nonconvex.

Another mathematical methods for solving nonconvex minimization problems are optimization algorithms that mimic natural phenomena and physical processes. Amongst others, notable formulations are the genetic algorithm, simulated biological growth, simulated annealing and the particle swarm optimization.

In all probability, the best known of the methods mentioned above is the GA (Goldberg 1989; De Jong 1975; Beasley et al. 1993), which mimics natural selection. A population of genes is ranked based on the fitness of the individual genes. The genes with the best fitness are selected according to a given selection criterion to reproduce. Reproduction is affected by the cross-over operator. Genetic diversity is introduced in the population by means of mutation. Elitism is often employed where the gene with the best fitness is copied to the next generation.

Simulated biological growth (Mattheck, Burkhardt 1990) mimics phenomena that have been observed in the mechanism of tree growth. This involves the self-optimization of living trees which always try to grow into shapes of constant surface stress. Another example is the phenomenon that has been observed in animal and bone tissue (Huiskes et al. 1987). This involves the addition of bone material in regions of high stress and conversely, the reduction of material in regions of low stress.

Simulated annealing (Metropolis et al. 1953) is based on statistical thermodynamics and is used to simulate the behaviour of the atomic arrangements in solid material during an annealing process.

Particle swarm optimization is still in its infancy. This method was proposed by Kennedy and Eberhart (1995) and is based on the simulation of a simplified social model. Some aspects that intrigued scientists were the underlying rules that enabled large numbers of birds to flock synchronously, often changing direction suddenly, scattering and regrouping, etc. Since these initial observations, bird flocking is one of the behavioural patterns which were sought to be mimicked.

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# Digital optoelectronic techniques for topography of industrial surfaces

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The mechanical (contact) measuring techniques or techniques based on the physical principle of optical holography, and moiré topography are still mostly used for making of measurements of the shape and deformation of the surface of various structures or structural parts in industry. A widely used measurement technique in practice is optical holography. The interference pattern in optical holography is very frequently detected by a photographic plate or film in two different states of the measured object. After developing the film we obtain a photography with interference fringes (hologram). The described process is experimentally rather slow.

The modern methods for measurement of the shape and deformation of the engineering surfaces are based on the principle of interference of coherent optical wave fields (object and reference) and a subsequent automatic evaluation of deformation in real time. These methods use modern optoelectronic elements to record the intensity distribution and to analyse the interference field. It is very well known that the phase change of the object wave field is closely related to the displacements of the test object. To determine the phase change from the intensity values we can use several phase evaluation methods, which are based mostly on the techniques of digital image analysis. These methods enable to evaluate the measurement results very accurately and automatically. For detection of the interference field they use modern solid–state array sensors, which rapidly increase the speed of the measurement process in comparison to classical holographic methods. The methods of classical two-beam interferometry are widely used for testing optically smooth surfaces. They can reach a very high measurement accuracy due to the modern methods of wave field analysis. The two-beam interferometry meets the difficulties with scattering of the light on an optically rough surface. A very usual technique that can be used for deformation measurement of objects with an optically rough surface is speckle interferometry.

Our work is focused on the method of electro-optic holography for static deformation measurement in industry. A general algorithm for evaluating the phase change of the interference field induced by a static deformation was derived. It has been shown, how to evaluate the phase values, which are closely related to the shape deformations of the test object. The experimental system, which is applied in static deformation measurement and which can be easily modified for industrial applications, is described. Furthermore, the influence of most important factors during the measurement process was investigated and the analysis of this process was performed. The performed analysis can be used for comparison of different evaluation algorithms.

The interferometric measurement techniques are very sensitive and accurate, but they require the use of a coherent source of light, e.g. a laser, and one is able to measure only small displacements, i.e. in the range of micrometers. It is necessary to use high power laser as a source of light, in order to make measurements on extended objects. Other optical methods of deformation measurement include the techniques based on an approximation for wave fields from geometrical optics. The geodetic methods are used for making measurements on large

and remote objects in civil engineering. They are not very accurate in comparison with the interferometric methods and cannot be used to measure dynamic deformations.

Our work is focused on another type of geometrical optical methods, which are called the ray methods. These methods are based on a purely geometrical optical approach. The basic concept behind these methods is that a shape of the test object can be sampled at a number of locations across it in a predetermined fashion, and then the change of the surface shape can be reconstructed from these sample points using suitable numerical methods. The Hartmann method is a widely used method in practice, especially in optical industry. We investigated an implementation of the ray methods for deformation measurement in industry.

A simply method for the measurement of optically rough surfaces with the ray methods has also been proposed. Optically rough surfaces are "smoothed" using the reflective foil that is affixed on the test objects. The surface becomes practically a mirror of a general type and the proposed ray method can be applied for measurement of deformations. The theoretical analysis of the ray method was performed and several techniques for calculation of deformations were proposed. The main advantage of the ray methods with respect to the interferometric methods is their relatively easy implementation in practice. The accuracy of the proposed ray method is comparable with the accuracy of common interferometric techniques. Another advantage is the possibility to measure extended surfaces in engineering practice.

The proposed technique seems to be a very accurate and perspective method for static deformation measurement in industry. The achievable resolution and accuracy of displacement measurements and real time processing permit subsequent numerical calculations and make the technique attractive for measurement of strains in experimental stress analysis. The advantage of the described non-contact measurement methods is the high precision, automatic evaluation of deformations in real time and possibility to simply analyse computed deformation with a computer. The described methods are suitable as the test techniques for machinery and building industry.

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# Mixing of Suspensions

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Suspension mixing is very important hydraulic operation. It is estimated that about 60 % of mixing cases is related to the heterogeneous system: particulate solid phase-liquid. It is generally understood that axial-flow pattern impellers are the most suitable agitators in such cases and six, three or four pitched-blade turbines are the most spread ones. Very important parameters for designing of mixing apparatuses for suspension are not only the critical (just-suspended) impeller speed and power consumption necessary for off-bottom suspension of solid particles but also often distribution of solid-phase in the agitated apparatus.

Solid-phase distribution in agitated batch can be described by the position of interfaces [1]: the particle layer sediment near the wall at the bottom having radius $r_e$ and height at the wall h, the particle layer sediment at the centre of the bottom having radius $r_i$ and the cloud of suspended particles having height $h_s$. For geometrically similar mixing equipment, the inspection analysis of equation of continuity, Navier-Stokes equation and equation expressing balance of forces affecting the suspended particle shown in [1] gives the following general relationships for dimensionless coordinates of interfaces:

$$\frac{2r_i}{D} = f\left(Fr', Re, \frac{d_p}{D}, c_V\right) \qquad \frac{2r_e}{D} = f\left(Fr', Re, \frac{d_p}{D}, c_V\right)$$

and

$$\frac{h}{H} = f\left(Fr', Re, \frac{d_p}{D}, c_V\right) \qquad \frac{h_s}{H} = f\left(Fr', Re, \frac{d_p}{D}, c_V\right)$$

where Fr´ is the modified Froude number, Re is the Reynolds number, $d_p$ is the mean volumetric particle diameter and $c_v$ is the mean volumetric concentration of solid phase. The characteristics describing solid-phase distribution in agitated batch are independent of the Reynolds number for high values of Reynolds number. All results of solid-phase distribution measurement were plotted in the form of dependence of dimensionless position of interfaces $2r_i/D$, $2r_e/D$, $h/H$ and $h_s/H$ on modified Froude number Fr´ and other observed properties of suspension. The conclusions obtained by the theoretical analysis were verified by the experimental results shown in [1].

During last 15 years the leading mixing manufactures developed so called hydrofoil impellers having the blade pitch varying from 45° at the hub to about 22° at the impeller tip. Our investigation into suspension efficiency of the selected hydrofoil impellers was done in a baffled dish-bottomed cylindrical vessel [2]. The following axial impellers have been tested:

- Hydrofoil impeller LIGHTNIN type A310
- Marine propeller EKATO
- Propeller designed on Anhalt University of Applied Sciences / Hochschule Anhalt (FH)

All impellers have been operated to pump the liquid downwards the vessel bottom. Suspension ability of axial impellers having more simple design (standard pitched three-blade turbine with pitch angle 45° and pitched three-blade turbine with diagonally folded blades according to Czech standard CVS 69 1043 [3]) was taken as a standard for comparison with impellers having more sophisticated design. Critical impeller speed for suspension was determined

visually according Zwietering definition – no particle remains longer than 1 sec on the vessel bottom. The following conclusions might be drawn from our suspension investigation:

- Hydrofoil impellers have higher suspension efficiency than the standard 45° pitched-blade impellers.
- All hydrofoil impellers have roughly the same suspension efficiency when compared at optimum impeller clearance.
- Propellers are more sensitive on impeller off-bottom clearance than the other impellers.
- Geometrical simplicity of the pitched three-blade turbine with diagonally folded blades at the comparable suspension efficiency with the other hydrofoil impellers makes this impeller the most favorable one.

Pumping capacity of impellers has significant effect on processes in agitated batch e.g. particle suspension and homogenization of miscible liquids. The comparison of axial velocity profiles, pumping capacities and pumping efficiencies of axial-flow impellers in dish-bottomed fully baffled cylindrical vessels is shown in [4]. The following axial impellers have been tested:

- Pitched three-blade turbines with various pitch angles $\alpha$ = 24°, 35° and 45°
- Pitched six-blade turbine with pitch angle 45°
- Pitched three-blade turbine with diagonally folded blades
- Marine propeller EKATO
- Propeller designed on Anhalt University of Applied Sciences / Hochschule Anhalt (FH)

Axial velocity profiles were measured by LDA (Laser Doppler Anemometry). Axial pumping capacities were obtained by integration of measured axial velocity profiles in outflow from impellers. The pitched blade turbines and propellers have similar shape of axial velocity profile, which has marked maximum. While the pitched three-blade turbine with diagonally folded blades has significantly flatter shape of axial velocity profile. Axial pumping capacity increases with increasing pitch angle and blade number of the pitched blade turbines. From comparison of the energetic criterion it can be said that the impellers having lower value of the power number have higher pumping efficiencies. The standard pitched blade turbines with pitch angle 45° have the highest energetic requirements for pumping of liquids.

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# Stance for Measuring Couplings and Gears

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This article deals with identification of drive operation parameters. Experimental evaluation of drive systems with transmission mechanisms is based on operational loading simulation, operational kinematics conditions, etc. It includes assessment of these main parameters: input and output torsion moment and speed. Having these four parameters we can determinate lots of useful parameters: real reduction ratio, torsion stiffness, lost motion, backlash, transmission accuracy, efficiency.

For laboratory testing of transmission boxes characteristics and their parts (e.q. gear sets, shafts and bearings) are used open and closed experimental circuits. For their relatively low energy intensiveness are very wide-spread the closed experimental circuits. In these circuits is constructed static pre-load - in closed circuit of aggregates is controlled or initially set.

The measuring circuit is constructed for the 1500 Nm moment and 3000 rpm. Thus in the closed circuit rises a (virtual) power $P = \frac{M_k \cdot n}{9550} = 471$ kW. Because of that purpose there is almost impossible to cover that power by an electro-motor in an open circuit, which is better to use for it's easy moment regulation during operation. There is a possibility to regulate the moment in closed circuit operationally, only in use with planet gearbox, which is too expensive to use for this stance. Therefore there is going to be used an initially preset pre-load here.

The measuring circuit consists of four main shafts, each is carried by two bearing houses. Each pair of shafts composes with two same pulleys and a belt transmission. There are two 1:1 ratio transmissions in frames made of U-profiles, where one is driven and position of the second one is adjustable according to the size of measuring object. The initial tension will be set with a pair of pre-load rings Ringfeder joined with a tube coupling. All bearing houses are turnstile and shafts are grooved for keys, so that the circuit could be as universal as possible. On these ends will be possible to attach either some adjunct power or loss unit or any measure device like IRC to read the circuit kinematics. Torque scanning will be performed by a professional HBM tension sensor. The output of electro-motor for covering the circuit losses during the maximum power of circuit was counted as 41,5 kW. In this loss power participate losses in bearings and mainly two belt transmissions, where each has "only" about 96 percent efficiency.

On this circuit will be performed short, middle and long time measurements, where probably the biggest emphasis will be set on the long time measurements. These are focused on study of reliability, kinematical accuracy and other parameters during whole service life, we have to simulate the load for a long time. It means loading for thousands hours. It is necessary to design the optimal type of loading cycle. It usually consists of starting, running, braking, reversing, waiting, etc. The most important parameters are temperature, torsion moment, and speed. To evaluate the wearing process or changes of efficiency during a long time experiment it has to be interrupted. The short or middle time measurement can be done according to what type of methodology it has been designed for.

Designed measure stance provides possibilities to evaluate a large assortment of types of rotary transmission members. Using modern universal device for checking, adjusting and displaying data, quick and exact evaluation of explored object can be provided.

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# Investigation of Acceleration Fatigue in the Category of Ultralight Airplanes

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The nineties of the last century are known by the great boom in the production of the small aircraft; known as Ultra Light [UL] or Micro Light [ML] airplanes. Their history is short; however, very dynamic. Nowadays, there are many planes, which differ in the manufacturing, used materials, traffic or maintenance. These planes are building at home (single-piece production) or in the professional workshops in the relatively big series. The common features of these airplanes are low maximum weight, wing surface load, operational speed, engine performance, relatively poor control instruments[1] and usually are equipped by the pilot of boundless courage.

The character of the flight can be described by the flying time and the spectrum of "g" achieved during the flight. The "g" spectrum is measured by the fatiguemeter TL-3412_CVU [1]. Measured "g" spectrum is written down in two-parametric form. For the purpose of verification the supplementary in-time measurement of the "g" spectrum is done. The in-time measurement is carrying out in the specified intervals. For the in-time measurement the TL-3412_LNG/FST fatiguemeter is used. Record from the in-time measurement is evaluated by the different method (e.g. rain-flow method) and resulting data are compared with the data obtained from TL-3412_CVU.

Both fatiguemeters TL-3412_CVU and TL-3412_LNG/FST are products of the Czech firm TL electronic. The fatiguemeter TL-3412_CVU was specially designed for this research. The fatiguemeter TL-3412_CVU base on the microprocessor components, which electro-mechanically scans the vertical acceleration in the center of gravity of the UL Airplane. Afterwards, the 12-bit A/D converter converts the analogue signal from the acceleration sensor to the digital signal. The resultant value of the vertical acceleration is saved in the memory of type EEPROM. The data can be saved in the memory for the period of ten years without the power supply.

The first plane on which the operation monitoring and data collection are carrying out is the TL-96 STAR, all-composite low-wing UL Airplane. TL-96 STAR is one of the top UL Airplanes manufactured in Europe and its performance is comparable with the small sport aircrafts. The TL-96 STAR is product of the Czech firm "TL ultralight".

The second one is Italian P-92 ECHO maid by firm Tecnam. It is all-metal high-wing UL Airplane. Especially high-wing configuration of this airplane provide very comfortable

[1] It has to be sad that cockpit of nowadays UL Airplanes manufactured in the professional workshop are relatively well equipped by the engine and flying instruments.

plane control during the flight; therefore, it is widely used as the school or training plane in the flying schools.

As mentioned above, the fatiguemeter TL-3412_CVU is fixed to the Airplane structure in the center of gravity, respectively as close as possible to the center of gravity. The fatiguemeter TL-3412_CVU is in the TL-96 STAR accommodated under the seat of the co-pilot. Two tightening strips fix the fatiguemeter on the metal holder, which is screwed on the bulkhead. To access the fatiguemeter and download the data, it is necessary to dismount the co-pilot seat, which is fixed by two screws only. In case of UL Airplane P-92 ECHO the fatiguemeter is mounted on the metal spar behind the first pilot seat. Similarly as in the case of TL-96 STAR UL Airplane the two tightening strips fix the fatiguemeter on the spar of P-92 ECHO.

For the purpose of separation of the aerodynamic load spectrum from the spectrum of the ground load, the both Airplanes TL-96 STAR and P-92 ECHO are equipped by the end switch mounted on the main landing gear.

For comparison and description of UL Airplane air traffic and operational load the one-parametric "g" spectrum [2] is used in this project. The record of the fatiguemeter TL-3412_CVU is spread out into two spectrums of Ascending and Descending half the load cycles. The result from the comparison of these two spectrums is that the occurrence of the Ascending and Descending half the cycles is the same [3]. Hence, there is no need for evaluation of both Ascending and Descending half the load cycles. Practically it is enough check their agreement and if both spectrums are the same than one of them can be considered and used as spectrum of whole load cycles.

Evaluated data correspond to the 72.49 flying hours of UL Airplane P-92 ECHO and 96.74 flying hours of UL Airplane TL-96 STAR. During these periods of time the obtained maximum value of "g" was +2.7 and the minimum 0. In this range of "g" the running of the "g" spectrums is smooth with a slight drop in the g = +0.5 and g = +1.5. There was registered only one case of higher "g" value than +2.7. It occurs on the Airplane P-92 ECHO and accessed "g" value was +3. There was registered sharp decrease in the area of the negative value of "g" what indicates that pilot "enjoyed" the flight. In the case of UL Airplane TL-96 STAR the maximum positive value of "g" never exceeded value of +3.

Next conclusion is that positive branch of P-92 ECHO "g" spectrum overlap the positive branch of TL-96 STAR "g" spectrum. Hence, the "g" spectrum of UL Airplane P-92 ECHO is in the positive "g" area "*harder*" than spectrum of TL-96 STAR. In the negative "g" area are both spectrums of P-92 ECHO and TL-96 STAR almost the same, which indicate that pilots of both airplanes did not like to fly in this area of "g" values.

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# Experimental Evaluation of Precise Gearboxes

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The precise reducers are based on various principles. They are planetary gearboxes, harmonic drives, cycloidal gearboxes. The modifying of the last one is called the bearing reducers. These transmission members of drives are usually used in robots and production machines. The other fields of using of these reducers are aircraft equipment, medical equipment, printing machines, woodworking machines, paper manufacturing machines, glass-working machines.
To transfer the power during required service life is the first duty of precise drive. There are other parameters, which are very important, especially kinematical accuracy, because this parameter determines motion of driven parts, it is very interesting. It depends on service wear, which changes during service life influence distribution of load in the mechanism.

The most interesting properties of these reducers are:

- High reduction ratio,
- High torsional rigidity,
- High positional accuracy,
- Backlash-free power transmission,
- Low gearbox temperature,
- High efficiency (minimum power loss),
- High acceleration torque,
- Low running noise,
- Compact coaxial hermatically sealing housing.

This paper is concerned with methodology of identification of precise reducer ´s parameters. Experimental evaluation of them is based on simulation of service loading, service kinematics conditions etc. It includes assessment of these main parameters: input and output torque moment and speed. Having these four parameters we can determinate a lot of spoken parameters.

Simulation of service

Very easy way how to arrange the measured post is the positioning of two drives opposite itself. Asynchronous electric motor of the first one is the drive motor and asynchronous electric motor of the second one is the loading unit. Regulation of torque moments and speeds of both motors can be done with operating feedback. Programmable software controls couple of frequency converters. They are able to operate both torque moments and speeds of both electric motors.

The transfer accuracy of motion

This experiment can be named “short time measurement”(STM). The accuracy of transfer of motion is the main and the most important parameter of precise transmission systems. The operating principle of used sensors is based on photoelectric scanning of individual periodic graduation tracks. It means that the measured value is determined by counting. It is an incremental measuring. Since a reference is required to find absolute positions, graduated disks feature a reference mark on an additional track is next to the incremental grating. The reference mark is also scanned photoelectrically.

Kinematical mistake defines accuracy of transmission. In the case of rotary reducer it is error of angle:

$$\Delta\varphi = \varphi_2 - \frac{\varphi_1}{i_{12}}, \quad (1)$$

where $\varphi_1$ measured angle of rotary of input shaft,
$\varphi_2$ measured angle of rotary of output shaft,
$i_{12}$ transmission ratio.

This value can be changed if the wear is determined by service life. It depends on the loading of the system.

Definition of efficiency and temperature state

This experiment can be named "middle time measurement"(MTM). It describes the effects in the start of service of drive. It means measuring of temperature from starting service to steady service, definition of efficiency depending on degree of loading etc. Usually, the information of temperature of environment of the gearbox and of the oil is recorded. Efficiency can be defined:

$$\eta = \frac{P_{output}}{P_{input}}, \quad (2)$$

Since:

$$\omega_{input} = \omega_{output} . i_{12}, \quad (3)$$

we can count :

$$\eta = \frac{T_{output}}{T_{input} . i_{12}} \quad (4)$$

There is $\eta$ efficiency of transmission,
$P_{input}$ input power,
$P_{output}$ output power,
$T_{input}$ input torque moment,
$T_{output}$ output torque moment.

The reliability and service life

Experimental evaluation of these parameters can be named "long-time measurement"(LTM). The reliability and service life of precise mechanical drives used in robots is firstly limited by a definite reduction of their kinematical accuracy. Manufacture, assembly, rigidity of drive parts and operating wear influence it first of all. Having methodology of STM and MTM, the assessment of quality of precise reducers during their service life can be realized. The service life has to be divided into the same-long periods. After finishing of every period the service loading has to be interrupt and STM and MTM should to be applied. Monitoring changes of results of these measurements the wear of reducer ´s parts can be determined.

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# Correlation Investigation between the Operational Load Factor and Structure Load of UL Airplane for the Purpose of Structure Fatigue Prediction

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This paper links to the authors' previous work [1]. This project tries to find the dependence or correlation between the operational vertical acceleration ("g") and stress in the selected "critical" part of the UL Airplane structure.

For the prediction of the Aircraft operational life according to vertical acceleration is necessary to know the correlation between the stress and "g". However, find such relation is quite difficult and the investigation is based on the experimental measurement "g" and stress in the selected critical place of the structure. There is the fundamental restriction for the application of "g" spectrum in the Airplane service life calculation. For the service life calculation the "g" spectrum can be used only if the correlation between the "g" and stress in the particular part of the airplane structure is known and experimentally proved. Hence, the vertical acceleration in the airplane center of gravity will with some appropriate accuracy provide information about the wing bending load; less accurate results will be obtained for the fuselage and for the tail wing calculation the "g" is practically useless [3].

The two inputs are necessary for correlation investigation. The first one is two-parametric matrixes [1] obtained from fatiguemeter TL-3412_CVU [2]. The second input is from the special "flying" logger, which measure the in-time "g" spectrum and in-time load spectrum of the structure in the selected place. The in-time load spectrum is obtained using by the strain-gauges. This in-time "g" spectrum and Load spectrum measurement has been done in the cooperation with the Technical University in Brno, department of Aerospace Engineering. As the second independent measure equipment, their Logger "DAS 12" has been used. During the fight measurement the "flying" Logger was placed behind the co-pilot seat. Two metal strips mounted the TL-3412_CVU fatiguemeter on the spar and next to it there was the TL-3412_LNG/FST fatiguemeter.

The correlation between the "g" and structure load was investigated on the spars cantilevers of the wing of the TL-96 STAR and on the wing strut of the P-92 ECHO. TL-96 STAR has two spars, one for each wing. The wing spars continue into the fuselage as cantilevers. For the purpose of correlation investigation the bending moment was measured on the three places of wing spar cantilevers of TL-96 STAR. Three independent half the strain-gauge bridges measured the resulting bending moment. Two half the strain-gauge bridges were placed on the right wing cantilever and one on the left wing cantilever.

The positions of half the strain-gauge bridges were measured from the airplane symmetric axis, which is defined by the wing spars connecting pivot. The distances were

300mm and 625mm for the right wing cantilever and 300mm for the left wing cantilever. The strain-gauge cross on the cantilever web measures the spars shear force.

On the UL Airplane P-92 ECHO the metal cover of the wing did not allow implementation of the strain gauges directly on the wing spar. Therefore, instead on the wing spar the two strain-gauge crosses were implemented on the wing strut. The two strain-gauge crosses measure the tension force of the strut. The influence of the "g" on the load of wing strut is clear, which allows use the wing strut in the correlation investigation. From known force of the wing strut the load of the strut attachment and wing spar can be easily defined. Consequently, this load can be used in the investigation of correlation between the "g" and stress of the particular structure.

The strain-gauge signal calibration of the wing strut of the UL Airplane P-92 ECHO was relatively simple. The wing strut was dismount from the plane and hanged by one end. On the other (free) end the defined load (weight) were placed. According to particular weight used the strain-gauge signal was calibrated.

Meanwhile the process of the P-92 ECHO wing strut strain-gauge signal calibration was relatively simple the signal calibration of strain-gauge bridges of P-96 STAR wing was more difficult. For the practical signal calibration of the strain-gauge bridges the special fixture has been made and used. Basically this fixture is a support, which one side has a mirror shape of the bottom side of the wing profile used on the wing of TL-96 STAR aircraft. During the calibration process the fixture were placed on the bottom side of both half the wing in the defined distance from the airplane symmetrical axis. The lifting device produced the loading force, which was distributed via the fixture to the wing structure. The lifting device was placed on the scale, which measured the loading force.

The whole process of calibration was done for several symmetrical and asymmetrical loads. The used calibration loads varied from the 500N up to the 1500N, which roughly represents the flight on the load factor equal to 1.53. The value of 1500N (150kg) is the wing structure limitation. It is due to the thin shell structure of the wing. The used fixture for the action load distribution is relatively narrow, which cause greater surface load on the wing in their contact place.

After the flight measurement the record from the Logger DAS 12 has been evaluated to the resulting in-time spectrum of the load factor and three bending moments. These results represent approximately 13 minutes uninterrupted in-time record of "g" and three bending moments. Unfortunately these spectrums are not evaluated yet (from the structure fatigue point of view); however, they will be used as the entry parameters for the investigation of the correlation between the vertical acceleration and load of the structure. Consequently, if the desired correlation will be found, it allows the prediction of the fatigue damage and service life of the UL Airplanes structure.

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# Investigation of Latent Thermal Energy Storage Use in Solar Heat Pump Systems

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This project is intended to integration low-potential source of energy to heating system by heat pump. The solar heating system is source low-potential of energy. Energy storage tank is filled with PCM as a heat storage material. This PCM use the latent heat for storage of energy. The combined system should be able to store enough of energy during winter season. This energy will be used as low-potential source of energy for heat pump. Due to this system will be achieved high energy cost saving.
Solar energy system and heat pumps are two means of reducing the consumption of non-renewable energy resources, and hopefully, the cost of delivered energy for domestic space heating and water heating. During winter, the energy that could be collected by a solar system but which would be too low in temperature to be useful for direct heating may be used as a source for the heat-pump.
Energy storage is much more important where the energy source is intermittent such as solar energy. A great disadvantage of this kind of energy shows up immediately, namely the large discrepancy between the supply and the demand. The heat demand is maximum in winter, or, in the short term, in the evening when the supply of solar energy is minimal or zero. This makes heat storage an indispensable element of a solar-driven heat-pump system. One way of increasing the economic competitiveness of the heat-pump is to integrate it with a thermal energy storage system.
In this system, the performance of solar heating system with a heat pump will be investigated both experimentally and theoretically. The experimental results will be obtained from October to April during the heating season. Some model parameters of the system such as COP, theoretical collector numbers (Nc), collector efficiency, heating capacity, compressor power, and temperatures ($T_1$, $T_2$, $T_3$,$T_4$,$T_{st}$) in the storage tank will be measured and calculated.

In system is arrived of three modes.
-charge storage tank
-discharge storage
-charge storage tank and utilization of residual heat from solar collector during great solar irradiance
When is not been enough solar irradiance solar collector is delivered heat only to storage tank (charge storage tank).

During night is discharged storage tank.

During great solar irradiance solar collector is delivered heat to storage tank and by the same mail is provided heat water for evaporator of heat pump.

Performance of storage tank and PCM.

System use latent heat for storage of energy. Latent heat is the name given to the energy either stored or liberated when substance changes phase. These changes occur at constant temperature. The energy absorbed or released during phase change is rather more significant than the energy required to decrease or increase PCM temperature(sensible heat).The quantity of energy stored for each type of nodule is proportional to the storage volume. The number of nodules in a system determines the heat exchange rate between the nodules and the heat transfer fluid.
Latent heat storage presents us with two significant advantages:
-high thermal densities can be achieved
-energy is released at almost constant temperature

The modules:
The envelope:
-material: blend of polyolefins
-chemically neutral towards eutectics and heat transfer fluid
-thickness 1.0 mm: no migration of the heat transfer fluid
-sphere obtained by blow moulding: no leakage
-sealing of the cap by ultrasonic welding
-exterior diameter: 78 mm
-exchange surface : Diameter 78 mm 1.0 $m^2$/kWh stored

The STL is composed of tank filled with nodules.
The tank has upper manholes to allow the filling with nodules. A lower manhole allows emptying. Inside the tank for diffusers spread the heat transfer fluid along the tank.

Simulation program TRNSYS will be used to analyze the experimental results.

This system will be able to use in ecological building.

| | |
|---|---|
| PCM | phase change material |
| STL | storage thermal latent |
| COP | heat pump coefficient of performance |
| NC | collector number |
| $S_t$ | storage temperature (K) |
| $T_1$ | collector inlet temperature (K) |
| $T_2$ | collector outlet temperature (K) |
| $T_3$ | inlet water temperature of the water-source evaporator (K) |
| $T_4$ | outlet water temperature of the water-source evaporator (K) |

# Hydraulic Circuits for Controlled Loading of Driveś Elements

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The experiments in a drive project work are contingent on variable loading assemblies which enable a swift response to the requirements on the spot. In these assemblies we can also successfully apply hydraulic mechanisms. Among their advantages belong low requirement on estate dimensions, relatively small inertia effects, variability of control elements and possibility to implement the electro-hydraulic circuits.

The project of assemblies arises from the requests given by experiment at programs of gears, brakes and couplings. The assumed parameters are:

- capacity 7,5 kW
- range of torque moment 0 ÷ 1000 Nm
- range of speed frequency 0 ÷ 3000 $min^{-1}$.

The basic assembly, designed and implemented in the project work, consists of

- a hydraulic power pack SA4 – 100H (Hytos) with a connecting area for body of control elements
- a block of elements in a circuit of hydraulic motor with solenoid–operated directional control valves
- rotary and linear hydraulic motors
- pressure and liquid flow sensors
- a control block (ZEPADIG – ZPA).

Its possibilities are significantly enhanced by

- an accumulator block
- proportional elements.

In the extended assembly, it is possible to provide the regimes with a given course of speed as well as with a given course of loading.

The more simple experiments will be controlled by the ZEPADIG(ZPA) process controller. The more demanding experiments with the links to the parameters of loading elements will be controlled by a station(PC base) for observing and controlling experiment with using a LabVIEW program.

The optimum operating conditions and favourable balance are achieved by a suitable positioning of the accumulator block and the proportional elements not only in the circuits of hydraulic motors, but also inside the extension of the hydraulic unit so that incoming power of the assembly will be minimum. The possibilities of energy recuperation are considered with the loading circuits for higher capacities. The more demanding experiments will run with a PC background not only in the controlling and monitoring stage of the experiment, but also in the period of preparing and interpretation and mainly when deciding about following optimising interventions.

For these purposes original computer models of assumed loading as well as loaded assemblies are prepared which can be relatively easily modified which is given by well-arranged mathematical description based on equations of motion

$$m * x'' = \Sigma F \qquad \text{actually} \qquad I * \omega = \Sigma M$$

and from continuous relations

$$M_{HM} = ( p_{HM1} - p_{HM2} ) * V_{gHM} / 2*\pi$$

$$p_{HM1} = p_{HM10} + ( K / V ) * \int \Sigma Q * dt$$

$$Q_{HM1} = V_{gHM} * \omega / 2*\pi$$

…

and further as well as using program software DYNAST.

The designed methodologies of experiments also cover the measuring connected with identification of original models so that it is possible to use them for simulation solutions. Some arrangements will surely emerge from the analysis of goal-directed results and authenticity simulation solutions. The arrangements will influence not only the quality of other assumed experiments with real samples, but they will limit their number and range as well.

The approach to the project and implementation of the circuits for controlled loading of drives and to a concept of preparation and evaluation, meets standard requests. Furthermore it creates the conditions for sound optimisation interventions in the process of the experiment and for continuous assessment of mutual influence of loading and loaded assemblies in dynamic regimes.

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# Static Check of Countershaft by Using Matlab

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Countershafts are machine elements of cylindrical shape. They serve as one of the main and irreplaceable parts of multistage gearboxes. In the course of operation they have to endure both torsion and spatial bending. The best shaft shape is that which corresponds to a beam of constant strength. The standard solution to the working strain is solved by using a multiple stepped shaft. The usage of a multiple stepped shaft requires an accurately and precisely checking bouth tension and deformation. The impact of the torsional moment is not usually difficult to resolve. However, the key point lies in the solving the deflection which has to be resolved as a deflection of a variable cross section; a simply supported beam which is placed on two supports in two normal planes.

The analytical method for solving the deflection curve, with only the assistance of pocket calculator, is complicated and time consuming. Moreover, the calculation has to be repeated several times during the design activity, i.e. using a pocket calculator is insufficient. On the other hand, using a computer for resolution is more suitable.

Therefore, a program of static check of the countershaft was created using Matlab as a teaching aid for the subject “Parts and mechanisms of machines”.

The reason why Matlab was chosen for the creation of the said program is that our students get acquainted with system at the beginning of their study. Other advantages include: easy programming, possibility of watching the run of the program and practical graphic presentation of gained results.

The program was written as an m-file, which sets off Matlab settings and enables easy access to algorithm for its possible modifications and supplements.

**Description of program algorithm.**

Input values of the program are:

- material constants – modulus of elasticity in tension and modulus of elasticity in shear, yield stress;
- transverse and lenghtwise parameters of single parts of shaft;
- number, position and width of gears;
- size of torsional moments between gears;
- number, position, intensity and orientation of load, which can be a concentrated force, a pure axial force, a bending moment, an axial force on pitch diameter, continuous load per unit lenght of shaft either constant or linear course and continuous load serving as a substitution of concentrated force.

The load can be on two levels but between the supports only.

There is a vector of coordinates created with the assistance of an elected step of calculation and of shaft length. The value of step influences the continuity of resolution. Each of the loads separates the shaft into one, two or three individual sections. Inside these sections there are the courses of shear force and bending moment described by the given equations. For each of sections a vector of load is created. The individual vectors are drawn up to a complete vector. The vectors of sectional characteristics are created in a similar way. For definition of complete inner static effects is based on the method of superposition of single loads. Numerical values of necessary quantities are calculated using an acquaintance relationship.

For definition of deflection was used the moment area method which consists in loading a substitute beam by reduced moment area.

Gained results are in the form of vectors again.

The output of the program are the values of reactions at the supports and graphical interpretation of the course for the following:

- shear force;
- bending moment;
- reduced bending moment;
- shaft deflection;
- angle of moving round of neutral axis;
- torsional moment;
- angle of shaft twisting;
- bending stress and torsional stress;
- reduced stress;
- safety against plastic deformations.

The output dates can be completed with charts of values.

The program allows students to get a notion of the course of inner static effects, stress and deformations of shafts as well as certain beams on two supports. It can be used in teaching Mechanics - elasticity and the strength of materials.

# Contribution to Methodology for Determination of Elastic Constants of Engineering Materials

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## Introduction

X-ray diffraction techniques are used widely in non-destructive measurement of residual stresses caused in polycrystalline materials during their mechanical, thermal or thermal chemical treatment, such as shot peening, grinding and quenching. These techniques utilize lattice spacing ***d*** of the polycrystalline material as an internal strain gauge and determine the strain tensor existing in the surface layers. The residual stress tensor is then calculated by using of Hooke`s law. This procedure requires knowledge of appropriate elastic constants ( Young´s modulus of elasticity E and Poisson´s ratio $\nu$) for the material under investigation. The elastic constants used in the X-ray determination of residual stress $s_1 = -\nu/E$, $\frac{1}{2}s_2 = (\nu+1)/E$ are called „X-ray elastic constants“ and are usually determined by means of X-ray diffraction. When experimental data are not available, these constants could be calculated from single-crystal elastic constants using procedures given by Voigt, Reuss, Hill or Kröner [1].

Ceramic parts are usually manufactured by sintering. Deficiencies of the surface quality due to the sintering process as well as demands for precise dimensions require a posttreatment of the sintered parts, which is mostly performed by grinding. On the other hand, grinding leads to changes in the surface layers state of materials, which may influence the mechanical properties of the parts as a whole. As a consequence of a grinding process, a shallow plastically deformed surface layer with an elevated density of dislocations [1] and a characteristic surface topography with a complex system of micro-cracks is produced. Furthermore, in most cases, compressive residual stressed of high magnitudes at the very surface and steep gradients perpendicular to the surface are created [2]. X-ray stress analysis has proved to be the most reliable and, due to the small penetration depth of the X-rays used, the most suitable tool for residual stress determinations at machined ceramic surfaces.

## Elastic constants determination using mechanical and X-ray diffraction techniques

This part of the contribution contains an outline of two procedures for determination of elastic constants of alumina bulk samples:

a) using the course of macroscopic deformation during loading,
b) derived from the lattice strains of crystals due to four-point (pure) bending.

## Specimens under investigation

Analysed samples of dimensions (37 × 10 × 0,35) $mm^3$ were prepared from micrograined powder U308 (99,5 % $\alpha$-$Al_2O_3$) pressed under three pressure levels (30 MPa, 50 MPa, 80 MPa) and consecutively sintered at 1550 °C, 1600 °C a 1680 °C.

**Basic principles of experimental methods**

Macroscopic elastic constants were measured using static three-point bending when a linear relationship between the deflection y and the load P was assumed. Loading was realised by a set of weights, deflection was measured by image focusing in the field of view of a metallographic microscope. The experimentally determined quantity $E/(1-\nu^2)$ was calculated with a value of Poisson´s ratio $\nu$ for a related material. This uncertainty influences the inaccuracy of E determination (approx. ± 3 %).

X-ray elastic constant $\frac{1}{2}s_2 = (\nu+1)/E$ was evaluated on the basis of a precise measurement of lattice strains on the (40.10) $\alpha$-$Al_2O_3$ atomic planes using a Siemens goniometer with CuK$\alpha$ radiation [2].

**Experimental results**

Values of the macroscopic Young´s modulus of elasticity $E_{mech}$ (GPa) and X-ray elastic constant $\frac{1}{2}s_2$ ($10^{-6}$ $MPa^{-1}$) found on the alumina plates of various thickness d (mm) pressed under pressure levels PL (MPa); all samples investigated were sintered at temperature (ST) 1600 °C.

| Sample | PL | ST | d | $E_{mech}$ | $\frac{1}{2}s_2$ |
|---|---|---|---|---|---|
| 1 | 30 | 1600 | 0.355 | 383 | 2.03±0.21 |
| 2 | 50 | 1600 | 0.333 | 407 | 2.44±0.14 |
| 3 | 80 | 1600 | 0.348 | 423 | 2.39±0.33 |

**Conclusions**

1. The coarse of relationship $E_{mech}$ vs. PL has an increasing tendency.
2. The values of macroscopic Young´s modulus of elasticity $E_{mech}$ varies between 383 and 423 GPa, and they are higher than the usually reported value E = 350 GPa [1].
3. The inaccuracy of X-ray elastic constant $\frac{1}{2}s_2$ determination was 10 – 14 %.
4. The differences between the values $\frac{1}{2}s_2$ determined for the samples under investigation are not statistically significant and the mean value $\langle\frac{1}{2}s_2\rangle = 2.23\cdot10^{-6}$ $MPa^{-1}$ is lower than the reported one $\frac{1}{2}s_2 = (3.07 – 3.70)\cdot10^{-6}$ $MPa^{-1}$[1].

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# Development of an Optimised Control System for a Multi-temperature Refrigeration Systems

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To satisfy customer demand for a wider range of fresh, high quality and affordable food products, the development of refrigerated transport technology has been forced to improve temperature control techniques, provide greater capacity and flexibility without compromising either reliability or increasing capital cost. Greater capacity and flexibility has been achieved by replacing the traditional single-zone systems with multi-zone refrigeration systems that typically consist of one common condenser section and a series of remote evaporators, one dedicated to each temperature controlled zone. The complexity of controlling these systems to provide good performance in cooling during the hot summer as well as heating during the severe cold of winter, is increased due to the number of temperature controlled zones present, difference in size of each zone, load and temperature set-point in each zone, as well as possible thermal interaction between adjacent zones.

Reflecting this demand the current research program sought to; i) provide a data acquisition and control system that would enable system behaviour to be thoroughly investigated by experiment, ii) improve multi-zone refrigeration system set-point temperature control, and iii) generate empirical models that would enable system performance to be predicted.

Early effort focused on the development of a temperature control algorithm for cooling an idealised multi-zone refrigeration system installed in three spatially and thermally isolated zones. The standard system design was modified by replacing on/off type flow control valves located on each evaporator outlet line, with evaporator pressure regulating (EPR) valves. Based on experience of the system operation the main control variables were identified and a simplified fuzzy logic control algorithm was developed and applied to the modified system [1]. System performance during cooling was recorded and compared with performance achieved when two different control algorithms were applied to the standard multi-zone refrigeration system with on/off type flow control valves. Using on/off-type control valves on the evaporator inlet line highlighted that set-point temperature control was sensitive to the frequency of activation, with temperature control improving as activation level increased. However, superior all-round performance was displayed by the control system that employed EPR valves combined with a software control algorithm refined from experience, as this system achieved; i) 40% faster temperature pull-down to the set-point, ii) 80% better set-point temperature control, and iii) reduced temperature control problems arising from sudden changes in the status of control valves used in neighbouring zones [2]. These results clearly highlighted the benefits of employing EPR valves in the multi-zone refrigeration system. However, to verify the performance of this control system in the real life environment the same modified refrigeration system design was installed within a 12 m long trailer where two, non-standard thermally insulating bulkheads were used to divide the inner space into three separate temperature control zones. Satisfying objective i) defined above, this resulted in development of a new multi-purpose test facility for the characterisation of multi-zone refrigeration systems in an application environment. This new test facility not only allows performance data to be

compared between standard and application type environments, but also provides the capacity to generate data that is directly applicable to end users of these products. To help satisfy objectives ii) and iii), this multi-zone refrigeration system was also tested within the controlled environment of a calorimeter room. The same set of temperature pull-down and set-point temperature control tests was repeated. Although the control algorithm for cooling provided the same temperature control as when applied to the idealised multi-zone refrigeration system, thermal interaction between adjacent zones influenced performance. Considering that multi-zone refrigeration systems have to operate at different ambient environment conditions with similar thermal interaction between zones, it was important to extend the previous work on cooling to include a control algorithm for heating mode or a combination of heating and cooling simultaneously in different zones (reverse cycle mode). As a result the second main objective to generate a control algorithm capable of maintaining set-point temperature from deep frozen (-20ºC) to fresh or room temperature (+25ºC), in any zone and independently of ambient air temperature, using cooling, heating or reverse cycle mode in any zone, was achieved and experimentally validated [3]. Further insights of system performance were gained through experimental measurement of cooling capacity over an extended range of conditions. This data helped steady state empirical models, capable of predicting system cooling capacity to be developed, as defined under objective iii). Model predictions were compared with experimental measurements and the agreement was typically within 12% [4]. While further work is required to extend this model to include heating, reverse cycle and defrost this helped to validate the model applied, increase confidence in its application to reduce test time in the future and provide a better understanding of system performance.

Combining all work reported in previous cited publications from this research program, it is believed that a reasonable description of multi-zone refrigeration system performance has been provided for the first time. As defined by the project goals, the topics investigated span zone air temperature control, system cooling capacity measurement and steady state empirical model development, as applied to multi-zone refrigeration system in a real life industrial environment. This study will be extended in the future to optimise control algorithms and to include the requirement for defrosting.

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# Optimalization of Parametres of Emergency Brake

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Emergency brake of a new design for escalators is represented by a conical friction brake with a progressive braking torque. This design eliminates the main disadvantages of the conventional drum brake. After the brake is set in operation it exerts a definite minimum braking torque (the initial rate of acceleration is relatively small) that increases until the escalator step band stops.

In the case of the maximum speed of the step band being exceeded (e.g. after the breakage of the transmission chain between the power unit and the main drive shaft of escalator steps) the overspeed governor monitoring the step band speed initiates the operation of emergency brake. A special screw is used on the brake that compresses the Belleville springs and thus increases the compressive force on the brake lining. The force on the brake linings and, as a result, also the braking torque increases linearly with the revolutions of the main escalator shaft.

The kinematics of the escalator step band is solved in dependence on the input parameters of the emergency brake. The braking process is split into two phases:

1. The escalator of initial speed $v_0$ moves with acceleration of gravity $g$. Translational and rotational masses are accelerated and the overspeed governor sets the brake in operation when the step band reaches the tripping speed $v_1$. The speed of escalator step band increases until the operational clearance of the emergency brake is taken up.
2. The brake operates with the initial value of the braking torque given by the magnitude of the Belleville springs prestressing. The braking torque is progressive as it increases in compliance with the spring characteristic.

**Formulation of equation of motion**

The kinetics of the univariant system (i.e. with one degree of freedom) will be formulated by means of a differential equation. The angle of rotation of the drive sprocket $\varphi$ will be chosen as the general coordinate.

$$\ddot{x}.\left[J_{\text{red}} + m_{\text{red}}.\mu^2(\varphi)\right] - \dot{x}^2.\left[\frac{1}{\mu^2(\varphi)}.\frac{\mathrm{d}\mu(\varphi)}{\mathrm{d}\varphi}.J_{\text{red}}\right] = F.\mu^2(\varphi) - M_{\text{b}}(\varphi).\mu(\varphi)$$

where braking torque

$$M_b(\varphi) = N(\varphi).f.R = \frac{f.R.c.s}{2.\pi.\sin\alpha}.(\varphi - \delta) + \psi.m.g.r.\sin\gamma$$

According to the fact that ratio between the revolutions of the low-speed shaft of the gearbox and the step band speed is not constant it is necessary to determine the ratio between the angular speed of the main drive shaft and the speed of the step band chain first. Ratio $\mu(\varphi)$ may be expressed in the form of trigonometric series as

$$\mu(\varphi) = \frac{r.z}{\pi}.\left[1+2.\sum_{i=1}^{n}\frac{(-1)^{i+1}}{i^2.z^2-1}.\cos(i.z.\varphi)\right].\sin\left(\frac{\pi}{z}\right)$$

The principal features of the emergency brake are:
1. The stiffness of Belleville springs of the brake.
2. Prestressing of Belleville springs that influences the value of the initial braking torque after the operational backlash has been taken.
3. The load represented by passengers on the escalator step band.
4. The ratio of an auxiliary gearbox that may be inserted between the main drive shaft and the shaft of the brake.
5. The influence of rotating masses in the case of auxiliary gearbox application.

**Conclusion**

The ratio between the drive sprocket and the step band is non-linear. The solution of the brake operation results in non-linear differential equations dependent upon the variation of the brake parameters. The dependence of step band acceleration and its variation upon the distance (trajectory) is depicted for different values of prestressing.

By analysis of principal parameters of the brake that influence the kinematics of the braking, final conclusions are achieved:

a) The magnitude of the prestressing of Belleville springs should be selected in such a way that the initial braking torque would be in balance with the torque generated by the load on the step band. The acceleration is zero at the beginning of braking and then the brake increases the braking torque and thus also the rate of acceleration approximately linearly until the step band is brought to a standstill.
(b) The stiffness of Belleville springs effects, first of all, the gradient of mean line of the graphic dependence of the acceleration upon the distance.
(c) The decrease of load on the escalator step band results in an increase of acceleration in the instant of stopping. In the anticipated extreme case (20% of rated load) the value of acceleration is acceptable.
(d) The ratio of auxiliary gearbox influences the braking pattern.
(e) The greatest possibilities for modification of the braking pattern are given by the correction of additional rotating masses.

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# Working Accuracy of Numerically Controlled Machine Tools

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Working accuracy together with production efficiency and big productivity is one of the most important requirements, which are demanded along contemporary numerically controlled machine tools. In the past, for individual machine tools has been created standardized procedures to check their geometrical accuracy. These old conventional measured methods include acceptance conditions. For checking accuracy of numerically controlled machine tools with three simultaneously controlled axes there are in addition used tests, which are able to determinate accuracy and repeatability of positioning of numerically controlled axes (according to ISO230-2) or tests for checking circular interpolation (according to ISO230-4).

It is truth that results of these measurements don't include some important factors (for instance cutting process), which influent working accuracy of each machine tool. That's the main reason why current producers of machine tools start preferring a new method of testing accuracy. This method is founded on producing a test workpiece. Resulting accuracy of tested machine tool is reflected directly on manufactured workpiece. The test workpiece contains the elements, which are able to assess possibility of machine tool or to assess interaction between individual components of machine tool (e.g. controlled axes).

At present time exist many test and acceptance workpieces. Well known is test workpiece according to NAS 913. In the year 1999 were all consideration about working accuracy formed into the standard ISO 10791-7. This one describes standard test workpieces with characteristic dimensions and establishes maximum tolerances to be kept. There are included finished conditions of manufacturing the workpiece, too. In the year 2000 the group NC-Gesellschaft (Germany) published results in the field of working accuracy of machine tools. This group suggested another test workpiece for HSC machine tools. Finally, there were also produced a customer-specific workpieces, which answering intended production schedule of machine tool. As a result of study and investigation has been designed own testing workpiece, which rose during last two years at the CTU.

Every test workpiece is designed for assessing the production accuracy during production of the workpiece. It can quickly check the performance of the machine tool under different kinematic conditions. The workpiece consist of the essential geometry elements, which are needed to compare machine tools with respect to dynamic performance, machining speed and working accuracy. The fundamental element of each test workpiece is a cuboid, the other elements are placed on the cuboid. The machine's path accuracy is tested at machining the diamond (square, inclined by 75°). During machining by linear interpolation in two axes is used different step and speed for each machine axis. Any difference between the servo gains

can be identified. The accuracy of the machine tool is also tested during machining of another cuboid. Peripheral surface of this shape is machined during linear interpolation in just one axis at constant speed. The result of measurement can provide an identification of the machine tool geometry with reference to the perpendicularity of the X a Y axes. The inside/outside cylindrical surfaces are each machined in two stages (at different machining speed). The top of each element is machined using circular interpolation at maximum speed of the machine tool. The bottom of the element has a diameter 0,1mm smaller/larger and it's machined at half maximum speed. The results of measurement provide errors depending on machining speed during almost the same circular path. The abrupt acceleration reversal of one axis while the other is moving at maximum speed causes vibrations. These vibrations are manifested by jagged edges at the reversal points. They can be identified and should be compensated by the control of machine tool. The elements, which are created by the edges with the small angle in plane XY and XZ/YZ can check the capacity of linear interpolation in two axes at extremely unequal speed and step. The test workpiece includes drilling pattern, consisting of five holes. The holes are predrilled and then machined by circular interpolation in the XY plane. The deviations of distances between the center hole and all other holes provide information about the machine's tool positioning accuracy. The other element of the test workpiece represents complex shapes, which can test circular interpolation of machine tool in the XZ /YZ plane. These elements are on the test workpiece CTU created by rotary ellipsoid and form surface with sudden changes of curvatures. Both complex elements are made up of three separate areas, which are milled at different machining speed. The measured deviations reflect machine's tendency to chatter at reversal points, where the curve suddenly changes.

Testing accuracy by using the test workpiece represents additional costs. Therefore, the shapes of workpiece are always designed to allow axial resetting and using the same workpiece for testing several times. In addition, the characteristic dimension of the workpiece should be changed within 10%. Cutting speed and other manufacturing parameters (feed rate, depth of cut, etc.) may be chosen with respect to [2]. The test of machine tool is usually performed in the XY plane. NC programs for manufacturing CTU test workpiece were created by means of CAD/CAM system I-DEAS. An original code was modified by hand to allow simple modify consequent cutting parameters depending on the material of test workpiece and tooling. After manufacturing is the workpiece taken to a required measurement on the coordinate measuring machine. Then there are drawn conclusions.

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# Batch Heating of Liquids

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Batch heating and cooling of liquids belongs to very important industrial processes. Not all the cooling and heating processes, particularly in food industry, are implemented as continuous, so modelling of batch heating or cooling is important to a design of technological equipments. Modelling of batch cooling or heating time can significantly reduce energy consumption, it can also help to develop a suitable technological technique with a considerable impact on the quality of products, microorganism growth, etc.

A time behaviour prediction of batch cooling or heating to a given temperature in technological equipments is influenced by many factors: vessel geometry (mostly cylindrical vessel with a bottom of various shapes - ellipsoidal, conical, flat), method of heating or cooling (heating by a condensing steam, cooling or heating by a medium flowing in a vessel jacket or tube coil inside the vessel), agitator parameters, thermophysical properties of the batch, … . All these factors affect thermal design parameters, in particular heat transfer coefficients on internal and external surface areas of the vessel and its jacket or the tube coil. A significant contribution to an overall heat balance can also form a dissipation of an agitator mechanical energy inside a viscous batch as well as a reaction heat.

It is obvious that the time behaviour of batch cooling or heating depends on many parameters which are often difficult to determine accurately. **BatchHeating** program has been developed to simplify the design of process equipments. This program allows a numerical simulation of batch heating or cooling in equipment of a given size and it enables to examine effects of individual parameters on a heating or cooling rate.

The first version of the program **BatchHeating 1.0** simulates numerically heating of an ideally mixed batch. The heat energy is supplied by a steam condensing at the outer surface of the cylindrical vessel, which is the method very frequently used in industry. Heat transfer coefficient at the outer cylindrical surface of the vessel is calculated here as for the case of condensation at a vertical flat wall, see **Šesták and Rieger (1998)**. The calculation of heat transfer coefficient at the inner surface of the vessel is based on the relation $\mathrm{Nu} = c\,(\mathrm{Re}^m \cdot \mathrm{Pr}^n + d)^r$, where Nu is Nusselt number, Re is Reynolds number and Pr is Prandtl number, and the experimentally determined values of the constants $c$, $d$, $m$, $n$, $r$ can be found in literature, see for example **Šesták and Žitný (1997)**. The difference between the bulk liquid viscosity and the viscosity at the wall is respected by Sieder-Tate correction.

The **BatchHeating** program has been written with the help of **PERL** programming language and graphical libraries **PERL/Tk**. All parameters can be entered interactively and numerical results of the simulation can be presented graphically by **GNUPLOT** program. The **BatchHeating** program uses public free tools and can run under operating systems UNIX, GNU/Linux or Windows 9x/NT/XP (basically it can run on any platform where **PERL** with **Tk** libraries and **GNUPLOT** are available). The source of the program can be found at the authors' WWW pages.

The second version of the program **BatchHeating 2.0** is developed at present. In contrast to the first version where only constant temperature of a condensing steam inside the vessel jacket is considered, the second version includes a temperature change of the heating or cooling medium which flows inside the vessel jacket. This also implies that the heat transfer coefficient inside the vessel jacket must be calculated. For the case of an annular cross-section relations based on **Schlünder et al. (1994)** are used.

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# Equipment for Simulation of Rotating Loading Using Frequency Converter for Controlling Induction Motors

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This report is connected to the article 'Identification of Drives Service Parameters Using Experimental Simulation' published in memorial volume of symposium WorkShop 2002.

Development of programmatic equipment with simultaneous progressive debugging of single components of measurement station used for gauging rotary parts continued throughout the passed year. Application of the converters in vector mode with speed feedback derived from independent incremental position sensor (720 scale lines per turn) was examined with comparable results, as well as evaluation of instantaneous spin velocity from motor parameters and supply voltage and current. For load simulation we tested converter mode with regulation to constant torque with use of external incremental position sensor. Run-up, loading and cutting-off strategy was determined for measurement chain in order to prevent mechanical shocks in the system. During experiments load-sensitive instability (otherwise bad dumping) of the whole system was discovered in some transient states. That follows the need of set change of converter parameters, which could not be looked into due to technical complication (gearbox damage), but will be probed about this year. Because of relatively small overload capacity of torque pickups and a possibility of mechanical shocks the system was supplemented with a set of torque friction clutches to avoid a damage of sensors. With respect to experimental character of the whole system it is not possible to ensure this only in electronic/software way.

For experiments programmatic equipment built-up in LabView environment is used in conjunction with universal lab card National Instruments 6024. Torques are measured via three analog channels in differential mode and two output analog channels are used to control rotation speed – converter No.1 and to control loading moment – converter No.2.

Use of 24 bits integrated counters was tested for position sensing from the incremental sensors. We are preparing use of special counter card with maximum frequency of the input signal as much as 80 MHz for evaluation of signals from 36 000 scale line sensors Heidenhain.

Communication via serial line RS232 was tested for pre-setting the converters and we are working on usage of USS protocol in conjunction with serial line RS485 to adjust and control the operation of the converters.

In the next period we plan to finalize the operational experiments of the programmatic equipment, calibrate the torque pickups and subsequently verify acquired data in the process of measuring parameters of selected gearboxes.

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# Determination of Residual Stresses in Bulky Forgings of Different Heat Treatments

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Contemporary requirements for higher outputs and simultaneous demands for higher reliability of structures compel application not only of better materials and modern means of analysis on a higher level during design but more precise technologies. Any failure of highly stressed parts in operation, has to bring catastrophic accidents as we know from aviation, high-speed train traffic or big energetic machinery. Railway axles or turbine rotors belong to the group of extremely dynamically loaded parts. That is why high attention is given to these parts during all steps from design over producing to operation. The weakest point is surface layer that influences limit states as service life of the whole structural part. The aim of all activities is to ensure the limits of residual stresses induced into the turbine rotors after all technologic operations - forging, heat treatment and turning.

Methodology for evaluation and determination of residual stresses in structures is given by the ASTM Standard E 837 [1]. This measuring procedure, when all requirements and conditions are satisfied, ensure repeatability $\pm 5\%$. Verification of this limits was carried out before [2].Thus the residual stress determination became one of the inspectional procedures during producing turbine rotors [3]. The task was to examine the residual stress state on the maximum of the examined surface. Time and financial conditions badly keep down the total number of measured points. It was concluded to measure the stress state in five cross sections, where two points are located on the diameter. To cover the maximum of the surface the cross sections were turned each other by $120^{o}$.

The rotor was made of steel ČSN 16536 and the safe limit of residual stresses is taken as $0{,}1.R_{p\ 0{,}2}$. The measuring can reliably fix the quality of examined structure as to residual stresses. If the rotor does not satisfy the residual stress limits the heat treatment has to be repeated under stiffened and more accurate conditions.

Material constants were determined by measuring the sample of the used material of the rotor. Constants used by calculating stresses from measured deformations were taken according to the methodology of company Vishay. Simultaneously there were derived improved relations [4].

In all points determined residual stresses in the surface layer of two examined rotors and two railway axles are in pressure, as it is required, and their protracted and unruffled course proves homogeneity of the residual stress state and maximal values do not exceed the prescribed limits (see attached figures). Also the orientation of the main stresses shows the homogeneity of the stress state and consequently the good quality of heat treatment and at the end good quality of the product.

Measurings done during last two years prove applicability of the standard hole drilling method as inspectional method for heat treatment.

After residual stress measurement fine turning takes off the layer containing the hole and we receive surface..

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# EMAS Program and Waste Heat Utilisation in the Industry

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The abbreviation EMAS stands for a simplified name of the said directive, viz. "ECO-Management and Audit Scheme". This instruction has been incorporated into the Czech Republic Legislation by governmental resolution No. 466 of 1st July 1998 as "National Program for Implementation of Plant EcoManagement and Audit regarding Environmental Protection - EMAS Scheme" (hereinafter only EMAS Program).

In spite of the apparent general character of EMAS Program comprising a wide range of environmental care, its integral part is also an effort for reducing the power demand of production activities. It is just this part of the EMAS Program that is paid special attention in the present proposed project, under which the problems of recovery and utilisation of heat amounts, considered now as industrial waste heat, should be solved and the respective tools therefor should be deviced. The project is focussed onto the waste heat from industrial processes in general as well as on waste heat generated by the operation of industrial refrigerating system and compressor stations. The merit of focussing onto this type of heat sources is documented as follows:

Refrigerating systems represent in many industrial plants one of the largest power consumers, and frequently also cooling water consumers. This is especially true for the food industry plants (meat processors and packers, breweries, dairies, cold stores etc), skating rinks, chemical factories, but also for industrial as well as residential comfort air conditioning. The present trend of environmental perfectioning of refrigerating systems, based on the decisions of the Montreal Protocol and on the replacement of refrigerants depleting the globe's ozone layer, should be, in accordance with the international agreements concerning limitation of so-called greenhouse effect gases, extended to the minimisation of driving power demand not only for the refrigerating systems proper, but for the whole process equipment complex, of which the refrigerating system is a part. In this respect the waste heat recovery may represent a substantial potential share of savings in capturing the condenser and cooling tower waste heat, which would otherwise be discharged into the atmosphere without any utilisation

One of many fields of power generation, transformation and consumption is the field of compressed air production, distribution and consumption, finding an ever wider use in most industrial branches and in other fields of human activity. Prime movers of air compressors consume, as announced in literature, approximately 8 to 10 % of all power generated in the whole world. This power is, however, utilised only partially for really necessary, i.e. useful increase of air pressure. The largest share of the driving power is transformed in thermal energy, which is discharged without any use into the ambient environment.

Owing to widespread us of refrigerating systems and of air compressor stations it is possible to formulate generally valid conclusions for them and to propose generally applicable waste heat recovery solutions. For refrigerating systems even the development of solutions in the form of model projects was envisaged.

The project conceived in this way represents a development continuation of the grand No. 101/97/0258 and fully utilises and valorises the investment assets, information and experience created thereunder. That is why no additional investment assets were required for the solution of the present project.

The objective of the project was to reassume the performed analysis of operation conditions, of industrial refrigerating systems and air compressor stations, and to prepare, making use of the resulting data and facts, not only for the equipment users, but also for project engineers and governmental agencies involved in the EMAS Program implementation, necessary documents for evaluation and tools for implementation of waste heat recovery and utilisation in the industry. The experimental part of the program covers the project and implementation of a system serving for verification of potential power savings in the industrial application of Coanda type ejectors, and also the measurements of the ejector proper. The outcome of this project has the form of recommendations, publications and model projects. The model projects was developed in Cupertino with the institution PP Projekt Praha, which has designed the first and till now the only industrial heat pump giving an output of approximately 1,8 MW and situated in the Czech Republic. All gathered information, elaborated documents and experimental equipment will be utilised for teaching purposes at the Mechanical Engineering Faculty of the Czech Technical University, Prague, in the study branch Machinery and Equipment for Refrigeration Technology, Compression and Transport of Fluids. The doctorands of the branch have taken part in some mentioned work. The technical public were informed about the results in some seminary meetings.

Solution of the project in the 3rd year:

- Continuance in searching of operators of refrigerating systems and compressor stations by them it is possible to realise the machineries for waste heat recovery.
- Preparing and foundation of publication “Saving energy in compressed air technology”.
- Experimental verification of energetical saving in use ejector of Coanda type.
- Elaborating and verification of model project for utilisation of an industrial two stage heat pump for purposes both cooling and preparing of warm water.
- Transfiguration of elaborated model projects on a CD ROM form.
- Selected results of a solution of above mentioned items were presented at the seminar “Economical production of compressed air and non-traditional sources of heat” (Prague, November 2002)

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# Mixing of Suspensions in Tall Vessels with a Draught Tube

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Mixing of suspensions is one of the most frequent operations occurring in mixing equipment. Tall vessels with a draught tube are used for mixing of suspensions especially in cases where high homogeneity and heat transfer are desirable. The poster deals with the description of flow behavior of suspensions in the tall vessels.

The experiments were carried out in model mixing equipments with vessel of diameter 300mm. The four baffles were placed in the upper part of the draught tube above the upward pumping impeller with six pitched blades.

**Measurement of critical impeller speed for suspension:**

A very important parameter for designing of mixing apparatuses for suspensions is the critical impeller speed necessary for off-bottom suspension of particles. One the basic of an inspection analysis of the governing equations the dimensionless equation was proposed for calculation of the critical agitator speed for geometrically similar mixing equipment and given particle content in the turbulent regime

$$Fr' = A_{s,v}\left(\frac{d_p}{D}\right)^{a_{s,v}} \tag{1}$$

where modified Froude number $Fr' = n^2 d\rho / g\Delta\rho$. Coefficients $A_{s,v}$ and $a_{s,v}$ were obtained from experiments.

For keeping particles in suspension.

$$A_s = 40{,}07(4{,}48\cdot 10^7)^{c_v} \tag{2}$$

$$a_s = 0{,}47 + 2{,}26\cdot c_v \tag{3}$$

For off-bottom suspension of particles.

$$A_v = 15{,}74(4{,}61\cdot 10^3)^{c_v} \tag{4}$$

$$a_v = 0{,}3 + 0{,}73\cdot c_v \tag{5}$$

The equation for off-bottom suspension speed was obtained for volumetric particle content up to 45%. The critical impeller speed for suspension was determined visually.

**LDA measurement of axial velocity profile:**

LDA method (Laser Doppler Anemometry) was used for measurement axial velocity profiles. The axial velocity profiles were measured in the draught tube and in space between draught tube and vessel wall [1]. . The flow rate $\dot{V}$ was obtained by integration from axial velocity profiles. Flow number $N_{QP}$ defined by

$$N_{QP} = \frac{\dot{V}}{nd^3} \tag{6}$$

was calculated from flow rate values. The experimental results of flow number $N_{QP}$ were compared with numerical simulation and other experiment.

**Nomenclature:**

| | | |
|---|---|---|
| $A_{s,v}$, $a_{s,v}$ | coefficient in Eqs. (1) | [1] |
| $c_v$ | solid phase volumetric concentration | [1] |
| d | impeller diameter | [mm] |
| $d_p$ | particle diameter | [mm] |
| D | vessel diameter | [mm] |
| Fr´ | modified Froude number | [1] |
| g | gravity acceleration | [m.s$^{-2}$] |
| $N_{QP}$ | flow number | [1] |
| n | impeller speed | [s$^{-1}$] |
| $\dot{V}$ | liquid flow rate | [m$^3$.s$^{-1}$] |
| ρ | liquid density | [kg.m$^{-3}$] |
| Δρ | solid - liquid density difference | [kg.m$^{-3}$] |

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# Research of the Construction Molded Panels with Hybrid Material Structure

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Subject of this paper is to describe and evaluate current production methods of test pieces for bending tests. The test pieces consist of metal sheet, which is reinforced by a composite coat made of carbon fibres. At the same time, usage of devices for production of test pieces for bending tests is described.

Demands on parameters of production machines, robots and manipulators and equipment are continually increased. As a consequence, higher toughness of design, precision in position setting, speed of movements and performance dynamics.

Metals most suitably satisfy these demands. Search for alternatives in design of machines is driven by

- Better performance characteristics
- Higher toughness and lower weights of parts
- Lower consumption of energy in production
- Shorter production path (from primary material to final make), easier production

A typical feature of new materials is higher degree of integration of functions in the design.

To meet these demands, composite and hybrid materials are considered to be appropriate.

Core of the composite/hybrid materials is reinforcement of a thin steel sheet with a composite layer of long carbon fibres. A basic shape of the part is given by a shape of a thin steel or aluminium die stamping.

Currently, a short fibre composite is used in practice. The layer is sprayed in a similar way as purely composite parts are sprayed on the form. The sprayed fibres are only randomly organized. Fibres have to be layed in an organized manner so that correct orientation and therefore desired characteristics of the material is ensured. However, production of such parts is more time consuming.

Long fibres carbon composites have an exceptional tensile strength along their orientation. For this reason, it is useful to lay fibres on that side of base plate, which is pulled in a bend. In the same way, a test piece is prepared for testing.

The test piece is a rectangle of a thin steel sheet (0.5 mm thickness) with carbon fibres layed on one side of it.

A machine producing cylinder parts by winding was used for laying the long fibres on the sheet. A special device was used for this purpose consisting of a spindle, two sides and four base plates on which the fibres are layed/winded.

Bundle of fibres is wound under a slow thread rise. When a desired layer of the fibres is on the plate, synthetic resin must harden. The sides are removed then and finished test pieces are separated.

A problem spot is the edge connecting test pieces because the fibre layer is spread along the test pieces unevenly.

Currently, two ways of mending this problem are considered.

One alternative is laying the fibres with greater pre-tension.

The other alternative is hand made laying of pre-cut fibres on the base plate. The plate is placed in a simple form to ensure an even thickness of the composite layer. At this time, we are only in the production stage. The form takes on a shape of a box. The base plate is laid on the bottom of the box and is covered with the synthetic resin. Then, the fibres are laid there manually. In the end, the form is covered with a lid pressing the fibres. When the resin is hard, the form is opened. A test piece is finished.

Prepared flat test pieces will be tested in cooperation with Mr. Vampola (U205.2 -Department of Mechanics, Division of Mechanics of Bodies). The aim of testing is to prove functionality of software for calculation of elastic characteristics of materials with heterogeneous structure i.e. consisting of a metal plate and a layer of carbon fibres.

At this time, we are dealing with the problem of production of flat test pieces with secured thickness of composite layer and even distribution of carbon fibres. Also, we are preparing a device for testing pieces with three-point bending. In case of a sufficient correspondence of measured and calculated values, we are planning to continue in development, production and consequent testing of more complicated test pieces. Our effort is optimisation of toughness and weight of more complicated parts and testing of newly created calculation software. In the future, we would also like to engage in winding the carbon fibres with greater tension in relation to presumed operational load of the part.

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# Design and Check of Air Heating and Ventilation of Film Studio

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## INTRODUCTION

At the proposal of air heating and ventilation in the film studio, designer can get together with a lot of unusual parameters and necessities which his designed mechanism has to realize. For example: frequent operating changes, variable internal conditions, every taking scene has it's own claims on inner environment. At a proper proposal of adaptation relevant to environmental situation in atelier the designer has came to decision that demanding condition of operation (absence of space, placing of lighting and camera's technique and also possible obstacles properties) can realized only air heating an ventilation. In atelier were designed two systems partly connected to each other. During a winter seasons the hot air is feeding vertically into the floor through anemostats. The air outlet is effected ventilating inlets. under the ceiling. In summer seasons the heat-untreated air is feeding through vertical channels in peripheral walls into the floor, where the heat-untreated air entered in habitable zone (in channels are also placed the silencers of noise). The air is leading away with ventilating inlets under the ceiling (dtto winter) with supplemented exhaustion through anemostats (in winter are used for the input of air) by system in which is the work reversed. This solution increases the intensity of ventilation in comparison with winter operation. By calculation for winter season was determined a thermal deficit of object by transmission on 346 kW and by compulsory ventilation on 333 kW. Thermal deficit by heat transmission of construction is comparable with the thermal deficit of the ventilation. Thermal profits are also the same as the thermal deficit of ventilation, but their resolution on the object's area is strongly depended into inner operation. For calculation of thermal deficit according ČSN 06 0210 was taking in to account the regional temperature $t_e$ = - 15 °C. For calculation of summer operation is accepted a condition that the maximum temperature of air in working area in side of atelier can not overpass the maximum temperature of out side air no more than 5 K.

## SIMULATION IN ESP-r

**Simulation no. 1** - Yearly simulation of temperature's process of inner air, without contemplation of inner heat recourses (profits from persons, lights) and without heating. From the process of temperature of inner air is following, that even at long term and low out side temperatures the hall cools down only on 14 °C respectively also in time, when temperature of inner air is under –16 °C (according to referential climatic year).

**Simulation no. 2** - Yearly simulation of temperature's process of inner air with contemplation of inner recourses, it means : profits from 600 persons, profits from lights, without heating. In the simulation was also evident the expansion of inner air temperature (compared to simulation no.1) so therefore also the expansion of days which we don't need to heat up. The coverage of thermal deficits is done by inner profits. On the contrary in summer season (compared with simulation no.1) the temperature of inner is going rapidly up.

**Simulation no.3** – Investor has described 2 situations – half an hour taking – half an hour heating or ventilation. The aim of this simulation was to demonstrate, that the difference between $t_i$ during heating and $t_i$ during taking is not higher than 2K, so as we can consider the process of inner air temperature approximately like constant. The simulation was done on 6th February in the coldest day of year (according to referential climatic year. The premise was realized – the vibration of inner temperature at intermittent heating is not higher than 2K.

**Simulation no.4** - The simulation provided an information when will be the object heated up at the extremely inconvenient conditions: there is no heating in hall till 5th February the heating starts on 6th February. The heating up of the hall on 18 °C takes 3 hours.

## SIMULATION IN FLUENT

This example was solved by the help of simulation programme Fluent. The main point of simulation was to described temperatures and velocities fields, which starts up at air heating. Becouse the whole object is geometrical similar (symmetrical) there was solved only the representative part of object A. The whole object has ground plan: 42 x 96 m and height 18,1 m the calculation in simulation programme would be disproportionaly long. That is why we have chosen a possibility of exploitation of levels of symetry levels at setting of environmental conditions. Designed part for calculation. The calculation of thermal deficits of object A has determineed deficit of hall for 129 kW, but becouse there was only ½ an hour for delivery of heat. It was taken into account with a double thermal deficit. The cubical flow of air 15,4 $m^3/s$ was determined for protection of thermal deficit of incomming air in temperature 33 °C. The figure of used incomming ventilating inletss was 16. Becouse it is straight pressure ventilation, letś say heating so there is a equality for inflow and outlet of air. The volume of model is devided into partial dimension. These are reticulation by menas of hexagonal web in model are placed four incomming ventilating inlets fy Trox type VDR 800 the cubical flow of anemostat is 0,96 $m^3/s$. Area of ciclical anemostat was replaced by equinoctial squere. Area of anemostat S =0,348 $m^2$ was devided into two same parts – right and left. Leaving velocity of air from anemostat was 2,76 m/s. The partition of velocities into the directions has comming out from requirements of inclination of prompted vanes under under 30 grade to horizontal. Every wall inclusive the inner volume of model must has defined enviromental conditions. Outer wall and ceiling is deviding line between inner and outer enviroment and it´s also defined by mean of coeficient of thermal conversion on outer side $\alpha_e$ = 23 $W/m^2K$, inner temperature is –15 °C, size of wall $\delta$ = 0,15 m and equivalent coeficient of thermal conductivity of materials $\lambda$ = 0,177 W/mK. Floor is defined by surface terperature 10 °C. Incomming anemostats are defined by mean of conponent velocities, outcomming anemostats are defined only like clear aperture.

## CONCLUSION

The proposal of air –heating and ventilation in film studio has been presented like solvable problem, checking of right function of air-conditioning system has been done in two simulation programme. First calculation was made in programme ESP-r, there were successfuly simulated same operational situations of building and air conditioning equipments. It was also simulated the real convection in atelier during the calculation in Fluent programme was found out the distribution of temperature in residential zone (height $\subseteq$ 2 m).

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# Dynamic Stability of Machine Tools and Cutting Process

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The topic in the title of this contribution is at least 50 years old. Lots of researchers worked on this field, but still the modern machine tools have serious problems with instability during cutting. Why? There are more reasons. To discussed it will not be very interesting neither important. We will talk only about one reason that is „Change of machine tool concept“ at the latest years.

In the present time is rather difficult to say, where the origin of these changes was. Let us suppose, it was development of new cutting materials, followed by new design of cutting tools, that started the changes. The tools allowed, and even required, higher cutting speeds. The whole process in called High-Speed Cutting, HSC. But, not only higher revolutions of tools and spindles are required. There is also a great demand of higher feeds in all NC axes. And a new concept of a machine tool is born!

Such a machine needs very light and simultaneously stiff moving parts, which are used for spindle and tool positioning. On the contrary, the frame must be heavy. Of cause, it must be also stiff, much more stiffer then moving parts. The excessive demands on acceleration and positioning velocity of the moving parts point to theirs mass reduction, which is accompanied by stiffness decrease. This is confirmed in a statistical data published in [4]. The relative stiffness of machine tools is related to theirs accuracy. So, decrease of stiffness means lover accuracy by the same force, and this is not acceptable at all. At this point, we come back to advantage of HSC technology. The HSC cutting forces are considerably lower and the loss of stiffness does not mean, in fact, low accuracy. The lover forces are achieved by cutting under high temperatures and with a smaller chip section.

This development suits to all finishing operation. By roughing and High-Performance Machining, HPM, we prefer high Material Removal Rate, MRR. To achieve this at the same machine tool, there is a necessity of machine and cutting process dynamic optimising. The contribution deals with a method, which is based on above mentioned “old stability research”, but, using new devices, opens large space for improvement of machine performance. A basic idea is to use so called “frequency transfer function”, FTF to stability condition calculation. Farther, a “stability lob diagram” is developed, which shows width of cut versus speed of cutter. The lobs divide stable and unstable areas for cutting.

These diagrams are calculated on the basis of measured data. The data must be collected at the edge of each tool by special accelerometer. The tool, clamped in a proper tool-holder in a spindle, is excited by modal hammer. The two signals, first from the hammer force pick-up, the second from the accelerometer, are used to calculate FTF. Naturally, further cutting condition, like material of a work-piece, parameters of the cutter, radial depth of cut, must be done to calculate stability lobs.

Stability diagram is useful especially for technologists and machine tool programmers. They can see, so called, critical width of cut in the diagram. This is minimum width of cut, which is suitable for the whole speed range of spindle. If we need greater chip cross section a space between two lobs can be used to choose wider chip. This is coupled with a speed, which must be carefully tuned.

The new possibility of the cutting process dynamic optimisation improves utilization of machine tools significantly.

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# The Test Stand with High Dynamic Motion Axis Driven by Linear Motor

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High accelerations, demanded recently for linear NC axes of machine tools bring about unpleasant effects like vibrations and shocks within the machine structures and foundations. These shocks appear in every acceleration and deceleration phase. To reduce these phenomena, new design principles are being searched, studied and experimentally evaluated. The Siemens Company has shown one of the new principles on the last EMO machine tool exhibition. The principle is applicable for motion axes driven by linear motors. It consists in an axially compliant connection between the secondary part of the linear motor and the machine structure. Inertia of the secondary part absorbs the shocks in axial direction of NC axis movements and softens the transfer of force to the machine tool frame and foundation. This method seems to be very efficient and promises better quality of feed back control. In laboratories of the Research Center of Manufacturing Technology, a special test stand called STD1 has been designed for deeper analysis of this principle and for acquiring new experimentally verified experience.

The stand has been designed in three variants with different types of axial connections between the movable platform including the secondary part of the linear motor and the machine structure:

- The **variant 1** is a conception of linear motor drive with the secondary part fixed firmly to the base or connected to it by relatively stiff rubber elements. The relative movement for the case with rubber elements can be up to 2 mm.
- The **variant 2a** has the secondary part of the linear motor attached to the movable platform, which is connected to the machine structure by springs and dampers. It enables strokes of the secondary part up to 80 mm.
- The **variant 2b** is the so-called “floating modification”, where the secondary part platform is in the axial direction completely free.

The maximum stroke of the table is always 530 mm.
For the future, a high-tech variant with movable parts made of composite materials and aluminum sandwiches will be prepared.

All the main structural parts including movable parts are designed as welded steel structures. The test stand is equipped with the type L1SK 120P linear motor, product of the Czech VUES Brno company and controlled by digital, type Bautz SCE906 servo amplifier. The motor peak force is 5300 N and nominal force 3000 N, which allows achieving maximal acceleration of 4g. The inductive, type STAR position measuring system with resolution of 1μm is integrated in the roller rail. The movement of the table is controlled by means of external PC with the Matlab Extended Real Time Toolbox and connected to the servo amplifier by the type MF604 multifunction I/O card.

The test stand has been designed, produced and activated during the last year. The following activities and experiments are planned for the next future:

- Optimization of dynamic properties of axially compliant connection between the secondary part of the linear motor and the machine structure (e.g. stiffness and damping of the connection), focused on reduction of vibrations and shocks within the machine structure
- Experiments with new control methods applicable to linear motor drives for position control (acceleration feedback, state space control etc.)
- Comparison of different position measurement systems (inductive measuring system integrated in the roller rail, optical scales, laser beam) and their influence on both positioning accuracy and feedback control behavior
- Measuring and evaluation of heat generation, heat transfer and stability of temperature

The acquired results will be published and the correspondent research report will be put for disposal to the Czech machine tool producers.

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Section 8

# PRODUCTION SYSTEMS
# &
# TECHNOLOGY

# Diagnostics of Large-Area Solar Cell Homogenity by Local Irradiation

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A low volume concentration of recombination centres is very important for the fabrication of high-efficiency crystalline silicon solar cells. The fast and non-destructive diagnostics of solar cells can give information about both the input material and the quality of the technological operations. The presented diagnostic method using local irradiation can be used to investigate the influence of technology on the homogeneity of solar cells, and consequently can help to increase their efficiency and reliability.

To determine the quality of large area solar cell, the volt-ampere characteristics and noise measurement methods are often used [1]. But, these entire methods do not precisely informs us the quality of the total area of the solar cell. Non homogeneity of the large-area solar cells can be due to differences in carrier lifetime and surface recombination velocity over the cell area. These parameters influence the current density $J_{PV}$, generated by incident light. On the generated current density $J_{PV}$ depends the open circuit voltage $U_{OC}$. Using monochromatic light of a proper wavelength, it is possible to simulate the influence of individual physical parameters on $U_{OC}$ and in this way to determine the cause of inhomogeneity. As $U_{OC}$ depends on several technological parameters, application of local irradiation using at minimum two different wavelengths is necessary for better interpretation of the cell inhomogenetity [2].

In this experiment, as mentioned above, the area of solar cell is irradiated by local radiation diodes (laser diodes). For the measurement, two types of laser diode were used. As the first diode was used a laser diode with optical power 10mW and wavelength $\lambda$ =820 nm (it gives resolution from the depth about 30μm from the surface). As the second diode, a laser diode with optical power 10 mW and wavelength $\lambda$ = 670 nm (it gives resolution from about 3μm from the surface) was used. For detail mapping the area of a large-area solar cells, it is necessary to make hundreds measurements. To obtain information about physical and technological parameters of a large-area solar cell in a relatively short time, automation of measurements is desirable.

A PM8154 X-Y plotter was adapted to obtain positioning system. The electrostatic paper holder was replaced with a table with electrode system. The writing system of the plotter, namely holders the writing pencil were used as a system which moves step by step the laser diodes which radiate light approximately 5mm of distance above the surface of a solar cell. During the measuring process, the plotter which holds laser diodes that radiate on the area with diameter of 2-5 mm and moves step by step by the help of computer program from the left bottom beginning of a solar cell area to the last up right side of the cell area in a programmable distance (e.g. 5 mm). The accuracy of positioning is higher than 0.1 mm. The programme enables changing laser diode (maximum 6 different sources of light), so measurements using different wavelength can be done in exactly the same position. And, since the digital voltmeter KEITHLEY (Model 2000 Multimeter) is connected to the bus of

the solar cell and then to the computer, it is easily possible to manage the system and measure the value of open circuit voltage $U_{OC}$ at each point with in much shorter time than measuring manually. Measured data are organised in a way to be worked out in EXCEL.

The measurement equipment was realised (including control software) and the correct function of the equipment was verified using two laser diodes (one of the wavelength 820 nm and the second of the wavelength. 670 nm). The measurement was made on 10 standards silicon monocrystalline solar cells and one polycrystalline silicon solar cell which have the dimension 102x102 mm and thickness 360μm. The number of measured points for each solar cell type was 400 (the number of measured points can be higher, e.g. 10000 for a step of 1 mm both in X and Y direction). Using this measuring method, we can measure a lot of points on whole total area of the solar cell in order to have sufficient information for determining the optimum quality of the solar cell.

Numerical simulation shows, that distribution of $U_{OC}$ measured using infrared radiation gives information about carrier lifetime distribution in the bulk of solar cells. Visible light gives information about recombination rate in a layer of about 3 μm thick at the surface. In future the equipment should be completed with a source of a green of blue light, giving information about the surface recombination. This way, the method can be used as for in-process checking of the solar cell fabrication.

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# Diagnostics of Recombination Centres in Silicon Solar Cells

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Several types of impurities and defects intentionally and unintentionally introduced in silicon bulk during material synthesis and solar cell processing. They are non-doping impurities such as metallic impurities (especially, electrically active transition metals such as iron), oxygen, carbon, hydrogen, nitrogen and impurities created by their interactions with each others and dopants (boron and phosphorous). The number of crystal defects, such as point defects, dislocations and grain boundaries with regard to impurities acts as recombination centres, which seriously reduce the minority carrier lifetime, efficiency and reliability of solar cells.

A low concentration of recombination centres with energy levels far away from around the middle of the band gap in the volume of crystalline silicon solar cells is very important when fabricating high-efficiency solar cells. Fast and non-destructive diagnostics of solar cells can give information about both input material and quality of technological operations.

The work investigates the possibility of checking carrier lifetime in the area close to the the space charge region by measuring dark forward current-voltage characteristics of solar cells at low current densities, where the generation-recombination portion of the current density dominates. From the characteristics at different temperatures, the energy level of dominant recombination centres can be checked.

Measuring the forward characteristic of a non-illuminated solar cell at low current densities (forward voltage drop $V_F \leq 300$ mV), the V-A characteristic can be approximated [1] by

$$I_F \approx SJ_{02}\left[\exp\left(\frac{eV_F}{2kT}\right)-1\right]+\frac{V_F}{R_p} \tag{1}$$

$$J_{02} = \frac{I_{02}}{S} = \frac{en_i d}{\tau_{sc}} \tag{2}$$

where $J_{02}$ is the recombination current density, d is the width of the space charge region and $\tau_{sc}$ is the carrier lifetime of charge carriers in the space charge region expressed as below [2]

$$\tau_{sc} = \tau_{po}\exp\left(-\frac{W_t+W_i}{kT}\right)+\tau_{no}\exp\left(\frac{W_t+W_i}{kT}\right) \tag{3}$$

where $W_t$ and $W_i$ are the energy level of dominant recombination centres in the space charge region and the Fermi level in undoped silicon (intrinsic), respectively. The minority carrier lifetime in the n- and p-regions of a solar cell, $\tau_{no}$ and $\tau_{po}$, is inversely proportional to the

recombination centre concentration $N_t$. The carrier lifetime $\tau_{sc}$ is a function of the recombination centre concentration $N_t$ and the energy level $W_t$. It is inversely proportional to the recombination centre concentration $N_t$ and increases with energy levels further away away from around the middle of the band gap.

From the temperature dependence of $J_{02}$ it is possible to evaluate the energy level of dominant recombination centre $W_t$ using the following approximation

$$J_{02}(T) \approx const \,.\exp\left(-\frac{W_t}{kT}\right) \tag{4}$$

During the measurements, the entire surface of the solar cells with the area of 102 x 102 $mm^2$ must be covered to eliminate light generated current. The range of measuring temperatures is about 20°C to 90°C with the step of 10 degrees. Both single-crystalline and poly-crystalline silicon solar cells made by deferent technologies are investigated.

The logarithmical dependence of generation-recombination current on temperatures (1/T) is linear. It increases with temperatures. So that by measuring dark forward current-voltage characteristics at two deferent temperatures it is quickly to obtain energy levels of dominant recombination centres.

It is also observed that a solar cell with a higher fill factor, which contributes to increase the efficiency $\eta$, has a higher shunt resistance $R_{p,}$ a lower generation-recombination component of dark forward current $I_{02}$ and a higher carrier lifetime $\tau_{sc}$. (lower recombination centre concentration $N_t$ and energy levels further away from around the middle of the band gap). The presence of defects and impurities also speeds up the degradation of other solar cell parameters.

The advantage of the method is that all measurements can be simply done on any large-area solar cell. The non-destructive method can be easily automated and provides an alternative means for monitoring manufacturing process variations, sorting solar cells and evaluating deferent technologies of solar cell production.

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# Influence of Configuration Air-Technology Elements on Velocity Fields in Cleanrooms

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This project is concerned with research of cleanrooms, namely the influence of configuration of air-technology elements upon velocity fields in controlled space.
Cleanroom is specific room, which is defined in the International Organization for Standarization (ISO) standard 14644-1 as room, in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation and retention of particles inside the room. This is achieved by supplying it with exceptionally large quantities of air that has been filtered with high efficiency filters. This air is used to dilute and remove the particles and bacteria dispersed from personnel and machinery within the room. Cleanroom can be generally divided into two parts: personnel protection and product protection.
Cleanrooms have evolved into two major types and they are differentiated by their method of ventilation. These are turbulently ventilated (nonunidirectional) and unidirectional flow cleanrooms. The unidirectional type of cleanrooms uses very much more air then the turbulently ventilated type, and gives superior cleanliness.
Unidirectional airflow cleanroom is known as “laminar flow”. The airflow is in one direction (horizontal or vertical) at a uniform speed that is normally between 0,3 and 0,5 m/s and throughout the entire air space.
In unidirectional airflow cleanrooms, the design of physical obstacles such as the process equipment, the operating procedures, personnel movements, product handling should consider basic aerodynamic requirements to prevent serious turbulence in the vicinity of the contamination – sensitive activity. Appropriate measures should be taken to avoid flow disturbance of unidirectional airflow.
The transfer of contaminants into a zone protecting a process or personnel can be prevented by using active aerodynamic measures, i.e. by arrangement and flow direction.
Purpose of this project is research of the cleanrooms with the modified vertical unidirectional airflow, the source of contaminants and personnel safety zone, such as for instance in pharmaceutical industry.
For these purposes a modular experimental chamber was built in the laboratory of Department of environmental engineering. The experimental chamber has the parameters: height 2,8 m, length 2,7 m and width 1,2 m and serves as the two – dimensional model of the cleanroom with a source of contaminants and a personnel safety zone. The chamber is adjustable and enables to build the variety of air inlet arrangements and velocities in the ceiling and variety of air outlet arrangements and outlet velocities in the contamination zone and in the personnel zone. The chamber is designed as the under – pressure chamber. Two fans are used for air ventilation in the contamination and personnel protection zones and are controlled by frequency converters.
As the first step of our research velocity flow fields in the chamber plane of symmetry will be measured and the suitable arrangement of air inlet and air outlet will be searched with respect to the personnel safety zone and operational costs for energy consumption of fans.

Simultaneously with experiments, the velocity flow fields are simulated by means of CFD programme Fluent and experimental and computed velocity data can be compared. The aim of the comparison is verification of the used model of turbulence in CFD programme.
In the second step of our research, the tracing gas $SF_6$ will be used as the source of gaseous contaminations in the operational zone and concentration profiles will be measured. These experimental data will be compared with simulated concentration data and the used simulation concentration model will be verified.
After verification of velocity and concentration simulation model, different arrangements of cleanroom will be simulated and optimum arrangement of this cleanroom type will be found.

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# Accuracy of Machine Tools

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Accuracy of machined components is one of the most critical considerations for any manufacturer. Many key factors like cutting tools and machining conditions, accuracy of the machine tool or the type of workpiece play an important role. However the consistent performance of the machine tool is determined by its ability to accurately position the tool tip against the workpiece.

The three major types of error are geometric, thermal and cutting force induced errors. Geometric errors make up the main part of the inaccuracy of a machine tool.

**Geometric accuracy of machine tools**

Three types of errors influence geometric accuracy: the linear displacement errors, the straightness errors and the angular errors. A complete measurement of these errors is very complex and time consuming, therefore usually only a part of them is evaluated for a particular machine tool.

A traditional way of determination of linear errors corresponds with ISO 230-2. This method is based on measuring positioning errors in each axis of the machine tool separately. The results give an overview of the linear positioning errors of each axis at one particular position of the working volume. Thus there is no guarantee that the same results will be obtained in a different position of the working volume. In general the results will always differ because of the influence of the rest of the above-mentioned types of errors. Nevertheless this kind of measurement is widely used by machine tool manufacturers in order to set together the compensation tables. These tables are subsequently loaded into the control system and contribute to the improving of the overall accuracy of the machine tool. The need for a more complex method, which would cover the whole working volume of the machine tool yielded in the United States into the preparation of a new standard ASME B5.54. It is expected that the International Organization for Standardization (ISO) will publish a similar standard under the label ISO 230-6 in the near future. The recommended way of measuring the positioning errors uses body diagonals of an ideal solid figure set together from the strokes of the driven axes of the machine tool. It is possible to calculate the positioning accuracy of each axis after taking measurements along four different body diagonals. This method is often called the body diagonal displacement measurement. The main advantage is that the results are sensitive to all of the error components. However there is still not enough information for the identification of the error sources and for their compensation.

A novel method developed by the company Optodyne is called the Vector or Sequential Diagonal Measurement. The basic difference from the ASME B5.54 method is that each axis is moved separately in a sequence, which starts and ends on the body diagonal. Thus for a three axis machining center the movement is carried out along the X-axis, then the Y-axis and finally along the Z-axis. This sequence is repeated until the opposite corner of the diagonal is reached. For such a kind of measurement special equipment is necessary. A standard laser interferometer has to be supplied with a flat mirror as target. Using this configuration the movement parallel to the mirror do not displace the laser beam and do not change the distance from the source so the measurement is not influenced. A considerable advantage of the

sequential movement is that the positioning error, the straightness errors and even the squareness errors between the axes can be evaluated separately for each axis. Thus from a single measurement we get enough information to consider the influence of the positioning error, straightness, squareness and angular errors on the overall accuracy of the machine tool in its whole working volume. Performed measurements show that the application of this technique improves the positioning accuracy of the machine tool at least twice in comparison with the traditional method based on ISO 230-2. Naturally the suitability to use the vector method increases with the growing size of the machine tool, respective workpiece, where the influence of nonlinear errors is extremely significant.

All the above-mentioned methods check just the statical performance of the machine tool. In the recent time manufacturers strive to use high-speed cutting in order to reduce in-process times and gain better accuracy of nonlinear profiles or surfaces. During the contouring mode two or more axes are moved simultaneously with high acceleration. Accuracy of this kind of movement cannot be determined from the positioning errors. The ISO230-4 standard describes circular tests of numerically controlled machine tools. This method is not just a measurement of accuracy, it can also serve as a valuable diagnostic tool when things go wrong. Another advantage represents the simplicity of the practical application based on a ballbar device. This instrument enables quick, easy to prepare shop floor measurement of contouring accuracy in all machine tool planes. These arguments made the ballbar popular among machine tool manufacturers, end users, service and maintenance companies and resellers. The ballbar consists of a telescopic bar with precision-machined magnetic balls and cup joints at either end. The bar houses a high accuracy position sensor, which monitors machine tool spindle movement as it follows a programmed circular path and then compares the test path to that of an ideal circle. The ballbar can see every motion affecting error that exists in the axes under test. These errors include backlash, reversal spikes, lateral play, cyclic error, servo mismatch, scaling errors and geometry errors.

Various methods are currently used for testing of the machine tool accuracy. Most of them are time consuming, require special and expensive equipment and, above all, give only partial results for a complex overview of the machine tool precision. Research is therefore focused on the development of an integral method able to catch and describe all the error components. The ASME B5.54 is just the first step on this way.

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# New Conception of Milling Centers For High Speed Cutting

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Requirements on productivity of machine tools increase. Therefore technologies of high speed cutting – HSC are applied widely. Machine tools for HSC have to enable in all axis high feed rates and high accelerations. Therefore masses of moving parts of machine tools have to decrease and power of feed drives has to increase. The high stiffness of basic machine frames has to be preserved at simultaneous decrease of moving masses.

There are possible shows the most important factors influencing the machine design of HSC machine centers:

a) Rigid machine tool frames with high natural frequencies (mid-range MC min.100Hz)
b) Low inertia moving subgroups of machine tools for multiaxis machining
c) High degree of inherent damping of frame and moving parts vibrations
d) Increasing acceleration forces impulse impact on machine structure vibrations
e) High-velocity and high-acceleration feed drives, mechanisms and guiedeways
f) High effective cooling subsystem for temperature stabilization of machine structure
g) Very fast removing of chips from the machine space
h) High-speed and high-power spindles with automatic tool change for HSC conditions

New machine tools as milling centers used offered relatively high value of acceleration for high speed cutting. HSC machines with ballscrew drives enable in common use linear acceleration from 1g to 1.5g and feed rates 60m/min. Machines with linear motor drives in principle enable highest acceleration. The best linear motor centers offer linear acceleration from 1g to 2g extremely 3g and feed rates in range 80-120m/min. Achievement of these parameters is possible by application of two following methods:

1) enhancement power and/or
2) mass reduction of moving parts.

For feed drives is possible to use:

1) rotary motors and a high lead ball screw, or
2) linear motors.

Low price and good allocation of driving motor (heat source) outside of structure of machine tool are advantages of the first solution. But its disadvantage is that drives with ball screw do not, in real structures of machine tools, enable to achieve acceleration of more then $15 \div 20$ m/s$^2$. Higher acceleration as mentioned is achievable with linear motors (experimental lathe from Aachen achieves acceleration of as much as 130 m/s$^2$).

Design of an experimental high-speed machine center is one of MŠMT project LN00B128 goal. This milling machine is developing in author´s departement of CTU. The machine center should be design and made as top machine tool for HSC with hi-tech solutions.

Design parameters of machine center LM-2:

Size of working table min. 500x500 mm

| | |
|---|---|
| Axis stroke (X,Y,Z axes) | min. 500, 400, 400 mm |
| Rapid feeds (X,Y,Z axes) | min. 120 m/min |
| Acceleration (X,Y,Z axes) | min. 25, 25, 30m/s$^2$ |
| Spindle speed | min 30000 1/min |

Three conceptual layouts for the new high-speed machine tool LM-2 were design. First is three-axis machine center with horizontal spindle moving in Z-axis and vertical work table moving in X-Y plane. Second is four-axis machine center with horizontal spindle moving in X-axis and rotating work table moving in Y, Z and B axis. Last concept is five-axis machine center with horizontal spindle moving in X-Y plane and rotating work table moving in Z, a and B axis.

Although all conceptual designs have very different kinematic arrangement all of them have similar main characteristics: welded steel structure of main parts, linear or torque motors on all axis, high dynamic parameters, roler preloaded linear guideways and roller bearing, hydraulic shockabsorbers, control system and so on.

First and third conceptulal layout was in detail designet and many computational analyses was perform on them. Resuls of FEM, design and financial analyses was compared and first concept was chosen as the best for achieving project goals. Machine will be realized in year 2003 and whereupon wide range of experiments starts.

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# The Returnability of Investment to Simulation Software and Monitoring of Costs for Foundry Al Alloy

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At present at Faculty of Mechanical Engineering CVUT in Prague is ran project, which have a task to map economic situation in foundries in Czech republic. The main aim this project is maped of expensived calculation particular type foundries, theirs compare with calculation expense at technology, which is conformation by means of simulation software. The main output of this project will be recommend for type foundry and its volume of production, a number staffs, how much money is able to permit the foundry per annum invest into modern technology. This project is supported investigative intention CEZ: J04/98:212200008.

Under present conditions of market economy foundries are not only, but also other industrial company, all the time obliged to reducing its manufacturing cost by reason of competition-possibility on market. This is teaked how variable, so fixed costs. This work is under-used to be especially reducing fixed costs and the mainly for using in the preparation of manufacturing. By reason of competitiv is needed price decreasing of product, but there is demand big flexibility too. This is meaning, that is needed the shortening load time a new products into manufacture and satisfaction of requirements and needs of consumer have to run over in the shortest time and what preferably, because all advantages above competition, which is always increased, is able to mean obtaining of order. Decreasing of fixed costs has meaning especially with pouring in small series or by castings with complicated design. By optimalization by means of computer is happened to increasing of quality castings too and to reduction of wastler number.

The convenience these software would ought to have consist in savings time and cost, because " The method attempts and mistakes" by iron out ingate and risering system with setting applied to computer and no directly in foundry, where would with have to expensive editing of pattern equipment and such iron out would was wiring with cast of many wastlers.

About convenience of investment to these software is decided volume and variety of production in foundries too.

From the graphics visualization is possible estimated placement inclusion, shrinkages and next defects, which they are in casting structure undesirable. According to the found of mistakes, systems and reasons of their arisen, is possible give to complete shape casting, ingate system or risers and whole process of simulation subsequently repeat.

This system reply for present trend data transmission, when is effort to all be in progress in electronic form and communication between supplier and consumer and sending of drawing be under way by e-mail. This reply for also present endeavour of integration into system computer-aided of manufacture CIM (Computer Integrated Manufacturing) and thereby also to connection with some further software intended for management and control of foundry.

The calculation is as a matter of fact other title for computation or computation procedure. In factory general practice means calculation computation set especially on determination of costs, which is necessary expend on incipient output. Thereby output resp. product can be particular product expression in physical units (a bits, kg, tons, m2, m3, etc.). The subject of calculation doesn't need to be only operation, but is able to be its service too.

By calculation of price of casting we are obtaining summary, how which productive operation share on prime costs, which rise by production of casting. The calculation price casting is way out economical monitoring costs of foundry production, which reflected its technological facilities.

The first part of this project under-used to be confrontation costs on product, by its is preparation production firstly effected classical way and after it with the help computer simulation, is shown process preparation production three castings, which were really manufactured. These three castings are also representative castings, which overlaying manufacturing assortment of foundry. This work was made for foundry, which has 60 staffs and volume her yearly production is 212 tons Al.

These three castings create only partition of production foundry. The supposed saving by using simulation software is cca. 500.000,0 Kč / year. Returnability of investment to simulation software depend on:

- The size foundry (whereby major foundry, thereby faster investment is returned),
- Loading a new products to manufacture (whereby more is a new products, thereby investment is returned faster),
- Numbers pieces in order (whereby more bits in order's, thereby is savings smaller),
- Complication products (by complicated products is returnability quicker),
- Additional edits pattern equipment and kind of these edits (is necessity set up pattern or only add chills).

Large advantage these software is also, that is trimming time of preparation manufacture. As far as pattern has repared in pattern shop, which isn't a part of foundry, so its adjustment can take of a order 1 as far as 2 weeks. If is necessity pattern a number of time repare, is able to time initiation production very extend. This can involved financial losses in looks paying of penalty or losses consumer. In case consumer leave foundry complete this order, but next reservation production at competition, which forever increase. This advantage isn't in this work implied, because investigate with of such losses would was very difficult. It have to would investigate with, if customers foundry not long ago casting work in other foundry, which has comparable technology and comparable prices.

In conclusion we would wanted even accent, that setting and utilization calculation technology no-means, that will be solved technical problems itself without specialist, but on the contrary of them help increase their efficiency, give to them accurate and entire data for their fundamental decision making and specify and speed up custom control, operative control of production and whole economical work.

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Section 9

# ENERGETICS
# &
# POWER ENGINEERING

# Load Regulation System for Micro Electric Energy Generators

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## Introduction

As product of the research task VZ 9917: Research of Effectiveness and Electric Power Consumption Quality a new regulation system for load regulation of micro-energy sources was developed. Main topic of partial research task was design and construction of electrical devices, allowing phase current control in three-phase synchronous generator output.

Synchronous generator power output is several tens kW. Inspiration for research was in operational problems of 40 kW co-generation source, working in "island" network with very variable load. Due to big phase to phase differences in currents, protection checking for current symmetry was very often activated. To limit phase current differences, additional equalising resistor load for each phase in four regulation steps were used. Dissipated energy is used for warm use water pre-heating.

To realize this regulation task, the new regulation algorithm was developed and implemented to existing HJ 306 type device. Device HJ 306 is special regulation apparatus, which enables to measure 3-phase currents and in accordance to their differences to switch 3 output channels. Each output channel switched 2 equalising resistors in four regulation steps:
1.step - without additional load (no regulation)
2.step - connected resistor Rv.a
3.step - connected resistor Rv.b, Rv.a disconnected
4.step - connected Rv.a and Rv.b
To restrict switching transient phenomena equalising resistors Rv.a and Rv.b are switched via semiconductor "zero" switches.

## Co-generation source parameters and its regulation strategy

Generator output voltage: 3 x 400 V

Output power: 22 kW

Output nominal current $I_n$ = 40 A

Output nominal current $I_n$ is adjusted in binary code on HJ 306 circuit board by means of digi-switches. Acceptable output phase current asymmetry is 25%. In case, when regulation procedure starts and phase current asymmetry is below 25% any uqualizing resistor is connected and first regulation step is used (all equalising resistors are disconnected).Output currents of all phases are permanently measured. In case, when current diference in some phase conductor exceeds 25%, second regulation step is used. Equalising resistor Rv.a is connected

to relevant output. Information about regulation intervention is stored in memory and used for following decisions.When current diference in some phase conductor exceeds 50%, third regulation step is used and equalising resistor Rv.b is connected to relevant output. Information about regulation intervention is again stored in memory and used for following decisions. Fourth regulation step is used, when current diference in some phase conductor exceeds 75%. Equalising resistors Rv.a and Rv.b are connected to relevant generator output. Information about regulation intervention is again stored in memory and used for following decisions. All regulation interventions are related to minimaly loaded phase conductor. Minimaly loaded phase conductor is always without equalising resistor.

**Efficient utilisation of dissipated energy**

Energy, dissipated in equalising resistors is proposed for pre-heating of warm use water. With respect to relatively high peak regulation power, sufficient pre-heating boiler volume must be used. To achieve desired water output temperature, additional boiler for water final heating is used.

Functional unit of regulation device was assembled with material sponsored by Schrack-Energietechnik Company and BMR Company. Laboratory tests confirm good correspondence of theoretical and practical results.
Works, connected with solved problem:
Current symmetry protection analysis in co-generation unit TEDOM 40 kW.
Design and implementation of new regulation algorithm.
Design and assembly of regulation device.
Laboratory tests.
Research works continue.

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# Forecast of Primary Energy Resource Consumption by IAEA'S Software Tool Message

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This paper will present software Message V, which is model for Energy Supply System Alternatives and their General Environmental impacts. International Institute for Applied System Analysis (IIASA), Luxembourg, Austria develops the software message from 1974. The last version message V from 2001 has more user-interface.

***Physical Flow Model:***

- For a given vector of demands for goods and services, it assures sufficient supplies utilizing available technologies and resources
- Based on specified criterion, it optimizes the system expansion and operation

The Mathematical formulation and Structure of software IAEA „Message" is on base of the linear and mixed integer programming. Optimization target of given model has to be to minimize cost of given resource on total energy production. Equations to model restrictions are technical, legal, environmental data.

Influence of the commercial operation of new nuclear power plant Temelin on future electrical resource share was main result, which was expected from calculation by Message. Main objective of this study was to make transparent and comprehensive comparison of existing and new nuclear power plants with other available power sources in the frame of the economic and energy situation of the Czech Republic and to assess their potential role in GHG emission reduction strategies.

As baseline we selected „year 2000" for making scenarios of this case study. The data was assumed from the preliminary energy balance of Czech statistical office.
Optimization resources were forecasted by „message" tool to 2025.

**All used scenarios are based on the following common assumptions:**

- The Dukovany NPP (1760 MW) will be operated on full capacity till 2025 after its rehabilitation.
- The commissioning of the Temelin NPP (2x1000 MW) is expected in 2002 (first unit) and 2003 (second unit).
- New technology candidates (GCC, BCP)
- Real Discount rate 4%
- Emission coefficient is according to IPCC Methodology
- Reference scenario of electricity consumption
- Cost (Investment, Fixed 'n Variable O&M, Efficiency) according official statistic data

We defined two scenarios for our case study:

- Business As Usual Scenario:
  Emission level will not exceed the Kyoto protocol target until 2012.
- No "Temelin" Scenario:

The Temelin NPP will be completely stopped.

The Result of Czech case study is if new nuclear power plant Temelin will not start to commercial operation, it will be very big problem for future energy situation in Czech republic. It will be necessary to increase dependence on import of primary resources in case No „Temelin" Scenario (main gas) or cancel fixed limited area for coal extraction from energy police. It is in conflict with Czech energy police, which is in harmony with European union energy policy due to support energy independence and sustainable development. This scenarios is unrealistic from the economic and environmental point of view.

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# DFT Spectrum Analysis in Power-Line Systems - Uncertainty by non-coherent Sampling

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Quality of measurement is at present often characterized by absolute or relative error of measurement. Since about 1993 there is internationally accepted another method of measurement characterization, namely by uncertainty of measurement. Basic definitions and rules concerning this uncertainty are given in Guide to the Expression of Uncertainty of Measurement [1]. Application of there presented rules is not always an easy task, especially if there are several sources of uncertainty correlated to each other. Computer simulation is suitable instrument, which can be used in these cases.

Finding of uncertainty of DFT (i.e. Discrete Fourier Transform) amplitude spectrum was published for the case of coherent signal sampling. We have tried to find DFT amplitude spectrum components uncertainties for the case of non-coherent signal sampling, i.e. for the case when sampling is not synchronized with the analyzed (periodical) signal. Computer simulation proved itself to be suitable instrument in this case.

If signal is non-coherently sampled, spectrum analysis is distorted by the well-known effect called leakage. To suppress this leakage, two basic methods can be used – either signal windowing and interpolation in frequency domain, or signal interpolation and re-sampling in time domain. Analysis and comparison of these two methods was presented in [2].

The basic idea of finding uncertainties of DFT amplitude spectrum components is to apply firstly some method of leakage suppression and afterwards to use computer simulations for finding standard uncertainty. We have used statistical signal processing to find the standard uncertainty. Standard uncertainty is in this case found as standard deviation of results of repeated measurements. This attitude is denoted as method A of uncertainty finding in the Guide [1]. Our simulations were performed in MATLAB environment, so finding standard deviation is very easy – just using one of the built-in functions. Since the result of repeated measurements is arithmetic mean of the series of measurements, the above mentioned function must be applied either on series of these means, or the formula must be modified respecting that the seeked value of standard deviation is the deviation of arithmetic means of series of measurement.

Our simulations were oriented to practically important case of a.c. voltage with power-line frequency, higher harmonic components of which correspond to the international standards of electromagnetic compatibility. The noise, which is always present in practical measurements, was simulated by inserting additive noise of magnitude corresponding to the desired value of the SNR (signal-to-noise ratio, expressed usually in dB). This noise was gaussian one and had zero mean. Its standard deviation was found according to the desired SNR value.

Computer simulations allow simulating not only harmonic signal distortion and external noise with given SNR value. We have simulated also the resolution of the ADC (analog to digital converter) used for signal equalization. Simulations were performed for the most common types of ADCs, namely 12-bit, 16-bit and 8-bit converters.

Since power-line frequency in reality differs from its ideal value (50 Hz in Europe, 60 Hz in USA and some other countries), simulations were used also to find the possible influence of signal frequency changes on amplitude spectrum components' uncertainties.

We have found during the simulations, that there is a bias in spectrum components depending in a predictable way on number of samples per period of the analyzed harmonic component, if method of interpolation and re-sampling of signal in time domain was used. Therefore, additive and multiplication correction factors were computed for both methods and uncertainties of these factors were found. Simulation results giving these factors and their standard uncertainty are give for both methods of leakage reduction and for various harmonic distortions (described by the THD - total harmonic distortion – values), ADC resolutions, signal and sampling frequencies and numbers of signal periods analyzed in [3].

More important than the uncertainties of correction factors of amplitude spectral components are of course uncertainties of amplitude spectral components as such. We have also found their values in dependence of all the quantities enumerated above. We have presented their values for leakage suppression using interpolation in time domain as functions of ADC resolution, THD and SNR values and also as functions of sampling frequencies for both fixed and varied harmonic components phase shifts in [4]. Relative standard uncertainties of amplitude spectrum components of type A depend on the absolute values of spectrum components. We have found out for example, that for 12-bit (ideal) ADC and SNR between 70 dB and 30 dB, the relative standard uncertainties of fundamental spectrum component are in the order $10^{-3}$ % to $10^{-2}$ %, and relative standards uncertainties for higher order harmonics defined by international compatibility standards are of the orders of $10^{-1}$% to 1%.

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# Using Computer Simulation for Estimation of Uncertainty of RMS Value of Digitized Signal

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Since about 1985 a new approach is being introduced to the evaluation of the accuracy of measurement. The classical theory of measurement accuracy uses as the key notion expression "error" defined as the difference between the measured value and the true value of the measured quantity. The problem is that in real measurement the true value is never known. Therefore based on recommendations of the CIPM (Comité International des Poids et Mesures) the new key notion characterizing quality of measurement is uncertainty of measurement. Its definition and practical instructions how to find the uncertainty of measurement is given in the Guide to Expression of Uncertainty in Measurement, published firstly in 1993 [1].

Uncertainty of measurement is according to [1] "a parameter, associated with the result of measurement, that characterizes the dispersion of the values that could be reasonably attributed to the measurand". The parameter may be e.g. a standard deviation or a given multiple of it. Uncertainty of measurement comprises in general many components, some of which may be evaluated as an experimental standard deviation of the series of measurements. The part of measurement uncertainty is called type A standard uncertainty. Other part of measurement uncertainty, called type B standard uncertainty, is also characterized by standard deviation, but in this case it is evaluated not from statistical processing of a series of measurements but from assumed probability distribution based on experience or other information.

Our work described in this contribution was devoted to finding uncertainty of measurement of RMS value of digitized periodical voltage. The tool for finding this uncertainty was computer simulation, and simulations were performed in MATLAB. Standard uncertainty of the type A was found, both using rules given in [1] and numerical experiments. Rules given in [1] are in practice sometimes difficult to apply, especially if there are several sources of uncertainty mutually correlated.

Besides computer simulations also some measurements on real signals were performed and the uncertainty of found RMS values of the measured voltages was computed.

Results of our interim experiments were presented at MATLAB'2002 conference [2]. Results of [3] and [4] concerning finding uncertainty of RMS values for the case of coherent sampling of the measured analog signal were used in the theoretical part of [2], comparing two different methods of finding signal period. This period is necessary for the RMS uncertainty estimation. The uncertainty of the signal period value is one of the components of the uncertainty of the RMS value, and the two above mentioned methods of finding signal period differ in their computation complexity and the uncertainty of the found signal period value.

RMS value can be found using the definition in the time domain or as the geometrical mean of all harmonic components of the signal, that means in frequency domain. In this case it is necessary to find the signal frequency spectrum, and the DFT (Discrete Fourier Transform) is used for this task if the signal is digitized (i.e. if it consists of a series of numerical values gained by analog-digital conversion of a series of time-equidistant signal samples). Most

frequently used DFT algorithms are the Fast Fourier Transform (FFT) algorithms. If the measured signal is not sampled coherently (i.e. if the sampling frequency is not multiple of signal frequency and the sampling voltage is not synchronized to the measured voltage), some interpolation methods in time domain or in the frequency domain can be used for leakage suppression.

Uncertainties of RMS values computed both from the digitized signal in time domain and from the signal spectrum in frequency domain were found and compared. The mathematical expressions for RMS uncertainty based on [1] were verified by computer simulations. Sources of uncertainty (uncertainty of signal period and quantization noise of the AD conversion) were simulated numerically. We have used $10^4$ simulation runs, and their results were statistically processed to find measurement uncertainty. The measured voltage was supposed to be sine wave with randomly changing period so that number of samples for 1 signal period is between N-1 and N, and the probability distribution is uniform. In this way the uncertainty of the signal period estimation is simulated.

Also the uncertainty of quantization (using analog-to-digital converter – ADC - with given number of bits) was simulated. Uniform distribution of the quantization noise was supposed here. Effective number of bits of the used ADC should be used in general instead on nominal one given in ADC data sheet. Sampling more signal periods allows significantly reduce the uncertainty RMS uncertainty.

Dependence of relative uncertainty of RMS voltage was found as a function of number of samples per signal period, number of signal periods sampled and number of effective bits of the ADC, both for the basic and modified algorithm of finding signal period. As for frequency domain computation, only the ADC quantization effect was studied.

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# Errors Measurement Analysis of Engine Rounning Roughness

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## 1. Introduction

The measurement of the instantaneous crankshaft velocity used for the non dismantling diagnostic method is based on recalculation of the angular velocity from the intervals of passing marks, eg. gear rack on the flywheel ring along a sensor [1][2]. These time intervals are recorded with a control apparatus developed in the Instrumentation and Control Engineering Department of CTU Prague.

Notwithstanding these measurements are charged with the errors, which are inherent in every physical measurements. The object of this contribution is to make the method in question more precise by analysing the errors, defining their origin and finding out the way for their removing.

## 2. Measurement errors

The error measurements cause the noise of the measured signal. The value of the noise signal is often greater than the one of the useful signal and for that reason there are losses of the information, which are important for the final effect. The errors were divided, as it is standard, into systematic and random ones.

### 2.1 Systematic errors

The cause of the most important error is the insufficient machining of the teeth on the flywheel especially with respect to the pitch. Another mechanical errors are caused with the wear of the teeth and with the running out of the flywheel. The magnetisation of the teeth contributes for the errors in question.

There are different manners for removing of these errors.
One of them is to compare the measured data gained with the uniform rotation to rotation of the loaded engine.

The uniform rotation was simulated with turning the unloaded engine by the independent supply, as it is eg. an electric motor, with the data gained on the loaded engine. Another simulation is to turn the unloaded engine by the independent supply, the valves being constantly mechanically opened. In this case there are only the inertia forces of reciprocating masses present and this operation is close to the state of ideal uniform rotation.

The second manner for removing or for minimising the systematic error is the method, when two magnetic pickups are used. The pickups are located side by side on the flywheel cover, the gap between the sensors and the rotated teeth ring ought to be as small as possible. The both sensors are connected to the electronic control unit. They measure and compare the time intervals between the leading edges of the teeth passing along two sensors. They evaluate the leading edges of a signal of one tooth between the first a the second sensor [3]. The distance between two sensors should be 3 – 5 teeth, in order not occurs the interference of the signal.

2.2 Random errors

Another group of errors having effect upon the course of the measured signal are the random errors caused by the vibration of the machine and the sensors frequency of which is different.

There are several kinds for removing of these errors the base of which is the flittering method. But there are some limits at using this method. The visible effect is the smoothing up of the measured course. On the contrary the degree of the smoothing must be done at the proper level, because the smoothing at too great level can deform and destroy the expected information. To find out the suitable level of smoothing means to get the suitable course without removing of important points and intervals.

One of the possibilities is the signal filtering method by means of Fourier analysis. This method is based in the signal distribution on single harmonic components and in the subsequent composition of the signal, now only from the chosen harmonic components. The disadvantage of this method is, that the phase is shifted in the extend of $0 - 2\pi$, the reason for that being the fact, that only real spectrum components are put into consideration and the imaginary component is neglected

The further method for removing off of the incidental errors is the usage of correlation method, which does not oppress rapid details of the course and makes possible to define and to separate the noise components. This method is considered as a perspective one and remains therefore in the focus of the further research.

3. Conclusion

The contribution in question deals with the errors, which influence in the significant manner the evaluation correctness of a diagnostic method based on the instantaneous crankshaft angular velocity. The most important errors were defined, which influence the measured courses and possible kinds for their elimination were found out.

The measured values were obtained at an experimental diesel engine ČKD Praha-2S110, bore 110 mm, stroke 130 mm, nominal output 16 kW, nominal revolution 1500 1/min.

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# International Comparison of AC Voltage Ratio Standards

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Two standard instrument voltage transformers (IVT) made by the firm Tettex Instruments, Switzerland were chosen as transfer standards. The ratios of the used transfer standards were (5 and 10) kV/100 V and 22 kV/100 V. The measurement of the ratio error ε and phase displacement δ was performed at 50 Hz frequency and with a burden of B = 1 VA at unity power factor. The errors of the transfer standards were measured with (40, 60, 80, 100 and 120) % of primary voltage rated value $U_R$. The participating laboratories are: Federal Office of Metrology and Surveying (BEV), Austria, Czech Metrology Institute (CMI), the Czech Republic, Helsinki University of Technology (HUT), Finland, National Office of Measures (OMH), Hungary, Central Office of Measures (GUM), Poland, Slovak Metrology Institute (SMU), the Slovak Republic, Laboratorio Central Oficial de Electrotecnia (LCOE), Spain and Swiss Federal Office of Metrology and Accreditation (METAS), Switzerland.

The methods used for comparison measurement performance: Comparison with standard IVT used BEV Austria, CMI the Czech Republic, OMH Hungary, GUM Poland, LCOE Spain and METAS Switzerland. HUT Finland and SMU the Slovak Republic used comparison with standard capacitors.

For precise determination of transformer errors it is important to adhere closely to the value of the transfer standard burden. For this reason the pilot laboratory measured the dependences of ratio error Δε and phase displacement Δδ variation versus the variation of magnitude ΔB and power factor Δcos β of burden B. Considering these results the pilot laboratory recommended keeping the rated burden value and its power factor with uncertainty better than 0,5 %.

The participating laboratories were asked to follow their usual measurement procedure to their best measurement capabilities taking into account the allowed time frame for the comparison.

The pilot laboratory calculated the resulting reference value as the weighted mean according to the formula

$$\varepsilon_r = \frac{\sum_{L=1}^{n} \varepsilon_L U_{\varepsilon L}^{-2}}{\sum_{L=1}^{n} U_{\varepsilon L}^{-2}}; \qquad \delta_r = \frac{\sum_{L=1}^{n} \delta_L U_{\delta L}^{-2}}{\sum_{L=1}^{n} U_{\delta L}^{-2}}, \tag{1}$$

where $\varepsilon_L$, $\delta_L$, $U_{\varepsilon L}$ and $U_{\delta L}$ are results and uncertainties of ratio error and phase displacement of each participating laboratory, $n$ is number of participating laboratories.

Uncertainties of the reference value calculated as weighted mean are given by the formulae

$$U_{\varepsilon r} = \frac{1}{\sqrt{\sum_{L=1}^{n} U_{\varepsilon L}^{-2}}} \; ; \qquad U_{\delta r} = \frac{1}{\sqrt{\sum_{L=1}^{n} U_{\delta L}^{-2}}} \tag{2}$$

A 95 % confidence level is given

$$\varepsilon_r \pm 2U_{\varepsilon r}; \quad \delta_r \pm 2U_{\delta r}. \tag{3}$$

Results of participating laboratories and reference value for 100 % of rated value of measured voltage are given in Table 1.

| ratio | 5 kV/100 V | | | | 10 kV/100 V | | | | 22 kV/100 V | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| error / lab. | $\varepsilon_L$ [ppm] | $U_\varepsilon$ [ppm] | $\delta_L$ [ ' ] | $U_\delta$ [ ' ] | $\varepsilon_L$ [ppm] | $U_\varepsilon$ [ppm] | $\delta_L$ [ ' ] | $U_\delta$ [ ' ] | $\varepsilon_L$ [ppm] | $U_\varepsilon$ [ppm] | $\delta_L$ [ ' ] | $U_\delta$ [ ' ] |
| **CMI** | +273 | 35 | +0,01 | 0,11 | +4 | 35 | +0,90 | 0,11 | -17 | 35 | -0,31 | 0,11 |
| **SMU** | +240 | 100 | +0,07 | 0,30 | -17 | 100 | +1,06 | 0,30 | -100 | 100 | -0,97 | 0,30 |
| **BEV** | +263 | 45 | -0,15 | 0,16 | -20 | 38 | +0,97 | 0,13 | -14 | 42 | -0,26 | 0,13 |
| **OMH** | +208 | 34 | +0,04 | 0,12 | -36 | 33 | +0,83 | 0,11 | -25 | 32 | -0,53 | 0,11 |
| **GUM** | +245 | 30 | -0,08 | 0,09 | -16 | 20 | +0,84 | 0,09 | -37 | 40 | -0,28 | 0,09 |
| **METAS** | +246 | 12 | -0,09 | 0,04 | -19 | 12 | +0,80 | 0,04 | -12 | 13 | -0,35 | 0,04 |
| **HUT** | +245 | 30 | 0,00 | 0,06 | -16 | 20 | +0,87 | 0,06 | -37 | 40 | -0,34 | 0,06 |
| **LCOE** | +249 | 200 | -0,04 | 0,60 | -18 | 200 | +0,84 | 0,60 | -38 | 200 | -0,31 | 0,60 |
| **ref. value** | +251 | 17 | -0,06 | 0,05 | -13 | 14 | +0,84 | 0,05 | -20 | 17 | -0,35 | 0,06 |

Table 1.

In this table $\varepsilon_L$ and $\delta_L$ are ratio errors and phase displacements measured by individual laboratories, $U_\varepsilon$ and $U_\delta$ are uncertainties of measurement of individual laboratories. Reference values and their uncertainties were calculated by means of formulae (1) and (2). Results and uncertainties of measurement of individual laboratories show good agreement with the reference value and its uncertainty.

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# Internet Teaching and Modernization of on Safety Problems Oriented Subjects at Faculty of Electrical Engineering.

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The grant project is focused on development of effective forms of teaching. Proposed project stems from a long time conception of subject Introduction to Electrical Engineering and from practical experience of investigators. The main content of the Introduction to Electrical Engineering and prepared subject in bachelor study is electrical qualification of students and problems of the safety in electrical engineering. The program is determined for all the 1st class students including foreign students and for students of distance study at present.

On university level the safety problems and introduction to electrical qualification is oriented not only to learning rules and instructions but must be study with systematic approach, must be focused to understanding of physical principles of the eliminations of hazard, to recognize systems of physical separation from the danger, from the theoretical point of view to detect safety parameters. Engineer must be skilled in the techniques of determining the possible cause of accidents. Important characteristic of university level is to prepare all students to manager position or supervising role in the future job.

The teaching process is divided into three components: theoretical part, practical part and examination. The team of teachers considers as effective the practical form of teaching in laboratory and now also application of web pages directly in education and in individual students work.

Successive innovation during two semesters brought improvements in organization and sequentially in better preparation of students. Limited practical knowledge complicates to understand properly the scope and importance of safety problems in different branches of Electrical Engineering for their future careers.

The project was oriented also on students of extra mural study, in which is complicated communication among students and teachers due to low hour capacity. Exceptional attention is paid to teaching in English courses. English version of web pages is a component part of the project.

Safety problems in electrical engineering and electrical technology are explained in broad outlines of electro engineering practise and with more systematically way.

Problems in this new approach included are conceived in consecution from physiological effects of electrical current on the human body through physical description of these phenomena to general requirements on basic safety parameters of electrical equipment and pursuance of safety and technological measures. Introduction to problems of electromagnetic compatibility of different types of electrical appliances were involved too. Essential part of electrical qualification is also basic knowledge of the first aid treatment of the electric shock. In the mentioned domains the subject fills out the discontinuity in teaching of electro engineering subjects of bachelor and master programs of study.

Part of teaching with practical training was focused on basic and representative type of work:

1) Progressive acquirement of work experience at school laboratories conformable with safety rules and with requirements for electrical qualification. Students are prepared in the sphere of electrical safety to executive and manager grades and they must be competent independently work within scope of their qualification.
2) Students perform individual mounting of devices and of assemblies for basic types of installation single-phase circuits switchboards, single-phase circuits, simple protective circuits with circuit-breakers in TN –C and TN-S networks.
3) Students perform the design and assembling of printed circuit board by manual soldering.

Authors of the grant project were concentrated on introduction of supportive teaching program on Internet for full-time education and for combined form of education in Czech and English version. The aim of this project is to bring actual information on web pages, that serves namely to accessing of basic data for practical part of teaching. Web pages are presented in seminars. That enables to compensate limited communication with students of part time study program.

Pedagogical part of the project reacts to current state of knowledge deficiencies of students at Faculty of Electrical Engineering and tries by constructive way to contribute in rationalization in teaching process in prepared new bachelor study program. This grant project emphasizes in the first place quality improvement of practical education. Innovations of the teaching process will be presented at web pages and in the form of textbooks. Innovation of teaching aids, designed to serve students, is another domain of the project. New types of teaching aids correspond to requirements on contemporary technological level (TN-S network).

The first stage of checking before assembling PCB is mathematic check of circuit design with special software. Computer supported workstation ensures also automation of routine operations of teachers, especially testing of soldering quality on PCB and circuit parameters on computerized measuring system for great number of students (1300).

Subsidiary teaching program oriented on safety problems in Electrical Engineering at Internet for all forms of study at FEL was established. Hardware and software innovation for web pages presentation was accomplished. Teaching aids for students and automation of many routine operations of teachers in laboratory became operational.

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# Power Electronics in Automotive Hybrid Drives

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*Abstract* - Paper deals with different kinds of automotive hybrid drives. Special attention is paid to electric power splitting. DC power splitting system, well-proved on Czechoslovak express railcars Slovenska Strela from 1936, is described. New idea to use a similar drive using AC machinery and power electronic converters is studied in Josef Bozek Research Centre of Engine and Automotive Engineering. An experimental working stand was projected to research, to perform measurements and to serve for doctor students.

Keywords - *AC machines, DC machines, Drives, Efficiency, Electric machines, Hybrid vehicles, Locomotives, Traction*

A modified power splitting system equipped with AC machines is described in this paper. In contrast to the DC system, AC/AC converter EC3 is added and it connects AC synchronous generator with permanent magnets SGPM and AC traction motor TM with different voltage and frequency levels that occur during operation of the drive. The DC intermediate circuit is via DC/DC converter connected to the super condenser for energy storage. Internal combustion engine is substituted by AC motor ACM1 supplied from converter EC1 and the traction resistance is created by AC machine ACM2 and converter EC2.

The synchronous generator SGPM is a special machine with rotor and stator both rotating. Both rotating parts can be coupled by clutch ELM together. The rotor is driven by ACM1. ACM1 torque is directly transmitted via air gap and electromagnetic forces to the SGPM stator. A conventional fixed stator would fasten this torque by foots but the mentioned type transmits it to the output shaft and adds it to the traction motor TM torque. During speeding up, when vehicle velocity is zero, full ACM1 power is converted in SGPM into electric power which supplies traction motor TM. In this state the function of electric part is similar to serious hybrid drive or electric power transmission but the driving torque is greater due to SGPM stator, which adds the ACM1 torque on the traction motor TM shaft. When the vehicle moves and output shaft speed is not zero then SGPM stator torque develops mechanical power so that part of ACM1 power is transmitted by mechanical way with minimal losses. The transfer efficiency is better then in serious hybrid dive. The second part of ACM1 power is transformed into electric power in the SGPM stator. Electric power decreases because differential speed between SGPM stator and rotor decreases too. At higher velocity the differential speed is small and the clutch ELM can be switched. All ACM1 power is then transmitted mechanically to the ACM2 with high efficiency.

Experimental working stand can be used not only for experiments with power splitting system. It offers many other experiments, for instance starting of internal combustion engine from super condenser, running as the series or parallel hybrid drive and the battery or super condenser charging.

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# Design and Realization of Active Magnetic Combined Bearing

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Progress in a magnetic bearing technology causes that their usage changes from special applications to industrial applications. Magnetic bearings are more and more an object of interest of designers, constructors and manufacturers of rotating machines. Their advantages as ability to work in vacuum, in weightlessness, in chemical aggressive environment are demonstrable. Also a possibility to change very simply their stiffness and a damping by tuning of controller parameters is convenient for variable speed applications.

Magnetic bearings can be subdivided on passive bearings and active bearings. Both types were studied on the Workplace of magnetic bearings by Department of Electrical Drives and Traction in the last year.

1. New trends in active magnetic bearings were discussed in [1]. One of the possibilities to reduce a power requirement is to use permanent magnets for the basic magnetic flux and to use exiting currents in multiphase stator winding only for stabilization. More details are given in [2].

   The Workplace of magnetic bearings is equipped with one radial active magnetic bearing with inner diameter 80-mm and clear length of magnetic circuit 36-mm. Second radial bearing was a classical rolling type bearing. Detailed construction drawings were elaborated during the first half of the year 2002 and a new bearing was produced and assembled by supplier on the Workplace at the end of that year.

   The new combined type active magnetic bearing is located on the opposite end of the shaft. Bodies of both magnetic bearings are similar and support stator magnetic circuits comprising windings, auxiliary classical rolling bearings and eddy current type position sensors. Bodies are located symmetrically to the shaft center.

   The Workplace is provided with power transistor box [3] and microprocessor plate. It allows us to realize the power supply and the control part for this active bearing. We plan to put into service this bearing during the year 2003. The aim is to compare characteristics of both types of bearings and obtain own experience with new bearing type.
2. The control system of the active magnetic bearing on the Workplace was modernized six years ago. We decided to improve this system before starting works of the control system for combined magnetic bearing. Mentioned control system can be divided in three parts:

   The **hardware** is realized on the control desk D8204 N1 with microprocessor 87C 196 and signal processor TMS320 C25. This part fulfils requirements and we decided to use it for next period without changes.

   The **software** was developed five years ago as a doctoral work. This program was elaborated without rules for structured programming and some detailed documentation does not exist now. New program was elaborated in structural form. The program STUDENT was used for communication and tuning. The new software is in last step of tuning.

The **power supply** is realized as separate box with eight half-bridges and was projected and realized in year 2000. It allows putting together different connections of the power converter. The active magnetic bearing on the Workplace needs four two-quadrant choppers for one current direction. Each chopper requires two half-bridges and all power part can be connected in one box. The new combined magnetic bearing needs one three-phase inverter. It can be connected also in one box.

3. We cooperated with the Institute of Thermomechanics of Czech Academy of Science. Its group of Dr. Kozanek elaborated an experimental set with two radial passive magnetic bearings. The principle of an attractive magnetic force is used for the stabilization in the axial direction. This experimental set was delivered at the end of the year 2001. The power supply and control part of the axial stabilization was realized in the Workplace. The method of mathematical simulation was used. We measured different relations between position, force and current. These relations represent nonlinear functions. We developed the simulation model in MATLAB – Simulink environment [4] and we determined correct setting of PID-controller parameters. We had to solve many mechanical problems in correct assembling. The final product was delivered to Institute of Thermomechanics for next research works.

More details is presented on the poster during the Workshop 2003.

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# Diagnostics of Rotating Electric Machines by Using of Expert System

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With the increasing power of new machines and equipment installed newly in the electrification network of the Czech Republic, problems of operational reliability of electric machines and equipment have come to the forefront of expert's attention. Insulating systems of electric machines is the main factor affecting general reliability of a complex high voltage installation (a power plant, a switching station, a factory etc.). It is possible to determine the reliability of this equipment based on tests and diagnostic measurements. The partial discharge measurement and evaluating discharge activity in the insulating systems of electric machines and equipment is one of the modern diagnostic methods for the evaluation of the state of insulating systems. The partial discharge measurement is also especially convenient for detecting the loosening of stator bars in rotating electric machines which leads to the vibration of the bars during the operation, to mechanical damage to resin insulation and, in some cases, to the breakdown of the insulation. From this point of view the measurement of discharge activity is one of the most effective method for evaluating the state of modern insulating systems based on the resin insulation. In addition, this method makes it possible to check the state of the machine during its operation without any interruption (on-line method).

The evaluation of the measurement of partial discharges and the impulse wave and the estimation of the machine performance in further operation are complicated, and that is why it is necessary to consult experienced experts. Expert systems are the best solution for the evaluation of partial discharge data and for the estimation of behavior of the insulation system in future operation, because they use knowledge base and experience of human-experts from the previous measurements. The evaluating procedure usually begins with input data collection. Then the measured data are statistically processed to remove false, accidental and disturbing data. These revised data are processed by the special expert systems. The results of the expert systems are not only in the form of processed data of diagnostic parameters, but, in addition, they give recommendations to servicemen for the future operation of the observed machine or equipment. The most advantage of these expert systems is the fact, that by means of an expert system, even an inexperienced worker is able to decide competently about the state of the insulating systems and about the equipment behavior in further operation. During an on-line measurement, the expert system indicates a defect of the insulating systems immediately and, at the same time, offers a solution with respect to the safety and reliability of the machine or equipment in further operation.

The new principle of partial discharge device has been developed at the High Voltage Laboratory of the Czech Technical University in Prague, Faculty of Electrical Engineering in the collaboration with the top diagnostic workplaces in the Czech Republic.

The goal of this project is to develop and make a complex diagnostic stand (measuring workplace, incl. hardware and software components) needed for the on-line (during the operation) diagnostic measurement of high voltage machines and equipment under operational conditions. The automation of routine tests of electric machines and their evaluation, including the modification of the expert system for non-interruptive diagnostic measurement of machines, or without disassembling will also be in the focus of our work.

Within this project, a measuring unit for the measuring and processing of partial discharge data, including calibration equipment, will be created. Based on our experience with commercial measuring units, the measuring unit will be made. This unit will enable quick and non-distorted scanning of partial discharge impulses and will digitize these data by a special A/D converter. A standard serial line (RS232) connection between the computer and measuring unit will enable a direct access of the measured data into the computer. This procedure will enable to evaluate diagnostic parameters immediately, and to use this diagnostic method as an on-line measuring (monitoring) method. Special software for the collection and evaluation of diagnostic measurement will also be created. The computer program (including built-in expert systems) will be able to evaluate, edit and save measured data from the diagnostic measurement, including information and notes about the machine (a piece of equipment, a sample) and the measurement conditions. Before the proper evaluation of discharge activity and the impulse wave, measured data will be statistically processed to eliminate random data and typical interference (transmitters, thyristors, etc). The evaluation of the input data (the calculation of diagnostic partial discharge parameters) and their visualization will be performed automatically.

A further stage of our research activity will be in the creation of the expert systems for the evaluation of diagnostic partial discharge measurement in the operation mode and for the monitoring of the state of the insulation during the operation. Two parallel expert systems will be created: a rule-based expert system will perform an amplitude analysis for determining the damage the insulation system, and a neural expert system (neural network) will be used for the recognition of partial discharge patterns (a phase analysis of partial discharge impulses) for determining the kind of discharge activity and the location of the source of discharge activity. Both expert systems will operate simultaneously, and special software will ensure the co-ordination between them. The expert system for evaluation of the impulse wave will follow both the previous systems. The construction of each expert system requires the construction of a "bank of experts" as well as the determination of limit values of diagnostic parameters and the development of a suitable training set.

The results of this project will increase the safety and reliability of the operation of large electric machines (motors, alternators and transformers) and high voltage equipment working in the Czech National Network System. On the basis of the partial discharge monitoring diagnosis (on-line measurement and evaluation during the operation) by the proposed partial discharge stand, the operational reliability and safety will rapidly increase.

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# Partial Discharge Measurement in Conditions of Disturbances

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In the case of the partial discharge measurement we want to find out the partial discharge magnitude, generally we made an integration of the current impulse. However, great problems in the evaluation of partial discharge data are focused in various sorts of interferences.
We can separate disturbing signals into internal disturbing signals and external ones. The internal interferences are dependent onto the actual voltage of the measured subjects; external interferences are not dependent.
The most of disturbing signals we can eliminate by using of a suitable circuit modification, e.g. by using of the four-capacity bridge, which is suitable due to its technical simplicity for small capacitance objects. We can also convert the partial discharge signals into digital (discrete) form and to use suitable computing programs for the processing and saving of measured data.
The staff of the High Voltage Laboratory of the Czech Technical University in Prague, Faculty of Electrical Engineering, is interested in the development of the new digital partial discharge measuring equipment. It also uses special software for the elimination of the interferences. By using of the special software we can recognize and delete disturbing signals from measured data sets.
We have developed two algorithms for the elimination of main disturbing signals from digitized partial discharge data. At first, we can eliminate randomize disturbing signals and SCR disturbing ones (from thyristors). We suppose that the randomize signal is only one pulse in each data set and the SCR signal are three periodical pulses in each set. Two math theorems are applied to all measured samples by the computing program. To identify randomize interferences, we use following the theorem to each set:

$$q_m / ((\Sigma q_i - q_m)/(p-1)) > k,$$

where $q_m$ is a maximal value of the set, $q_i$ is an i-value of the set, $p$ is a number of elements in one set, $k$ is a constant and $k \in \langle 2;10 \rangle$.
To identify SCR interferences, we use two parts of theorem. At first, we find three highest charge magnitudes in each set and we sort them ($m_1$ to $m_3$). Each of these elements has the own charge magnitude $q_{mmi}$ and the own phase shift $\varphi_{mmi}$ . The amplitude condition of this theorem is:

$$((\Sigma q_{mmi}) /3) / ( | \Sigma q_i - \Sigma q_{mmi} | /( p - 3)) > k,$$

where $p$ is a number of elements in one set ($p$ = 200), $q_{mmi}$ is an $i$-element from the three highest values of the actual set, $q_i$ is an $i$-element of the set, $k$ is a constant and $k \in \langle 2;10 \rangle$.
The time condition of this theorem is:

$$| ( p/3) - ( | \varphi_{mmi} - \varphi_{mmi-1} | ) | \leq k_0,$$

where $p$ is a number of elements in one set ($p$ = 200), $\varphi_{mi-1}$ is a position of an *(i-1)*element, $\varphi_{mi}$ is a position of an i-element, $k$ is a constant and $k \in \langle 0;5 \rangle$.
In another way for the elimination of disturbances from partial data is the mathematical Wavelet analysis, which makes possible the elimination of more types of disturbance. The best way in this case is to use the discrete Wavelet analysis. We have used several families of wavelets (Haar, Daubechies, Biorthogfonal, Symlets and the others). Their unsteadiness is

really excellent for unsteady signal analysis, inclusive of the partial discharge signals. It could detect signal changes and variabilities as a signal noise.

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# Propagation of Partial Discharge Impulses in Windings

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Although the greatest attention is focussed to quality control during the construction and fabrication of high voltage electrical machines and equipment, it may become occasional external and internal defects in insulating system, which implicate partial discharges at the test voltage or even at the rated voltage. Partial discharges in transformers can occur at various positions in the windings, at leads, at sharp corners or edges of supporting parts, at defects or voids in the dielectric e.g. gas bubbles in oil or voids in celluloid material (paper, transformer board, wood). Furthermore, these are facilitated or even initiated by impurities as well as locally enhanced humidity values or a totally very high humidity content of the insulating material.

The detection and measurement of partial discharges in the transformers insulation is one of the most useful diagnostic tools for quality assurance testing during design, manufacturing and service life assessment.

The measurements of partial discharge impulses damping on transformer winding model was performed in the High Voltage Laboratory of the Czech technical University, Faculty of Electrical Engineering. Our goal was in the finding and describing of deformations of partial discharge impulses after the passing through the winding and in the developing the evaluating methods for these deformed impulses.

All measurements were made on the model of transformer windings. For simulation of partial discharge impulses the calibrator TETTEX, type 9216, was used with the following characteristics:

Charge range: switchable 10 pC to 10 000 pC
Charge error: 1 %
Counting rate: 100 Hz
Output capacity size: 14,1 pF (for 10 pC and 100 pC)
141 pF (for 1000 pC)
1410 pF (for 10 000 pC)
Synchronization: Light sensitive diode
Power supply: battery IEC 6F 22 - 9V
Calibrator rise time: 100 ns

For measurement and evaluation of apparent charge of partial discharge impulses the digital scope LeCroy 9350 was used with built-in math functions and with the following characteristics:

Bandwidth: 500 MHz
Sampling: up to 2 GS/s for single-shot signal
up to 10 GS/s for repetitious signal

It results from performed measurements, that from practical view is optimal take the apparent charge of partial discharge impulses as sum of all, i. e. positive and negative parts of deformed pulses. Apparent charge $q$ was evaluated by mathematical function of the digital scope according to:

$$q = \int |i(t)| dt = \frac{1}{R_m} \int |u_m(t)| dt ,$$

where $i(t)$ is current impulse generated by the calibrator, $R_m$ is loading resistance and $u_m(t)$ is a voltage impulse measured by the scope.

As we presumed, partial discharge impulses were damped on winding. In the middle of the coil, the winding signal attenuates approximately to 80%, which is the acceptable value for operational measurements. Since damping on winding was measured on transformer winding model, can be results on other types transformers (above all with oily filling with big values of spread parameters *L* and *C*) different. In real orderings partial discharges occur above all in the area of higher values of voltages on the coil, i. e. above all in the area 100 - 70% of coil longitude, and that is why it is possible to tell, that these results values are generally applicable.

In comparison with other methodologies we made out that values of apparent charge deviations determined with this methodology are within supposed tolerances for the operational measurements.

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# Development of Neural Network for Recognition of Partial Discharge Patterns

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Insulating systems of electrical machines are the main factor affecting general reliability of a complex high voltage installation (a power plant, a switching station, a factory etc.). It is possible to determine the reliability of this equipment by tests and diagnostic measurements. The partial discharge measurement and evaluating of discharge activity in the insulating systems of high voltage electrical machines and equipment is one of the modern diagnostic methods for the evaluation of the state of insulating systems. The partial discharge measurement is also especially convenient for detecting the loosening of stator bars in rotating electrical machines which leads to the vibration of the bars during the operation, to mechanical damage of resin insulation and to the breakdown of the insulation. From this point of view the partial discharge measurement is the most effective method for evaluating the state of modern insulating systems based on the resin insulation. In addition, this method enables to check the state of the machine during its operation without any interruption (on-line method).

The evaluation of the discharge activity and the estimation of the machine performance in further operation are complicated, and that is why it is necessary to consult experienced experts. Expert systems are also a convenient solution for the evaluation of partial discharge data and for the estimation of behavior of the insulation system in future operation, because they use knowledge base and experience of human-experts from the previous measurements. The results of the expert systems are not only in the form of processed data of diagnostic parameters, but, in addition, they give recommendations to servicemen for the future operation of the observed machine or equipment. The most advantage of these expert systems is the fact, that by means of an expert system, even an inexperienced worker is able to decide competently about the state of the insulating systems and about the equipment behavior in further operation. During an on-line measurement, the expert system indicates a defect of the insulating system immediately and, at the same time, offers a solution with respect to the safety and reliability of the machine or equipment in further operation.

Nowadays, the most modern processes for partial discharge data evaluation are the amplitude analysis of current partial discharge pulses (for determining the damage of the insulation system) and the phase analysis of current partial discharge pulses (to determine the kind of partial discharge activity and for the localization of sources of partial discharge activity, respectively).

The phase analysis of partial discharge patterns is the process, which needs the high level of an abstraction. That is why we must use an intelligence system with the largest abstraction – neural network. However, the training of a neural network is very complicated – we must create a credible training set.

The aim of this project is to develop and make a neuron network for the recognition of partial discharge patterns (a phase analysis of partial discharge impulses) to determine the kind of discharge activity and the location of the source of discharge activity. Neural network will work separately or in cooperation with other evaluating systems, e.g. with the rule-based expert system for the amplitude analysis of partial discharge pulses.

As an empty expert system the NEUREX expert system (developed at the Mining University of Ostrava) will be used. This software approved oneself very good in last years. The neural network is back-propagation type. Input layer has 200 neurons (according to the input data set within in the one period of supply voltage 50 Hz, sampling 1.8°el. Output layer will be consist from 5 or 7 neurons, according to the results of variants od neural network. The count of inner layers and number their neurons will be specified after testing of all developed variants of neural network.

The final neural network for the recognition of partial discharge patterns will be modified stepwise (step-by-step) by following training sets:

1st step: A training set for the modification of the neural network will be developed on the basis of information from literature and experience of human experts. The special SW generator of partial discharge impulses will be developed and created for the training of neural networks.

2nd step: A training set will be created following a direct measurement of partial discharge activity on simple high voltage arrangements.

3rd step: A training set will be created on base a direct measurement of partial discharge activity on real high voltage apparatus with known defects.

The quality of expert systems is significantly influenced by the quality of the knowledge base created by human experts. For that reason, the scientific staff will cooperate with several Czech top workplaces, including universities (Czech Technical University in Prague; Technical University in Ostrava; Technical University in Brno; West Bohemian University in Pilsen); research institutes and laboratories (EGÚ Research Laboratory, Běchovice; Škoda Research Company, Pilsen; the Temelín Nuclear Power Plant; West Bohemian Power Company); specialized companies (the Czech Power Company, the ORGREZ Company, the HESIA Company); and with individual experts worked in this area.

The aim of this project is to develop and create a neural network for the phase analysis of current partial discharge pulses to determine the kind of partial discharge activity and for the localization of sources of partial discharge activity, respectively.

The MATLAB® and the Neural Network Toolbox will be applied for the developing of artificial neural network with the backpropagation algorithm. It will be the multilayer feedforward network and try to train neural network for recognition of partial discharge patterns.

The results of this project will expand the scientific field of electrodiagnostics and artificial intelligence. In operation, the results increase the safety and reliability of the operation of large electrical machines (alternators and transformers) and high voltage equipment working in the Czech National Network System.

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# Power Supply of Deep-Sea Mining Machine

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Intensive preparations for mining and exploitation of polymetallic materials from the ocean bed are progressively performed of late years. Therefore new systems and devices for the prospection of polymetallic nodules on the deep seabed and their mining for the practical use are designed. Typical mining systems consist of floating level base, of one or more mining machines and of a number of navigation devices. Mentioned mining machine is proposed like a self-propelled vehicle applicable for the operation in mild sediments. Collection of polymetallic concretions sized from 20 to 100 mm can be realized by the mechanical or hydraulical way. Mined material can be transported up to the sea level repository by pumps, lift or airlift. Electric energy can be fed to the mining machine by the special coaxial cable from the level base. Some light conductor for the control and information signal transmission will complete the cable. The cable body is furnished with the steel cover for its surface protection, tenacity and mechanical ruggedness advance namely during aggregate lowering and raising.

Mining machine power devices are intended for traction and technological drives and for control system. Named device design and its operation conditions depend on the mining machine power supply type. Mathematical model of mining machine autonomous network was created and particular electric energy transmission versions were analyzed:

- single-phase transmission at 50 Hz
- single-phase transmission at the raised frequency, speculated 400 Hz
- three-phase transmission at 50 Hz
- three-phase transmission, item 400 Hz
- DC transmission.

The software applied for mathematical model solution enables the energy transmission simulation. Common mining machine power consumption 250 kW was chosen for mutual comparison of separate transmission variants. Supply source voltage was done 3000 V; used cable length is proposed 8000 m. Cable parameters were picked up from the manufacturer´s offer. The cable was divided to T-elements for the electric energy transmission modelling.

Simplicity is the main advantage of the single-phase AC transmission at the industrial frequency 50 Hz. Electric generator is situated on the floating level base. On the board of mining machine there is the transformer reducting the incoming voltage to the level applicable for used semiconductor frequency drive converters.

Transformer weight is lower for the single-phase energy transmission at the raised frequency than by the industrial one. This is particularly difficult by the machine operating on a mild seabed. Arrangement for transmission at the speculated frequency 400 Hz is similar like by the transmission at the frequency 50 Hz. However, cable inductance and capacitance can bring some troubles at the operation.

Higher frequency component about 8 kHz is added to the transformer current input. This component is caused by the action of quick rectifier openings and closings. Frequency of this component depends on the transformer inductance and cable capacitance.

Three-phase AC 50 Hz electric energy transmission offers itself like the most ordinary conception. The induction motor drive without frequency converter is usable; eventually the high-voltage induction motor without transformer can be used when necessary. Three-phase supply cable construction is more complicated in comparison with single-phase one, its price is higher and therefore this variant is more disadvantegous.

The energy transmission variant at 400 Hz allows the transformer weight reduction. Cable inductance and capacitance can make some troubles. Cable resistance may act as a critical parameter at the full load run.

DC transmission is the simplest variant from the very transmission viewpoint. Cable losses were calculated using factual cable parameters picked up from the catalogue for the calculation example. Cable losses by DC transmission were only approximately 40% of single-phase AC 50 Hz transmission losses by the same cable use. Switched converter control is pre-set for its output voltage 500 V. Some troubles can occure on the cable output when the voltage has to be decreased. The switched converter evokes them. However, converter switching can provoke current pulsation in all the cable. The DC transmission seems to be advanced from the efficiency view-point. DC transmission properties can be improved with the semi-conductor converter development.

Elaborated and drawn up mathematical model programs enable technical evaluation of autonomous network function by the choice of different motors for separate drives located on the collecting machine board. Applicable motor types for traction- and technological drives and optimal drives- and supply network combination can be chosen according to the supply network characteristics understanding. Except technical viewpoints, there is very important to respect the economical aspect, which comes out particularly in the needful cable price because it creates the indispensable price item whole of arrangement.

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# Renewable Energy Sources Support Policy in the Condition of Power Market Creation

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Currently, only approximately 1.5% of primary energy sources in the Czech Republic belong to the renewable sources group and only approximately 3.1 % of power (gross power production, 2000) is generated from renewable sources. In relation to DIRECTIVE 2001/77/EC, share of renewable power sources is expected to grow significantly. Mainly the biomass is considered a promising renewable energy source in a long run. However, power produced from renewable energy sources cannot compete directly with the "traditional" power sources in the Czech Republic and needs some kind of direct or indirect support (e.g. subsidy for investment cost, fossil fuel tax, or administratively set purchase price of the electricity produced from renewable power sources, etc.).

Gradual liberalization of the power market started in 2002 and this affects significantly purchase of power from renewable energy sources. Companies buying electricity from small (independent) producers (in the Czech Republic, it is mainly eight regional distribution companies) are willing to pay for the electricity only as much as what equivalent alternatives on the power market cost. This means that when purchasing power, specific technical parameters of the power supplier are also respected. Basic power parameters include mainly: voltage level, supply diagram shape, supply reliability, adjustability of output, ability to offer ancillary services, etc.

From the viewpoint of the producer and the buyer, so-called "trade interval" can be defined for the power price. The power producer needs to sell the power for at least a minimum price that will ensure required return on the capital invested. The maximum price the buyer will pay for the electricity, on the other hand, does not exceed the price of alternative offers of power on the market, taking into account location where it is delivered.

Appropriate estimation of energy potential in renewable energy sources needs relevant information about their cost (in relation to GJ or kWh produced). Plantation of fast growing trees are taken as one of the most promising alternative with other positive effects (energy sources diversification, increase of regional energy independence, new type of business for farmers, esp. in regions with not optimal conditions for intensive agriculture, etc.). The problem with cost calculation of biomass used as fuel in the Czech Republic is that large plantations of energy crops do not exist and therefore data are not available. The existing plantations are usually small, and various agricultural practices, harvesting methods, etc. are applied to them.

Research in the year 2003 was targeted, among others, to final data collection for economic model of fast growing trees plantation that was developed in co-operation with research institute VUKOZ Průhonice in year 2002. This model of 5-ha poplar and willow plantation includes all the relevant phases, activities, inputs and outputs for biomass production and can serve as information for decision making of potential investors either to biomass planting or biomass energy utilization and for setting up appropriate level of state support for biomass producers and biomass users. Model structure is based on real data from experimental plantations of poplar and willow.

Minimum price of biomass (price of heat in biomass) calculated with model is at the level of app. 160-170 Kč/GJ (in biomass wooden chips, supposing state subsidy 50 thousand Kč per

ha for plantation establishment) for real discount rate at 5%. Basically, this price is comparable with price of natural gas, but utilization of natural gas is more flexible and effective for the final users. But results of project indicate that biomass from fast growing trees plantations is one of the most promising renewable energy sources for ČR conditions.

In the Czech Republic, the administratively-set-purchase-price method was chosen as a support philosophy for power generation. This is to ensure that investors who invested in power stations using renewable energy sources can achieve adequate return on the capital invested. This support system was launched at the beginning of 2002. During the year 2002 purchase prices were validated, in case of planted biomass, results of research in 2001 and 2002 were used and should enable implementation of well-prepared projects in suitable locations.

Utilization of renewable energy sources for heat production and delivery has different condition in comparison with electricity generation. Basically, electricity is sold and purchased in gradually liberalized market and electricity production from different sources competes each other. Economic impact of power purchase from sources based on renewable energy sources utilization is relatively easy to calculate and different kind of (state) support can be introduced (e.g. investment or operation cost subsidy, administratively-set purchase price, etc.). On the other hand, central heating systems are only local or regional and conditions for heat generation differ significantly. Power purchase from cogeneration, either based on classical fuels or renewable energy sources, is being intensively discussed, esp. in relation to chosen principles of heat price regulation.

One of the most important problem is definition of the most effective system for renewable energy sources utilization (either for electricity or for heat production) that would reduce the necessary state agenda incl. state regulation of heat price. EU countries currently have no common policy in this field. EU Directive 2001/77/EC defines main aims at this field, the member states have obligation to define effective support policy for renewable energy sources so that they can do “their best” in contributing to EU targets to the year 2010 (12% share of renewable energy sources in primary energy sources and 22.1% in power generation structures).

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# Measurement of Space Characteristics of Illumination

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Space illumination best qualifies the scalar integral characteristics. Some of these are the average spherical illumination, the average cylinder illumination and so on. Each characteristic is an average value of planar illuminations of surface of an object (with zero dimensions) appropriates for name of each characteristic. It means, for example, the average spherical illumination is an average value of illuminations of the sphere, which has a zero dimensions. It is an average value from infinite values.

Measurement of these characteristics requires quite expensive equipment. For measurement of the average spherical illumination it is required a spherical receiver. It is a hollow sphere, which is made from the special material. This material (in ideal case) reflects all light in the direction from the middle to out and it passes all light in the opposite direction. The similar situation is with the others receivers (cylinder, semi-sphere and semi-cylinder). In the receiver is placed usual planar photocell with cosine adapter. In the ideal case, this photocell has zero dimensions. Or the receiver has to have quite big dimensions, because photocell needs to have inconsiderable dimensions.

There exist many different objects, witch can be used for qualifying space illumination and they have finite number of sides. The most similar object it names the average cubic illumination. It is an average value from of planar illuminations at each side of cube. This characteristic also very good qualifies space illumination. The average cubic illumination can be easy measured by single planar photocell, which is placed on the each side of the virtual cube. There are few possibilities how to measure this characteristic. The cheapest, but the most difficult and erroneous way of them is placing the planar photocell to right position by hand. But this way very waste the time and it is impossible to set the photocell into the right position exactly. This is the source of most errors of this type of measurement. Other way to measure of the average cubic illumination is using of six photocells, which each is placed in the one side of the cube. This type of measurement is exactly placing the photocells in the right position, but each photocell needs special correctable electronic circuit for data processing, because usual photocells is indispensably changing its properties during the time. The best way of measurement of average cubic illumination is using only one photocell and some special mechanical equipment, which can automatically set the photocell step by step to the six sides of the cube.

At the Department of Electroenergetics was this special equipment, but it had some problems. At first it stopped working, however the measurement at the bottom side of cube was hardly affected by mechanical devices and by tripod. New equipment doesn't have these faults. Main idea of suggestion was fixed photocell by mechanical shank, which contains the same angle with earth like diagonal of virtual cube. This shank is combined from two pipes. First of them (external) is rotated by bigger stepping motor and flexed. Angle between both parts of the external pipe is complement to right angle to the angle between earth and shank. Second (internal) pipe is independently rotated by smaller stepping motor. In the place, where external pipe is flexed, internal pipe verges to the hollow crank and rotates the photocell. Right control of the stepping motors it is possible to measure average cubic illumination.

Distance of photocell from the tripod is 60 cm. It means, that an error of measurement of the middle cubic illumination by influence of shadows from mechanical devices isn't higher then 1 %. Construction of this equipment can be used not only like a cubic receiver, but also like many other receivers. For example receiver, which is similar to cylinder. It names many-sided prism. It is an average value from the illuminations of the vertical planes.

In additional this equipment is also able to measure very important characteristic. It names light vector. This characteristic is very important to describing space characteristics of illumination.

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# Mathematic Description of Model of Light Reflection

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**Introduction**

In these notes we introduce a measurement of reflection characteristic of light, measurement of spectral reflection characteristic and simple model of light reflection. A light reflection is very important part for indoor illumination calculation and design of light sources or reflectors. Therefore we are measuring an indicatrix of light, which describes the interaction of light with a surface.

The most surface are not perfectly matte or glossy as the lighting theory describes. Specular reflected light can be seen for viewing directions close to the direction of the reflected beam and diffuse surface have some glossiness. This reflection is called mixed reflection. The mixed reflection can be modeled by considering ideal matt, ideal specular reflection and

**Luminance Indicatrix**

The measurement instrument was constructed for experimental exploration of various reflecting surfaces' characteristics. The luminance indicatrix is used for proper description of reflection characteristic. The luminance indicatrix is dependent upon three angles - viewing angle $\beta$, incident angle $\alpha$ and azimuthally angle $\gamma$.

It is possible to measure luminance factors of these surfaces in full range of angles. Measuring cell and evaluating part is based on Bruel & Kjaer luminance and contrast meter. Direction and values of angles is provided by PC and corresponding software. It is possible to find three angles for every value of luminance factor.

**Measurement of spectral reflection characteristic**

For exploration of wavelength of light reflected from a surface was constructed a simple measurement device. With this equipment is not possible measure in all three angles. We can provide a wavelength measurement at changeable viewing angle $\beta$ and incident angle $\alpha$. The azimuthally angle $\gamma$ is not possible to change in this instrument.

**Model of light reflection**

We measured the diffuse, spread and glossy surfaces. We have measured samples of walls, papers, tables and materials for light source and for these samples were created a model. The model of light reflection consists of three models reflection. The basic models are an ideal diffuse model, a model of specular reflection and spread model. The third model is supplemental. Model of light reflection for one azimuthally angle $\gamma$ is a combination of these three models.

There are several possibilities for description of light reflection models. The final solution of this question depends on a final way of illumination calculation. The description of indicatrix has to suit to the final way of calculation. It means that the data protocol has to be modified for

type of final calculation. On the way of data description depends speed of calculation. Due to this topic is important.

We are working on tree way of data description right now. The first one is the easiest way. We take the data of measurement reflection and make the table for every materiel, the incident angel and azimuthally angle. From this description is clear that this way is very easy but it also means big amount of folder and tables, which will be large for such amount of material.

The second way include some modification of measured dates. The model of light reflection could include three basics models that are an ideal diffuse model, an ideal seculars model and a model of spread reflection. From measured data we create a model of light reflection for one azimuthally angle $\gamma$ as a combination of these three ideal models. In this method we eliminate the data amount on table of function where for one incident angle and azimuthally angle will be only describing function and a table.

The third method includes the maximum elimination of data tables. In this method we are describing the indicatrix for one incident angel as one function. The output in this method is set of function for every incident angle. The elimination of data table amount is immense.

The final description samples will be use for advanced calculation of illuminative systems and for visualization programs.

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# Seasonal Storage of Solar Energy and its Long-Term Monitoring

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The exploitation of solar energy has almost equal conditions over the whole territory of the Czech Republic [area of 79 000 $km^2$]. The duration of direct sunshine is between 1600 to 2100 hours per year with yearly average irradiance of approximately 650 $W/m^2$. These values give average annual incident energy of 1200 kWh/a per square meter of horizontal surface. Considering our geographical location, 75 % of this energy comes in the period of April to October and only 25 % remains for the colder half of year from October to March. The solar energy comes to the Earth in the form of electromagnetic radiation of all wavelengths with dominant part (more than 60 %) in visible light spectrum (wavelengths from 390 to 790 nanometers). Solar radiation incident on dark body (absorber) is transformed heat with wavelengths increasing 800 nm. This so-called *photo-thermal conversion* of the solar radiation offers the simplest technique for the exploitation of solar energy,

Photo-thermal conversion can be used in two modes:
- passive; the conversion occurs directly in building constructions, or
- active; the conversion occurs on the absorbing surface of a solar collector, the heat is consequently transferred by a liquid or air and can be used for space heating or (more often) to warm up service water.

The main problem of solar heat use for space heating is its storage (*short time* – from daytime to night, *middle time* – from weak to weak or from month to month and *long time – seasonal* – from summer to winter). During the years 1994 – 1998 ten EU countries worked on common research and development program of seasonal heat storage. In this project every country built and tested another type of seasonal heat storage. The results were provided to all other participated countries.

Independently on this EU program the first Czech solar system with seasonal heat storage was built in small town of Slatinany. The equipment was put into operation at the end of summer 1995. The system consists of flat plate liquid solar collectors of total aperture 148,5 $m^2$, on-ground steel water tank of 1100 $m^3$ volume, heat pump with heat output of 37 kW, small operation storage 3 $m^3$ and reserve electric boiler of heat output also 37 kW. The equipment serves for space heating of house with nominal heat loss 50 kW.

The system is equipped by measuring and monitoring equipment taking off 53 temperatures, from them 27 values in the storage, 5 values in the ground in different depths and distances from the bottom of the storage and 20 temperatures at heat circuits near other main parts of the system. Also 5 values of flow rates in circuits, logical stages of 5 circulation pumps, electric boiler and heat pump are taking off.

*Values directly measured:*
- electricity consumption of heat pump and circulation pumps
- solar energy incident onto collectors

*Values which are evaluated:*
- heat volume delivered from collectors into storage
- heat volume consumed from the storage
- heat losses of the storage
- heat volume delivered into space heating
- total electricity consumption
- solar fraction of heat consumption
- whole-year efficiency of solar system

Monitoring equipment was put into operation in summer 1998. The results of the system monitoring published on the poster include years 1999, 2000 and 2001. In 1999 following results were reached:
- incident solar energy 166,46 MWh/a
- heat volume delivered into storage 95,863 MWh/a
- heat losses of the storage 9,995 MWh/a
- heat volume delivered into space heating 95,863 MWh/a
- total electricity consumption 12,298 MWh/a
- solar fraction of heat consumption 87,2 %
- whole-year efficiency of solar system 57,5 % (thanks to heat pump)
- specific energy gain of the collectors 646,5 kWh/$m^2$,a

These results could be evaluated as splendid under Czech climate conditions.

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# Automated Measuring System Search Examination Induction Motor Computer-aided PC

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Measuring system is found on apparatus system Tektronix series TM5000 controlled of GPIB-AT from National instrument from computer PC. Whole system is managed interactive program „Omega 2002", which be created on K314 by the help of environment „LabWindows CVI 6.0" in language „C++" . Simple interactive in a way program choke database service capacity funds metering machinery and amends is record single metering search examination induction motor according to CSN 35 0300.

Programs govern personal examination and pursue collection measured data, which subsequently evaluate to the requisite resulting tables, explicit funds and depict requisite graphic dependencies. Program output is entire search record induction motor and database resulting funds and characteristics recourse function detailing substitution diagram checking motor, applicable for resulting computerized simulation and setting movement control element v modern a.c . Drive. Program is calculated for metering of those examinations search record, that are fit for autoimmunization and supports computer. Among basic examination belong to according to CSN 35 0300 following measuring:

Measuring winding resistance behind cold state
Measuring current and losses in work no-load
Measuring current and losses in work for a short time
Measuring after-running characteristics machinery solo
Measuring operating characteristics check power factor and come into operation
Measuring static moment characteristics
Measuring starting-up machinery
Measuring heating machinery

Bases metering and resulting evaluation examinations is substitution diagram induction motor with keeper for a span. Application algorithm for power balance-sheet metering machinery are rated all requisite characteristics and characteristics. In singles characteristics substitution diagram are step by step plotting and described by the help of recourse mock-up in dependence on supply voltage U1, frequency f1 and temperature Th. Nonlinear description parameter we are able reach for enough largely specification whole machinery for determination quality indifferent way requisite operating mode. Bases gauging system are apparatus Tektronix series TM5000 in extensor programmable manageable by the help of bus GPIB.

Gauging system is creation:

millimeter DM5010, counter DC5009, 3 x DC sources P 501030V / 1.5A, accurate sources PS5004 0-20V, BNC scanner SI5010, scanner for metering 50M41, scanner for steerage 50M40, oscilloscope DSO 3014, driving computer PC with GPIB bus system adapt and actuating appliance and arrangement for attendance measuring.

Diagram gauging system is found on tenet operating of the chief clamper for steerage examinations driving cards with scanner unipolar sewer. Measuring articles quantity are connection by the help of the three-polar relays on millimeter , which pursue gradual restrained single requisite metering quantity by the help of fit inverter physical quantity (Uef, Ief, P, Ux, Un, M, n ...). Feature gauging system is program for steerage, metering and evaluation examinations specified search record. Program is created in world LabWindows CVI from National instrument. At the beginning examinations is necessity create new directory for measuring machine with data set containing scutelliform funds metering machinery and further information for creation entire search record. Interactive in way order requisite information to the preparing stationery see following picture.

Little-go, which pursue be always, metering resistance stator winding in cold state. For inquest resistance using indirectly Ohm method metering volt drop on known resistance Rn and unknown winding resistance machinery Rx. Measured funds re-count on temperature 20°C and phase and association funds.

After restrained resistance follow current measurement and losses in work no-load. According to CSN metering transaction from funds 110% to the 30% Un

In fine examinations is construction circle diagram. At calculation issue from solution to entire substitution diagram induction motor, where characteristics are described recourse mock-up. These mock-ups were defined by in previous basic examination search record. Input characteristics for calculation circle diagram are funds supply voltage U1 [V], supply frequency f1 [Hz] and temperature machinery Th [$^{o}$C]. Calculation circle diagram proceed step by step from idling cycle till after short run, when for rated slippage count in singles requisite characteristics and quantity.

Section 10

# NUCLEAR ENGINEERING

# Time Behaviour of Reactor with Liquid Fuel

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The concept of reactor with liquid fuel differs from currently operated light water reactors - LWR. Two biggest differences are that small part of delayed neutrons can be drifted out of the core and that the heat from fission is predominantly released directly to the liquid fuel. To study the time behaviour of this system space dynamics code is needed. From this reason the cooperation with Research Center Rossendorf – Germany was started. The space dynamics research of nuclear reactors has long tradition in FZR. During last two decades the three-dimensional code DYN3D [1] for calculation of steady states and transients in LWR was developed there. The neutron kinetics of DYN3D was connected with a two-phase thermo-hydraulic model and a fuel rod model.

**DYN3D-MSR**

MSR modification of DYN3D code should be designed to calculate steady states and transients in Molten Salt Reactors [3], where the molten salts mixture is a carrier of fuel. First step of development is a 1D version, which is based on a numerical method for hexagonal fuel element geometry from original code and includes new models with flowing fuel modification.

**Delayed neutrons model**

In MSR delayed neutrons precursors are drifted by the fuel [2]. From this reason is a small part of delayed neutrons released out of the core. The ratio of usefully released neutrons is a function of fuel velocity and of fuel salt fraction in core. New model of the precursors distribution was found supposing that whole primary circuit and core are divided into nodes and that the fuel velocity is constant within one node and during one time step. The second used condition was that the precursors source function $Q(z,t)$ has a polynomial character in space and exponential character in time. Then the nodal solution can be found analytically. The overall distribution is calculated by method of characteristic using these nodal solutions.

**Thermohydraulic model**

The choice of TH model is mostly determined by the fact that the energy from fission is predominantly released to the fuel salt and is directly drifted out of the core. However, there is a small fraction, which is released through the gamma radiation in surrounding graphite and another small part is released with delay through the decay heat. If there will be neither boiling nor solidification of fuel salt, one-phase TH model can be chosen. In the present model it is supposed that the pressure is constant and the fuel density is calculated from steady state equation. Knowing all energy sources within nodes, the temperature distribution can be found using method of characteristics from energy equation in form of an integral. First of these needed sources is the heat released from fission to fuel and it is supposed to be proportional to neutron flux, second source is the decay heat which is supposed to be constant during transient, and third is the heat outgoing or ingoing to graphite [4].

To evaluate the heat exchange between graphite block and salt method of effective coefficients is used. Each coefficient represents the heat exchange between relevant segments of graphite. These coefficients are calculated from analytical solution of steady state for given geometry and are supposed to be constant during transient. The distribution of temperature in graphite is found for each time step like a solution of linear equations set. The coefficients of this set are constant during one step, but may change in time.

**First transient calculation**

Fuel pump coast-down was chosen as the first transient to be calculated. During this type of transient power of reactor is the mostly influenced with two antagonistic effects. The fuel temperature is increasing and due to negative feedback coefficient inserting negative reactivity. However, in the same time the change of delayed neutron distribution introduces positive reactivity. In long-term view the third effect will appear due to the delayed increase of graphite temperature, which can introduce positive or negative reactivity. The graphite coefficient of thermal feedback is dependent on the core size and geometry.

**Summary**

DYN1D-MSR as the first step of 3D version development is already an effective tool for transient analysis of MSR. New delayed neutrons model together with TH model are integrated into original numerical methods of DYN3D. First calculation for fuel flow slowdown has shown the ability to provide space dynamics calculation.

The future development of DYN3D-MSR will consist from following steps: consideration of other transients, implementation of heat exchanger model, modelling of graphite – salt heat exchange coefficient, and extension to 3D version.

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# Influence of Selected Scavengers on Radiation Degradation of 1,2-Dichloroethane

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In recent years an increasing attention among environmental technologies especially waste-water and ground water purification is focused on processes involving formation of free radicals. These processes can enhance the efficiency of oxidation processes. Radiolytic degradation of targent toxic spicies is one of these processes [1]. During irradiation of water various free radicals (OH, H, $e_{solv}$) and molecular products ($H_2$, $H_2O_2$) are formed. These products may react with mostly of organic components occuring in water systems. Efficiency of this technology depends not only on the amount of these radicals (applied dose), but also on their consumption in parralel reactions, caused by the presence of some other components in irradiation systems, named scavengers [2]. Interaction of these species with existing components may also iniciate processes leading to formation of more toxic undesirable products. Presence and quantity of these components by this way significantly influence economy of waste and ground water purification processes. Great attention is also expended to remove the various chlorinated organic compounds from ground and waste-waters.

The aim of this study was to investigate effect of some scavengers (bicarbonates, nitrates, sulfates and $Fe^{2+}$- and $Fe^{3+}$- ions) on the efficiency of radiation degradation of 1,2 dichloroethane (DCE) - water system. Decomposition of DCE by electron irradiation has been studied in laboratory-scale experiments, in synthetic aqueous samples.

The irradiated samples were prepared by dilution of saturated DCE water solution by distillated water. The study was performed in the presence of oxygen in irradiated systems owing to the practical use. The experiments were performed in the concentration range $10^{-4}$ – $10^{-3}$ mol x $l^{-1}$ of targent compound and $10^{-4}$ – $10^{-3}$ mol x $l^{-1}$ of scavengers. Irradiation by electrons (4.5 MeV) was performed by linear pulse accelerator LINAC - 1200. Applied doses were 0-32 kGy. The chemicals were analytical grade purity.

Course of DCE radiation degradation (dose dependence) in distilated water and in the scavengers containing DCE solutions was controlled by a gas chromatography (GC) measurements (CHROMPACK model CP9002, ECD, DATA-APEX integrator). Amount of inorganic forms of chlorine was measured electrochemically by selective chloride electrode.

GC measurements showed that, DCE was decomposed completly at the doses 2-4 kGy. Very sensitive detection (ECD) showed a large range of degradation products, especially dimers containing different number of organic bounded chlorine. Radiation degradation of these products was performed at the doses from 16 to 32 kGy (depending on the DCE concentration). Inhibition effect of scavengers increases in the following sequence: nitrates,

bicarbonates, sulfates. The inhibition effect of $Fe^{2+}$ ions was found to be about of 3x larger then of the $Fe^{3+}$ ions.

These results indicate that the presence of scavengers under study influences significantly the efficiency of radiolytic degradation of 1,2 dichloroethane in water. These results will serve for study of radiation purification of real waste-water in a large volume pilote plane [3], [4].

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# Biomonitoring in the Neighbourhood of NPP Temelin in the Years 2000-2002

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Biomonitoring is conducted by employees of Czech Technical University (CVUT) in Prague based on requirements of Nuclear Power Plant Temelin. The year 2000 was designated as reference year before the start of the NPP operation and 2001 was the year of the initial operation. Research will continue in the following years.

Atmospheric radionuclide deposits monitoring in the environment is often conducted using bioindicators. Using ecological principes, the changes in environment quality are indicated by biological indicator changes. This could be entire living organism, its parts, its non living parts (tree bark, fallen leaves...) or decomposed organics matter. In our case were choosen forest humus, surface of pine bark, Shreber moss, edible mushrooms and forest berries.

Monitored area contained 29 sampled locations along eight radial profiles intersecting the area of interest up to distance of 20 km from NPP Temelin (the measuring points are located 2-5-10-20 km from NPP, distance of 20 km is a comparison area, where no real radioactive air pollution should occur). The pine bark and moss were sampled at the selected sites twice yearly, at spring and fall, forest humus once in spring months, mushrooms and berries once in a growing season. In total 203 samples in 2000, 222 samples in 2001 and 223 samples in 2002 were collected. Top 3 mm of tree bark were taken in reference height of 1m above ground along the circumference of the trunk from 8-10 trees in a given point. To prevent contamination by soil scossors were used to cut moss samples. Forest humus was sampled by a small shovel with respect to resolution of surface layers, according to the degree of humification.

For the determination of radionuclide presence and their activity in samples was selected a method using laboratory gamma spectroscopy. The gamma spectrometric method enables to determine presence of many natural and manmade radionuclides, emitted gamma rays, with very good limits of detection. It is non-destructive method requiring relatively simple samples preparation and is based on the proportion between designated radionuclide peak area in the measured spectrum and its gamma activity. The measuring equipment consists of HPGe detector with built-in preamplifier (mfg. by EG&G Ortec), amplifiers 2022 Canberra, Source VN31060 Canberra, ADC built-in analyser, analyser model 4202 Canberra and a PC. After drying (for example on case of mushrooms the weight loss was 90%), samples were enclosed in Marinelli containers with a volume of 0.5 l, surrounding during the measurements coaxial HPG detector. Processing of measured spectra in the range up to 3 MeV provided mass related activity of naturally radioactive elements ($^{40}$K, $^{226}$Ra, and $^{232}$Th) and contaminant $^{137}$Cs (resulting from nuclear weapon tests in the fifties of last century and from Cernobyl accident fallout).

The results were statistically processed. The measurement results confirm that in monitoring of biological plant samples a larger spread of measurement values is normal. The trend analysis will be performed at the end of the year 2002, when there will be a sufficient amount of data available (six point per all type of samples).

The main task of this project is to describe the influence of NPP Temelin on radiation increase in its neighbourhood. Two model situations have to be studied. Firstly, one accident

or several ones occurring in short term, lead to relative extensive radionuclide escape. Secondly, small amount of radionuclides is continuously escaping and depositing during the common operation. In the case of the accident with extensive radinuclide escape, the radiunuclides with short half-life appear in the samples collected after the accident. Our measurements carried out before fuel activation in the first block of the NPP Temelin detected the presence of $^{137}$Cs and uranium and thorium decay products. No short-lived radionuclides were identified. Similar results have been obtained during three-year monitoring till now. This shows that no accidents with enormous radiation escape happened during the time, the NPP Temelin has been operating. Secondly, the long-term continuously escape can be observed according to $^{137}$Cs activity increase in the samples that are regularly collected for long time. Three or six measurements were carried out for all sorts of samples and all areas in the last three years. Since the steady escape is presumed, the $^{137}$Cs activities are fitted to a reference line. Eventual activity increase is comparing with calculated uncertainty. The ratio of the activity increase per year and its uncertainty is related to Student t-distribution. If this ratio exceeds certain value, the activity grow is confirmed with the probability corresponding to given confident interval of t-distribution. All areas must be studied independently due to different $^{137}$Cs background caused by contamination after tests of nuclear weapons and the Cernobyl nuclear accident. Different sorts of samples must be studied also independently because of differences in radionuclide income. Although the assessment of the radiation increase is complicated due the fluctuations that are typical for most environmental measurements, this method seems to be appropriate for such investigation.

The biomonitoring for year 2000 and 2002 included assessment dosimetry and spectrometry characteristic of photon-fields (that is determination of reference background) at 15 selected points. Two methods were selected with corresponding types of measurements:
1/ determination of air kerma rate (by direct measurement with device TESLA NB 3201 and by calculation based on spectrometry data)
2/ measurement of photon-spectra by use of scintillation spectrometer MCA μ NOMAD EG &G Ortec with scintillation detector NaI(Tl) diameter 3" by 3" in the energy range up to 3 MeV.

All measurements were conducted in reference altitude 1 meter above surface. Total of 99 (2000) and 134 (2002) measurements were conducted using device NB 3201 with integration interval of 100 seconds. The spectra during spectrometry measurements were collected for 2700 seconds. The measured values corresponded to nominal values on natural background, depending mainly of geological substrata (soil contents), concentration of radon in soil or air etc. The methodology selected enables identification of individual contaminants and their contribution or occurrence. With the exception of the identified $^{137}$Cs (resulting from nuclear weapon tests in the fifties of last century and from Cernobyl accident fallout) it is not possible to identify among the measured spectra any significant contribution of any other manmade radionuclides.

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# Methodology Preparation of Radon in Caves Continuous Monitoring

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There are many caves located in the limestone deposits in the Czech Republic, but only twelve caves are open to the public (two caves are used for speleotherapy). A serious problem in those locations is a high airborne radon content. All such caves are under the supervision of National Nuclear Safety Office and the potential health damage for permanent workers is established by National Radiation Protection Authority using routine alpha-track detectors monitoring. Those data are converted into annual effective doses in agreement with the ICRP recommendations. The calculations show that six of the twelve caves reach the upper dose limit allowed. The Bozkov cave extends the highest annual effective dose about 4-6 mSv that should imply some restrictions for time spent in the underground. But there are three main problems in dose calculation that could not be resolved by track detectors:

- in the radon concentration monitoring (not only in caves) strong temporal variations were observed (dependent on time of year, day or part of the day – i.e. external temperature, pressure, horizontal/vertical cave layout, etc.); the dependence on changes in the aerosols composition by the visitors presence is expected
- conversion factors recommended by IRCP/65 were used in the dose calculation – however, it is necessary to consider specific conditions in the cave microclimate, regarding unattached fraction, that are due to very low concentration of aerosol particles in the cave atmosphere (unattached fraction is almost 10 times higher in comparison to deep mines); it is necessary to introduce and use the correct conversion factor based on exact long-term measurements
- influence of the high humidity (99%) on the measurement data must be considered
- accidental flings up in the curve of radon concentration in order of tens thousands Bq $m^{-3}$ are occurring

Based on those problems it is necessary to evaluate short-term radon concentration changes using a continuously monitoring equipment.

Many test-measurements were carried out in the faculty basement, in the cooperative NRPI workplace in Prague and in Koněprusy caves. The Koněprusy cave (radon concentration found in the past was about 2 kBq $m^{-3}$) is one part of the Czech karst region. Koněprusy cave is open for public from April till October. This cave is closest to Prague, so the initial and test-measurements, which require regular frequent checks of equipments, were carried out there.

After those test-measurements a new target location for routine monitoring was choosen – Bozkov cave. Bozkov dolomite cave is located at the eastern part of the Železný Brod upland. It consists of two caves (original and newly discovered) connected by an artificial tunnel. High radon concentrations (~10 kBq $m^{-3}$) were found here by the track detectors in the past, esp. during summer. This cave is open for public the whole year. That fact should limit the time spent in underground by some guides. The continual monitoring has been started here three years ago by one RADIM2 monitor owned by the cave management. In the spring of 2002 we have started the set of regularly recurring measurements, one per month, using the following measuring devices:

*As the fundamental equipment for continual radon measurement the RADIM3 has been chosen. We have carried out a comparative measurement of all of our four RADIM monitors (against Genitron's AlphaGuard) under the laboratory conditions (the dry radon source; radon concentration in the test room had varied from 400 up to 13000 Bq $m^{-3}$) with the suitable results. For the "cave" measurement RADIM3 was placed into an untight (the air should flow through a leak between upper and lower parts) plastic toolbox (dimensions about 20×20×45 cm) together with a small amount of desiccant ($CaCl_2$) which was chosen because it has no radon absorption. This desiccant effectively suppresses relative air humidity from practically 100% down to 30-50% and keeps this value for one up to two months. This layout has been tested under the laboratory conditions and in Koněprusy cave.

*The ionisation-chamber-based continual radon monitor (RADONIC) with the active volume amount of ~8 l and with the forced airflow – this monitor is still under development (has no official calibration), the electronical part is water-resistant.

*The set for radon daughter products measurement (air pump+2×PSDA reader) – this set gives a possibility to estimate equilibrium radon concentration or equilibrium factor with relative high accuracy by one-shot sampling methodology.

*The gamma dose rate monitors TEMA (RM 552 GS) and Eberline (FH 40F2).

*The radon-in-soil test set (incl. reader ERM 2) – the ionisation chambers from this set were used for one-shot sampling on the underground places that were not measured by continual monitors. For the radon estimation in soils the standard procedure was used.

*The TESTA apparatus for airflow measurements.

*The laboratory HPGe-gamma spectrometry apparatus for sediments analyses (the water-samples analyses were done by the National Radiation Protection Institute laboratory in Hradec Králové).

*TSI instruments for particle size distribution measurement – at the end of August we carried out 5 days aerosol particles measurement in cooperation with FNS Charles University, NRPI and ICPF AS. The results will be processed together with the FMP CU in Bratislava.

The annual measurement series will be concluded in March 2003. All data obtained will be used for the calculation of a more exact effective dose. This was the first year of our programme that is expected to continue for several years, to resolve measurement issues in the extremely demanding cave environment.

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# Complex Preparation of Specialisation Extension from Nuclear Reactor Theory and Engineering into Nuclear Installations Theory and Engineering on FNSPE

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The following results were obtained during the project focused on the complex preparation of specialization extension from Nuclear Reactor Theory and Engineering (NRTE) into Nuclear Installations Theory and Engineering (NITE) on FNSPE (Faculty of Nuclear Sciences and Physical Engineering) CTU.

The present syllabus for the courses nuclear engineering programme NRTE specialisation has been complemented by new topics. They were concerned in installation for radioactive materials treatment, especially with spent nuclear fuel materials from nuclear power plants (containers for spent fuel assembly, transmutation of radioactive waste and so on).

Obtained results are as follows:

1. The complement and extension of current courses of the specialisation NRTE which enriches and deepes knowledges of students in the field concerning in spent nuclear fuel treatment. Detailed syllabus for nine courses, covering the main treatment with radioactive materials areas, has been elaborated. The name of these courses are as follows:

   - Reactor Physics,
   - Experimental Reactor Physics,
   - Experimental Neutron Physics,
   - Machines and Equipment of Nuclear Power Plants,
   - Nuclear Safety (including actual legislative),
   - Radioactive Waste Management,
   - Liquid Nuclear Fuels and Separation of Radionuclides,
   - Another Energetic Sources,
   - Dosimetry.

2. Accurate preparation and choosing of individual student works topics (subjects).

3. Assembling of computational codes and teaching aids (models, codes) focused on observed area.

Courses according to the new complemented and expanded syllabi of NITE specialisation will be opening in the winter-semester 2003/2004. Procceding about official change of specialisation designation will be initiated after.

Syllabus design for complement and extension of current courses of the specialisation NRTE are prepared in co-operation with external specialists from Nuclear Research Institute in Řež.

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# Microtron Beam Position Control in the Electron Transmission System

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The relatively complicated electron beam transmission system in the Prague MT-25 microtron installation needs very accurate alignment of the beam with all deflecting and focusing magnetic optical elements. To facilitate the alignment, it is advantageous to dispose of information about the beam position in crucial places of the transport system. Such information should be obtained without disturbing the electron beam. There exist several types of non-disturbing beam position detection systems described e.g. in [1]. We decided to modify the system of wire detectors already used at the output of our microtron for automatic stabilization of the beam position on the target [2]. Several questions had to be answered experimentally before the final decision on the system design could be taken. Contrary to the wire detectors used for stabilization of the output beam position and working on free air, the detectors for control of the position of the beam in the transmission line should work in vacuum and, in addition, also in the magnetic field inside the acceleration chamber.

The system is based on detection of the secondary electron emission from the impact of accelerated electrons on a thin metallic wire. The amount of energy dissipated in wire is negligible and therefore no supplementary cooling of the wire, which otherwise would complicate the installation, is necessary. Although the wire is traversed only by a small portion of the beam, nevertheless the scattering of the electrons has to be taken into account. The degradation of the beam quality by scattering on a wire becomes even more significant, if several wire electrodes are situated along the beam path at critical points of the transmission system. Therefore the wires can be used only in the period of alignment of the beam and must be removed after the alignment has been achieved.

Preliminary experiments were carried out with the aim to verify the applicability of this system for position control of the iron channel, through which the electrons are extracted. The axis of the channel must be directed tangentially to the electron orbit and the center of the input orifice of the channel must coincide exactly with the point of contact. The electron energy during these experiments was fixed to 22 MeV. To find correct position of the channel, an isolated stainless steel wire $\Phi$ *0,3 mm* was situated perpendicularly to the acceleration plane in the axis of the channel in a distance of 20 mm before its input orifice and secondary electron current was measured as function of the channel position relative to the electron orbit.

The experiment furnished two important information's. Firstly, it was confirmed, that vacuum and magnetic field of the order of 0,2 T, parallel to the wire electrode, existing in the acceleration space, do not prevent its functioning, which was not evident in advance. Secondly, a strong parasitic effect, leading to the inversion of electron current direction from the wire, was found. The current inversion has its origin in the secondary electrons emitted from the construction and support material of the channel hit by the beam, which are collected by the wire. This effect was especially strong when the channel was out of the aligned position. By putting the wire electrode on a negative potential of about -27 V against the channel, the

collection of secondary electrons from its construction and support material was suppressed to great extent and the maximum of the current peak became clearly identifiable.

The experiments gave also the order of magnitude of the secondary emission current. At 1 μA of the accelerated electron current at the end of the electron transmission line, the maximum of the secondary electron current was of the order of 20 nA from a $\phi$ *0,3 mm* wire electrode situated in front of the orifice of the iron channel, where the width of the beam is about *6 mm* Because of the unknown distribution of the current density in the beam and unknown current losses in the transmission line, the coefficient of electron secondary emission could not be calculated and compared with experimental results. A low noise low shift analog amplifier, placed close to the microtron, has been built working in current loop with the measuring instrument on the panel in the distant control room. In this way the influence of strong electromagnetic noise in the microtron room on measurement of the small direct currents was effectively suppressed.

The possibility of using the system for changing the channel position from one to another electron orbit has been also verified experimentally. In course of the travel of the channel to a next position, the effect of secondary emission from construction and support material of the channel was very strong and it could not be fully suppressed even if the bremmspotential has been used. For the same reason, the determination of the position of the channel relative to the orbit by differential wire detectors, which has been tested too, gave not a satisfactory result. Nevertheless, the correct channel position on individual orbits was identified unambiguously.

The supposed perturbation of the beam by the presence of the wire was also confirmed by the above experiments. Therefore a system has been designed which will be used in the electron transmission line, with a wire electrode, which can be removed from the beam after the alignment procedure has been accomplished. It is supposed to place the wire electrodes at the inputs of the magnetic quadrupole lenses and deflection dipoles, both to align the horizontal and vertical positions of the beam. Only the wire electrodes, crossing the transmission line axis and perpendicular to it, for setting the central position of the beam, will be made removable. Additional differential wire electrodes system will be placed at the periphery of the beam, serving for determination of the sign of deviation of the beam from the axis. Being situated at the periphery of the beam, the wires will not perturb significantly the beam and can be installed permanently in the transmission line.

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# New Trends in Nuclear Reactors Development

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The Department of Nuclear Reactors FNSPE observes a new trends in the energetics area.

The construction of new energy sources is an important aspect of the energy politics in the advanced countries. The aspect components are as follows: qualified estimation of the situation development (in the international context), orientation in engineering and research trends and several types of devices.

The analysis of situations in the EU countries gives this data:

The fossil-fuel power plants comprise the main proportion in electricity production in EU, it is over 50%. The nuclear power plants are the second important, with a rate of about 35%. The last 13% cover especially the hydro-electric power plants and wind power plants. The fossil sources rate (about ½) is thus 30% lower then the rate in the case of total energy consumption. In this case the fossil sources would take about 80%.

It is possible that some new nuclear reactors will be economically favourable in the near future (years 2003-2010), especially in the years 2020-2050. This nuclear reactors of the new generation are designed with a high inherent and passive safety in order to satisfy safety standards. Therefore the influence of the nuclear power plants on natural environment is negligible and it is possible to say that they belong among the cleanest electricity source.

Nuclear power engineering has some negative aspects too. The main problem is the nuclear spent fuel. Some new technologies are investigate, which transmute nuclear spent fuel, with long half –time life isotopes ($10^5$-$10^7$ years), to the matter with short–time life isotopes ($10^2$ years). They are called ADS (Accelerator driven systems).

The main types of advanced nuclear rectors are following:

- EPR – pressure water reactor (developed in France, Germany)
- VVER-640 - pressure water reactor (Russian type)
- AP-600 - advanced pressure water reactor (Westinghouse) ,
- SWR - boiling water reactor (Germany),
- GT-MHR – high temperature gas cooled reactor (more types)
- ADS – Accelerator driven system.

Actual experience in using of nuclear energy and new knowledge in science and engineering are projected in design of the new reactors. Component units with inherent and passive safety have all along greater area in design. All these reactors will be able to satisfy requirements “European Union Requirement for LWR Nuclear Power Plants”. Some exceptions exist at Russian advanced reactor VVER-640, which will have hexagonal fuel assemblies, although requirements EUR prefer fuel assemblies square section.

The main characteristics of advanced nuclear rectors:

| Identifier | EPR | VVER-640 | AP-600 | SWR | GT-MHR |
|---|---|---|---|---|---|
| **Reactor type** | PWR | PWR | PWR | BWR | HTGR |
| **Power density [MW/m$^3$]** | 94,1 | 64,5 | 78,69 | 47 | 6,5 |
| **Nuclear fuel [t]** | | 68,64 | 66,8 | 121 | |
| **Coolant type** | $H_20$ | $H_20$ | $H_20$ | $H_20$ | He |
| **Lattice type** | Square | Triangular | Square | Square | Micro-particle |
| **Reactivity controls** | Rod absorber, Boron acid | Rod absorber, Boron acid | Rod absorber, Boron acid | Rod absorber, Boron acid | Rod absorber |
| **Boron controls** | yes | yes | yes | yes | no |
| **Burn-up absorbers** | yes | yes | yes | yes | no |
| **Temperature reactivity coefficient** | negative | negative | negative | negative | negative |
| **Cycle length [month]** | 18 | 18 | 18 | 24 | continual |

It is highly difficult to select an order of applicability of new perspective reactors and the choice will be consist of more additional aspects.

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# MCNP Calculation of Segmented Gamma-scanner Calibration Factors

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Calibration and data analysis techniques for radionuclides concentrations and volume or superficial activities measurement are often based (namely for complex arrangements and conditions) on models using radiation transport simulation. This approach was used for simulation of segmented gamma-scanner (SGS) response for different radioactive wastes compositions/arrangements in ISO 200 liter drums used for the wastes storing (storing in bitumen or concrete was taken into account). On the other hand the experimental response of gamma-scanner for special concrete calibration pads was used for comparison of calculated and experimental data to verify applied model (described for MCNP code) and simulation technique. Aim of this work was to improve methods of gamma-scanner experimental data processing and interpretation.

Segmented gamma-scanner consists of turntable divided into 12 segments with 24 adjustable angular positions (including half segment rotation) and detector support with 12 selectable vertical positions (segments). Detection system integrate HPGe detector (with 7 l Dewar vessel) and 50 mm lead collimator with front aperture 70x45 mm and collimation angles 15x30 deg. Positioning of measured object (typically ISO 200 l drum) and detection system is electrically driven and controlled by computer and control software. Data from detector are processed by gamma spectroscopy system.

Three concrete pads with diameter 550 mm (inner diameter of ISO 200 l drum), thickness 67 mm (total thickness of three pads 201 mm) and 31 holes for positioning of calibration source (holes are symmetrically located in 12 segments and 6 different distances from pad center) were prepared for SGS calibration. Multispectral $^{152+154}$Eu source is usually used as calibration standard, but more complex activity distributions can be simulated using more types/positions of different sources.

SGS experimental arrangement model – calibration pad(s) and source, HPGe detector and collimator – was described by means of MCNP transport code. Some simplifications and/or approximations of the detector description were necessary because real detector exact internal structure design was not available. Photon scattering in more distant parts of the detection system (Dewar vessel, detection system support) were neglected. Detection system pulse height spectra for different arrangements of calibration source versus detector were simulated as calculations result. Photon flux energy-angular distributions on the front of collimator aperture were also calculated with aim to study influence of collimator presence/size/shape on spatial resolution of the activity distribution. There are 14 detection system positions described in the model (considering the arrangement symmetry). Detection system positions are divided into two sets taking into account overlapping of the adjacent positions. Prepared model enables to execute calculations for the whole detector set in one run to reduce the necessary computational time.

Calculations were done for calibration source 152+154Eu in position 1 (central hole), 4 (hole closest to the pad's circumference) and 6 (second closest to circumference) and for all 24 angular positions (detector positions are numbered from up, clockwise by even numbers 80-92 for 1st set of detectors and by odd numbers 81-93 for 2nd set of detectors). Peaks of all used calibration source significant energy lines in the calculated spectra were integrated for direct comparison with experimental data.

Experimental measurements for three pads together (one over the other) were done. Calibration source was positioned in middle pad in center of holes 1, 4 and 6. The photon spectra for all source positions and radial/axial segment positions were measured, radial and axial profiles of activity relative distribution were done from experimental data.
The peak areas of more intensive energy lines of calibration source for central vertical position (see pos. V2) and all angular positions were determined from experimental and calculated data. Comparison of results for source positions 1 and 4 is shown in Fig. 7.

Good agreement (in frame of statistic errors) for the symmetrical central source position (hole 1) was achieved. Acceptable agreement was achieved also for source positions 4, 6 in detector positions close to source. For reverse detector positions (positions about 86 and above) increase source shielding by concrete layer and corresponding statistical error of measured results as well as stochastic calculations. Source of difference (systematically higher experimental values) can be also peak area calculation method, 152Eu and 154Eu ratio (not known precisely), detector model description (exact internal structure design), etc.

Next comparison was done for MCNP calibration experiment model and Gamma-scanner calibration software ISOCS. Absolute detection efficiency of detection system for calibration pads, calibration source in position (hole) 4 and detector position 80 (source closest to detector) was calculated by MCNP model and ISOCS. Two ultimate approximations of real calibration experiment geometry had to bee used for ISOCS (taking into account limited ability of ISOCS to handle with more complex objects). Result of comparison for energy interval up to 1400 keV show relatively good agreement (max. deviation 26%) if we consider necessary approximations of real arrangement in ISOCS. Uncertainties in MCNP model description (see above) can also affect observed differences.

We can conclude that Monte Carlo radiation transport codes represent effective tool for simulation of measurements and/or scanning radioactive objects (including complex objects, activity distributions and experimental arrangements). This codes and corresponding models can be used for optimization of the experimental arrangement and developing/improvement of the experimental data processing and interpretation methods. Presented comparisons of experimental and calculated data show, that model and its parameters, and all results must be verified very carefully to get proper results. Improvements of model (including arrangement with real ISO 200 l drum) and some new measurements are prepared to reach better agreement and point next work to practical application.

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# Nuclear Data for Target and Blanket Neutronic Calculation of Accelerator Driven Transmutation Technology Systems

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Future of nuclear engineering, end of reactor fuel cycle, advanced reactor concepts problems, thorium fuel cycles etc., should be solved by various ways with different points of view on spent fuel problem. Systems based on accelerator are one of the most hopeful solutions.

New generation accelerator driven transmutation systems or energy amplifiers consist basically of two main parts – the target and the blanket. Target bombarded by high-energy protons (from 0.5 to 10 GeV) is used as a neutron source for blanket which should be classical reactor core similar or based on liquid fuel. Research of these complicated systems is joined with many significant problems also in nuclear data, computer codes, physical simulations, and theoretical physical models area. Nuclear data fussiness is in wide energy region, in high-energy region for protons, high-energy, intermediate energy region, and also reactor neutron spectra region like in reactor of nowadays for neutrons. Due to this two systems coupling many various cross-section and computer code problems have to be solved. Nuclear data needs can be divided into two parts too – blanket low energy part (below 20MeV) and target high-energy part (above 20MeV); very important is data for interim region (20 – 150MeV).

In the target, spallation and electro-nuclear cascade processes cause of reactions of high-energy protons with target heavy metal nuclei (Pb, Pb-Bi eutectic, U, Hg, W, Tl etc.) with considerable other partition influence (mesons) is intensely in the motion. These processes are accompanied by massive neutron production with difficult energy spectra (with high-energy neutrons production). Protons and neutrons cross-sections in this energy region (20MeV-2GeV) are not available with every material and there are only small amounts of energy points. Theoretical nuclear reaction models have also significant deficiency. Computer simulation are performed by e.g. LAHET-LCS, HETC-CALOR, GEANT, FLUKA, CEM codes. Target-blanket coupling simulation can be done by MCNPX code.

Number of libraries contaning high-energy data has risen last year. There are special purpose HE files in ENDF/B-6.8 library (produced in APT research program), JEFF-3.0 and JENDL-3.3. They contain data for some isotopes (mostly heavy metals) in energy region 20-150MeV (200MeV respectively). New KAERI evaluations exist up to 400MeV. We have also at disposal special small libraries WIND (Waste Incineration Nuclear Data Library) and TENDL (Transmutation Evaluated Nuclear Data Library). Some data for energy region above ~200MeV are contained BNL high-energy library and JAERI HE library.

These libraries have to be processed from general format ENDF-6 to special formats before use. It has been done by new version 99 of NJOY code. Other processing codes PREPRO and CALENDF are tested. For visualizasion of cross-section there are used codes JANIS, NDX or improved moduls of NJOY and PREPRO.

Main part of research work which has been studied is based on blanket cross-section problematic. In relevant energy region (0-20MeV) relativelly big amount of data exists. General purpose and neutron induced reaction libraries which are using in DNR are ENDF/B-

6.8 (american), JEFF-3.0 (european), JENDL-3.3 (japan), BROND-2 (russian), CENDL-3 (chinese) are the world used ones, there are also other libraries e.g. from IAEA – FENDL, FOND, IEAF, ENDSF and many other special purpose libraries. There are problems with data for minor actinides, some data is completely missing, mostly are missing only data for some resonance or high (1-20MeV) energy regions, but there are big differences between libraries (in most cases in higher energies). These libraries are mostly used for convectional reactor computation so there is large amount of computer codes to use: MCNP, WIMS, ANISN etc. Processing codes (NJOY, PREPRO, CALENDF, TRANSX) are also used for the codes cross-section data production. Processing, using and comparing computation with various libraries, validating them by different reactor concepts, and finding possibly problems, and the best data for future use is very important work.

Future research in nuclear data area in DNR FNSPE is to provide even more comparison and benchmark computation with data which has been produced yet. To intensify target calculation and produce coupling simulation of the whole target-blanket system will be very usefull. Author is also participated in measurements of natural uranium cross-section with 660MeV protons (and also $^{239}$Pu, $^{237}$Np and $^{129}$I with spallation neutrons) which have been realized in partnership with JINR Laboratory of Nuclear Problems and he will countinue in this cooperation.

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# Experimental Study of Subcritical Blanket Blažka with External Neutron Source NG2 at Nuclear Physics Institute in Řež

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Faculty of Nuclear Science and Physical Engineering, Department of Nuclear Reactors (FNSPE DNR), solves problems associated with a dynamics behaviour of subcritical reactor with external neutron source and provides wide information for study of transmutation technology. FNSPE DNR closely co-operates with Nuclear Physics Institute (NPI), Academy of Sciences of the Czech Republic in study of this issue. In a close collaboration of the NPI Řež and at the FSNPE DNR , the high-power external neutron source at the NPI Fast Neutron Facility (FNF) and the module of the fluoride-salt subcritical blanket Blažka at the FSNPE DNR were developed. Both, the basic characteristics of these facilities and the forthcoming research program are outlined. Experimental research program concerns the neutronics of AD (Accelerator Driven) system which employs a subcritical blanket Blažka and an external fast-neutron source.

*General Description of NPI Fast Neutron Facility*

The NPI Fast Neutron Facility (FNF) employs the variable energy cyclotron U-120M, operating in two modes. In the positive-mode, protons, deuterons and $^{3,4}He^{++}$-ions of energy up to 22, 18 and 50 MeV, respectively are at disposal for the NG1 target station. Higher-power beam (current up to 20 μA) of protons and deuterons (energy of 35 and 18 MeV, respectively) could be delivered on the NG2 target station in the negative-ion extraction mode. Fast neutron sources based on protons and deuterons from low energy cyclotrons provide intensities that cannot be generated by other methods. The present FNF activities are based on results of the experimental investigation of light-nuclei break-up reaction at medium incident energies, performed at the NPI. In a series of experiments the deuteron break-up process in light nuclei reaction has been proven as the most powerful neutron source with respect to accelerated particles and beam energies available for the NPI cyclotron. Results have allowed to formulate various benchmarking experiments of the fast neutron production, neutron transport and neutron activation calculations, being formulated at NPI under auspices of the EFDA (European Fusion Development Agreement) and in the collaboration with FZK Karlsruhe and ENEA Frascati. The source strength of developed NG2 neutron source seems to be suitable for the target/blanket neutronics benchmarking as well.

During the last three years an upgrade of optical system hardware of the NG1 beam-guide was performed to improve options for neutron spectrometric experiments presumed by the benchmark tests of the neutron production and the neutron transport calculations. A triplet of quadrupole magnets and beam diagnostics were located on beam-guide to reach a loss-free

transport of accelerated beam to the target. New installation of NG1 target station permits to enlarge a neutron flightpath to perform data acquisition at acceptable count-rate with correctly handled dead-time effect (pile-up consideration). Large database, concerning the energy and angular distribution of neutron spectral yields from proton, deuteron and helium-3 induced reactions on various thick targets (D, He, $D_2O$, Li, Be, Al and Ta) is collected employing the NG1 target station.

Design and manufacture of NG2 target station which includes the high-power heavy water target and a beam line from the negative-ion extractor have been completed. Here, the location of nowadays, parameters (i.e. a beam emmittance, a beam spot) and trajectories (i.e. a point of beam line entrance, an output angle) of extracted beam are extensively studied and optimized. Variably designed targets of NG2 neutron source correspond to user requests. The outer dimensions of heavy-water target tube ending (500 mm long, 70 mm of outer diameter) correspond to the inner hole (the inlet for the external neutron source) of the blanket Blažka.

*General Description of the Subcritical Blanket Blažka*

Department of Nuclear Reactors prepared design and fabrication of subcritical blanket Blažka. Blanket consists of graphite, NaF, and fuel element EK-10 (core of fuel element is constructed by mixture of $UO_2$ and Mg , $^{235}U$ enrichment is 10%, $\rho$ = 5.87 g.cm$^{-3}$, height – 500 mm and diameter - 3.5 mm, number of fuel elements EK-10 is 232). NaF was stored in polyethylene covers (covers isolate chemically aggressive NaF from fuel elements). Fuel elements EK-10, NaF and graphite were assembled in regular square lattice. These all materials were stacked up in aluminium cover (height - 731 mm, cross section - 355x355 mm). Value of blanket's multiplication factor is approximately 0,6. There is a graphite block in the centre of the blanket, which can be changed for another materials or some equipment (for example the inlet for the external neutron source).

*Future Experimental Research at the Target/Blanket Assembly*

Subcritical system with external neutron source will be created in year 2003. This system will be composed of subcritical blanket Blažka and NG2 target station. Experimental measurement will be proceeded at Nuclear Physics Institute of the Academy of Sciences, Řež. Measurements will be focused on neutron characteristics (especially measurement of the delayed neutrons) of the subcritical blanket with external neutron source.

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# Training Reactor VR-1 On-line on the Internet

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The VR-1 reactor is operated for the training of university students and nuclear power plant personnel, R&D, and information services for non-military nuclear energy. Training at the VR-1 reactor provides students with experience in reactor and neutron physics, dosimetry, nuclear safety, and nuclear installation operation. Students from technical universities and from natural sciences universities come to the reactor for training.

State-of-the-art information technologies allow on-line access to information about operation of any facilities to experts, customers, users and as well as public. Today, all nuclear installations are in the focus of the public audience and therefore is necessary open information from operation of the any nuclear installation. Because now the most common, comfort and cheap information channel for release non-stop information is Internet, web-portal Vrabec (Sparrow) was installed on the Internet with on-line information from the training reactor VR-1 operation. Bilingual (Czech and English) web-site is intended for:

- students and teachers who take part in the training and teaching process at the reactor as a source of information on reactor experiments which are performed at the reactor,
- regulatory body in Czech Republic (State Office for Nuclear Safety) and international organizations (IAEA, EURATOM, etc.) as a tool which can help them to fullfill all aspects of the safe operation in the frame of non-military use and non-proliferation treaty,
- public audience as a source of information on construction and safe operation of the small nuclear installation located in the university campus in the Prague municipality.

Web-portal Vrabec consists of the four main modules. First is Basic information module which includes basic reactor parameters, description of reactor, nuclear fuel, control rods, neutron source, control and safety system, reactor use and priciples of nuclear safety, radiation protection, physical protection and emergency preparedness.

On-line operation module cosists of web-cameras and direct on-line output from operator's desk. Thorough three web-cameras located in reactor hall, control room and reactor vessel, visitor can see actual situation in reactor hall and control room. Actual state of the reactor visitor can study thorough on-line output from operator's desk to internet server. Web interface is same as in operator's desk and can display basic operation parameters as reactor power, velocity and deviation, position of control rods, three types of on-line graphs, actual core configuration, reactivity margin calculation etc.

Previous operation module can display operation of the reactor in the past time. Visitors can select some predefined history and study all basic reactor parameters and graphs as in the on-line operation.

Significant part of the reactor operation is training and teaching. Last module Experiments describes all important and often used experiments performed at the reactor. Students and teachers can find in this module the methodology for each experiments in short description or in full range in attached pdf file. If previous operation, module includes history

of operation associated with certain experiments. Thus, history is part of experiment description too.

Web-portal Vrabec with on-line information from the training reactor VR-1 operation brings new potential in the aspect of educational process at the Department of Nuclear Reactors and it will be useful tool for anyone who in want to find up-to-date information on VR-1 reactor operation.

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# Basic Critical Experiment with Core B5

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Basic critical experiment is held at the Department of Nuclear Reactors as a part of the Experimental Reactor Physics course every year. In this experiment wholly new reactor core becomes for the first time critical. Doubtless, basic critical experiment is the most demanding of all experiments, which are held at reactor VR-1 Vrabec. Basic critical experiment was taken place from 17$^{th}$ May to 31$^{st}$ May 2002 on the Department of Nuclear Reactors and the operational reactor core B1 was exchanged for experimental reactor core B5 during this experiment.

Basic critical experiment was authorized by State Office for Nuclear Safety (SONS) on the basis of the decree no. 7102/2002 issued on 30$^{th}$ April 2002 after the technical documentation [1] was submitted. After successful realization of basic critical experiment, a process report was elaborated [2], which was sent to SONS again to check up.

We made a careful theoretical preparation before this experiment. During this preparation the new reactor core is designed and the procedure of its piecing together is developed. For every step of composing, the neutronic calculation is performed by program MCNP (Monte Carlo N-Particle Transport Code System). The results of MCNP calculations determine the positions of control rods for safety reaching of criticality. There was also projected a procedure for determining weight of control rods. This determining of weight of control rods is made two times during this experiment**.**

There are two main aims of basic critical experiment with the core B5: the first aim is experimental verification of hitherto unknown criticality. Second, the students of Department of Nuclear Reactors acquire the practical experiences of realization this experiment.

The motivation for reactor core B5 design was necessity of verification of computer model of graphite double blocks used like a reflector was. This was also why symmetrical reactor core with broken border between fuel and graphite reflector was designed.

Reactor core B5 contained seven six-tube and five four-tube fuel elements IRT-3M with enrichment 36 % $^{235}$U. Moderation was ensured both with light water and with twelve graphite double blocks (dimensions of this blocks are 71,5 x 143 x 880 mm). Three scram rods; two experimental rods and two regulation rods were used. Pipes of absorber were inserted at all rods into six-tube fuel elements.

The reactivity was found out by SOURCE JERK method where the time integral of impulses from neutron detectors SNM-10 after quick removal of neutron source is measured. Three experimental channels (one of them was inserted into central four-tube fuel element, the others were situated besides reactor core) and also operational power measurement (four detectors) were used for this reactivity measuring.

We calculated that the reactivity of reactor core B5 is 4,37 $\beta_{ef}$ when control rods are in upper terminal position (of course, there is no experimental proof of this value) and when the control rods are in lower terminal position the reactivity of reactor core is –14,47 $\beta_{ef}$ .

We achieved criticality of reactor core B5 on 22nd May at 14:31. The control rods were in this positions: the scram rods were in upper terminal position, the first experimental rod was in lower terminal position, the second experimental rod was in position 350 mm, the first control rod was in position 500 mm and the second control rod was in position 450 mm.

We can say, that the basic critical experiment was successfully realized. "Unknown" critical state was authenticated by safety procedure. When we take standard deviations of calculation into account, the positions of control rods at achieving criticality tallied with positions of control rods, which were pre-calculated. Moreover, all measurements performed near criticality confirmed calculated outcomes. It means that the model of reactor core of VR-1 with fuel IRT-3M as well as with graphite double blocks used in program MCNP is very satisfactory and corresponds to reality.

We can also observe that the results of SOURCE JERK method is quite inexact in deep "undercriticality" ($\rho < -5\ \beta_{ef}$). The accuracy of this method is getting higher, when the reactor drew near the critical state. The inaccuracy has two reasons. Firstly, we do not take in account that the time of the removal of neutron source is not equal to zero and secondly the synchronization between removal of neutron source and initiation of measure device is not electronic performed. But this fact had no impact on safety of basic critical experiment, because accuracy of SOURCE JERK method at important measurements near criticality is satisfactory.

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# Monte Carlo Simulation of Linear Accelerator Electron and Photon Beams for Radiotherapy - Geant4

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Radiotherapy plays an important role in cancer treatment today. The principle of radiotherapy is to destroy cancer cells by delivering high dose to the cancer tissue, while keeping the dose delivered to the healthy tissue as low as possible. The dose is delivered by particles like photons or electrons, produced by radiotherapeutical accelerator or radionuclide sources. Electron linear accelerators have become the widely used option for producing the particles in distance radiotherapy. The electrons are first accelerated to a chosen energy and then bended into the accelerator treatment head. In this head, the beam is shaped and homogenized for the needs of clinical treatment. If there is a need for an X-ray beam instead of electron beam, an X-ray target is positioned in the electron beam direction and photons are produced as bremsstrahlung photons. Other main parts of the treatment head are usually the primary collimator, vacuum window, field flattening filter (photons) or scattering foil (electrons), beam monitor, mirror, movable collimators, electron applicator (electrons).

Particles interact with the material of the treatment head, air and structures placed under the treatment head such as patient body or water phantom. Exact analytical solution of the resulting quantities of interest, such as dose and its distribution, would be infeasible even if the properties of particles entering the treatment head were known exactly (which is unfortunately not the case anyway).

So if there is a need to know, for example, the dose distribution in a water phantom simulating the human body, one can use either experimental methods such as measuring with an ion chamber or the Monte Carlo method. The Monte Carlo method is a numerical analysis technique based on the use of random numbers sequences to calculate sample values for variables of interest. The calculation is performed by a computer program. In order to make the programming easier, there are several software libraries providing the programming infrastructure for radiotherapy simulations, such as EGS4, Beam, Penelope, MCNP, Geant3, or Geant4.

Although measurements remain the primary method for obtaining reliable results, in many cases (such as dose distribution in complex structures) the experimental method is not applicable. In such cases, the Monte Carlo method becomes the most exact feasible approach.. The reliability of simulation has to be always verified by comparison with results obtained experimentally; if there are no such results, it is highly desirable to compare the simulation results with results of other simulation tools. For my simulation, I used Geant4, which is a quite new, versatile and freely available object-oriented toolkit, developed as a successor of Geant3 mainly for the use in high energy physics.

The final simulation program is written in C++ programming language. It consists of the main program and several classes describing the geometry, physical processes, actions taken at every event and step, detector response, primary particle generator, visualization etc.

The type of linear accelerator that I simulated was Varian 2100C, which is clinically used in the Faculty's Hospital Motol. The accelerator operates at nominal energies of 6MeV, 9MeV, 12MeV, 16MeV, 20MeV for electron beams, and 6MV and 18MV for photon beams. Another simulated equipment from Motol is a Wellhofer water phantom. To measure the depth dose curves in water, a planeparallel ionization chamber for electron beams and a diode for photon beams were used. The simulated energies were 6MeV and 9MeV for electron and 6MV for photon beams. The simulation will be extended to all available energies by changing the appropriate geometry parts of treatment head (scattering foil for electrons, target and field flattener for photons) and the energy of primary particles entering the treatment head. For registering the absorbed energy and the reconstruction of depth dose curves, the water phantom was divided into 100 sensitive pixels (2cm x 2cm x 0.1cm) in the beam direction beginning at the surface. The initial energy and direction of primary electrons entering the treatment head, which was not provided by the Varian company, was derived through the comparison of simulated and measured depth dose curves in water. The field size at the isocentre was 15cm x 15cm for electrons and 10cm x 10cm for photons. The SSD was 100cm for electrons and 95cm for photons. The simulated and measured depth dose curves were finally found to be in a good agreement for both electron and photon beams.

With relevant changes in implementation, the developed simulation can be used for different types of experiments or practical needs. For example, it is already used in the development of 3D gel dosimetry. Due to introducing some stepping actions, it was possible to obtain, in addition to depth dose curves, also energy spectra of particles in different depths of water phantom. The obtained results will be used for the determination of correction factors, if the dependence on energy spectra of irradiated gels is found. I would like to thank my student colleague Viktorie Štísová for help with data processing.

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# Quality Assurance of PLA Design for Nuclear Devices

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Programmable logical arrays (PLA) are up to date means that are utilised to solve hardware logical functions. The utilisation of PLAs is convenient in such cases when there are not available specialised large scale integrated circuits for intended functions and the number of intended applications is too small for ASIC development. Some manufactures also offer the possibility to develop the circuit with PLA and after a successful development to produce the circuit as an ASIC for frequent applications.

PLA application in systems important to nuclear safety is closely connected with qualification and quality assurance. The quality of PLA consists not only of hardware but also of software. So the utilisation of PLA in nuclear safety critical application brings similar features like computers. The software for PLA is substantially less complex than for computers in safety and safety related systems. There are international standards for systems important to safety software (e.g. IEC880, IEEE 603 P7-4.3.2) but there are no similar standards for PLAs. This paper gives an overview about PLAs available, about tools and methods for PLA design and finally tries to find methodology for quality assurance of PLA design in systems important to nuclear safety.

The PLAs today can be divided into three basic groups. The first group consists of more or less simple circuits up to hundreds logical gates like PAL or GAL circuits that are typically used for simple logical functions or as a glue logic in microcomputers. Second group are middle complex logical arrays up to hundred thousands gates for complex logical functions. The third one is represented by very complex logical circuits combined with a microcomputer for very demanding applications. The leading manufacturers of PLAs are Xilinx, Altera and Lattice Semiconductor [1]. Because of strong competition in the world market, their offer seems to be similar. We decided to concentrate on Lattice Semiconductor products because of their good availability and support in Czech Republic.

There are two typical ways for PLA design today. One way is based on schematic plans of required logical functions, the other one utilises alphanumerical description of designed circuits. The description was previously based on Boolean equations of the logical. Today, there are special description languages available like HDL, VHDL or Verilog HDL. The advantage of schematic plans is the possibility use old approved plans for innovation. Furthermore, people do not need to learn new technique. But the maintenance, documentation and readability in complex designs seem to be the disadvantage of this method. The text oriented description languages need to be studied, and there are at least three above mentioned description languages. All of them are based on Boolean equations, but the description can be completed with true tables and state machine descriptions. The VHDL [2] represents today the most utilised standard. This language was developed for hardware description parallel to ADA programming language for software. Originally, the VHDL language was intended for

hardware description and simulation only. Lately, synthesis tools for the PLA design were developed. There are some very powerful tools for the VHDL design (e.g. Synopsys), but these tools are very expensive. The HDL language originally based on ABEL development system provides also many features like VHDL or Verilog HDL, last versions enables hierarchical structure, state machine and true table design, and it is easier for synthesis with cheaper design tools. To promote their circuits, the PLA manufacturers offer more or less free of charge or cheep tools for the PLA design of its own products. As example, there could be mentioned the ISP Lever design tool [3] of the Lattice Semiconductor cooperation, that provides synthesis, function and time analysis of designed circuits. The design can be made on basis of either schematic plans or HDL or VHDL description. But the VHDL synthesis and simulation are not on so high quality as HDL one.

The methodology of the PLA design is based on standards and experience with the software for applications important to nuclear safety. Three principal documents shall be prepared before the start of a design. The first one - quality assurance plan defines the procedures and methods of design. The second one – verification and validation specifies the methodology of approval and testing of design and the third one – configuration management controls design management, access and changes rights and data storage.

The life cycle of the PLD consists of following stages: requirements, design, coding, verification and validation, PLA programming, final testing, operation and maintenance. The requirements have to be complete, consistent, unambiguous, modifiable, traceable and verifiable. In the design stage, required functions are specified and hierarchical structure is proposed. During the coding, the description of the PLA is produced. The text description is recommended. All stages are thoroughly verified and designed circuit tested. The test strategy was also studied. There is no general approach universally applicable for circuit tests, and it is necessary to find the most critical transients for testing because it is not possible to carry out complete tests of complex circuits. After complete synthesis, the PLD is tested with a simulator with regard to functional and timing requirements. The PLD is then programmed and tested at the hardware level. There is necessary to follow the measures of quality assurance and testing also during maintenance of circuit design.

Finally, the proposed methodology was approved during the PLA development for communication units of the new VR-1 nuclear reactor human-machine interface [4] and for the safety chain control circuit of innovated VR-1 I&C safety channels.

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# Training Reactor VR-1 Control Rod Drives and Safety Circuits Upgrade

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The VR-1 training reactor has been operated since 1990 by the Department of Nuclear Reactors FNSPE CTU in Prague. The reactor was designed and constructed by the Škoda Company in co-operation with the Faculty. The VR-1 reactor is a pool-type light-water reactor based on enriched uranium (36%). Its thermal power is up to 5kW. The moderator of neutrons is light demineralised water that is also used as a reflector, a biological shielding, and a coolant. Heat is removed from the core with natural convection. The VR-1 reactor is utilised particularly for training of university students and nuclear power plant staff. Research at the VR-1 reactor is mainly aimed at the preparation and testing of new educational methodologies, investigation of reactor lattice parameters, reactor dynamics study, research in the field of control equipment, neutron detector calibration, etc.

The present control and safety system (I&C) of the VR-1 training reactor was developed in the mid- 80s. The system is digital, it utilises 8-bit microcomputers with software written in the assembly language. Even if the present control and safety system fully covers the demands that are put on it, its technical design is obsolete to a certain extent at the present time. There are also problems with maintenance because of a lack of spare parts. Mainly mechanical components with contacts – like connectors and relays – are not produced any more, and the old ones in stock are usually also corroded. Furthermore, during development and production, some new internationally respected demands to ensure the quality and the qualification (e.g. the IAEA, IEC, and IEEE recommendations and standards) were not or could not be considered. Therefore, it was decided to upgrade the present control and safety system with the aim to apply the latest available techniques and technology observing the above-mentioned recommendations and standards.

The principal upgrade of the control and safety system was started in the year 2001. Because of the frequent utilisation of the VR-1 training reactor during the academic terms, it has been decided to carry out the upgrade of the control and safety system gradually during holidays so as not to affect the educational process at the reactor. The plan of the complete I&C upgrade consists of four stages. Each stage will be independent and after its completion, the reactor has to remain functional. Moreover, the necessary changes of the just carried out upgrade stages because of a new stage completion would be minimised.

The human-machine interface upgrade as the first stage of the control and safety systems upgrade was carried out in the summer 2001. The aim of the upgrade was to improve ergonomic and aesthetic properties of the operator's desk and the control room, to enhance the operator's comfort and thus to increase the utilisation of the reactor and nuclear safety.

The control rod drives, motors and safety circuits were upgraded in the year 2002. The former motors of the rods were not available any more which caused a problem for the maintenance and the former rod drives were also very difficult to maintain because of

unavailability of spare parts and awkward electronic circuits. The rod motors were replaced with new ones that provide appropriate properties and dimensions. The selected motors are produced by the ESPO Company. Necessary mechanical changes on the control rod mechanism, induced by the utilisation of the new motor, were done by the Škoda Company. As a drives of the motor there will serve a PLC Simatic S7-200 equipped with a proper power electronic board. Appropriate software to control the PLC was being developed. Before the control system upgrade, the PLC is connected to the interface of the present control system that consists of digital outputs for the rod up and down movement, an analogue output signal to define the velocity of the rod movement and two digital inputs for the counting of up and down steps to evaluate the rod position. After the control system upgrade, the PLCs will communicate with the control system via a RS485 (ProfiBus) line.

The original safety circuits suffered from ageing of utilised relays. There were problems with the quality of contacts. The contacts corroded, lost the conductivity, produced heat because of increased transitional resistance and deteriorated the functionality of the relays. These relays are not produced any more, and the spare ones, not utilised, suffer from the same problem because of ageing and corrosion. The new safety circuits utilise high quality relays with forced contacts to guarantee high reliability of their operation. The safety circuits are installed in a 19'' crate for easy installation in new cabinets of the upgraded control and safety system.

The upgrade of the control rod drives and safety circuits was done by the Škoda Nuclear Machinery Company in close cooperation with the Department. The upgraded system was installed during September 2002, tested and put into operation in October 2002. These activities were complicated by flooding effects from August 2002. After the installation, all subsystems and then the complete nuclear reactor I&C were thoroughly tested. After completion of these tests, the State Office for Nuclear Safety licensed the reactor operation.

The upgrade of the control rod motors, drives and safety circuits carried out during the year 2002 improves the nuclear safety, availability and maintenance of the reactor. The reactor I&C upgrade will continue with the control system upgrade in 2003 and the protection system upgrade in 2004. The complete reactor I&C upgrade will bring the reactor I&C to top conditions and will enable a prolongation of their functionality and maintainability for at least 10 next years.

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# Determination of Iodine by the Short-term INAA on Training Reactor VR-1 Sparrow

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The research of bromine in the human body is related with increasing its amounts in food chain. Bromine and iodine are similar chemical elements and thyroid is the target organ for both of them. Goitrogenic effect of iodine is known very well, possibility of this effect for bromine cannot excluded. Increasing amounts of Br is connected e.g. with the application of brominated hydrocarbons in pre-planting fumigation of soils and post-harvest fumigation of commodities as grain, spices, nuts, fruits and tobacco.

For determination of iodine and bromine concentrations in samples of thyroid non-destructive method instrumental neutron activation analysis (INAA) was used. Iodine and bromine in irradiated samples were determined by high-resolution gamma-ray spectrometry using the induced radioactivity $^{128}I$ (half-life 25 min, $E_\gamma$= 442.9 keV) and $^{80}Br$ (half-life 17,4 min, $E_\gamma$= 616,2 keV) [1], [2].

The sensitivity of non-destructive determination of low iodine a bromine concentrations depend on the background level of the accumulated spectrum of the gamma radiation conditioned by the contribution of Compton scattering generated by the photons emitted from the activation products of the other elemental components of the analysed sample, e.g. $^{24}Na$, $^{38}Cl$, $^{42}K$.

Another problem consist in preparation of inadequaate elemental homogeneity of thyroid matrix, therefore irradiation of one lobe or whole thyroid gland is the correct solution of the analytical procedure. Such samples of dry weight between 1 - 5 g after irradiation in high flux of thermal neutrons ($>10^{17}$ $m^{-2}.s^{-1}$) yielded too high radioactive source with undesirable radiation level for handling.

On the basis of this fact the following analytical procedure was modified for irradiation in a core of training reactor VR-1 Sparrow (FNSPE CTU in Prague). Maximal thermal power was 1kW, it was corresponding thermal neutron flux density 2 .$10^{13}$ $m^{-2}.s^{-1}$. For measurement were prepared samples of thyroid. Their typical mass was between 1 and 3 grams. The tablets were made by compress from lyophilised material. The diameter of tablets was 13 mm; their height was proportional to mass from 10 to 30 mm. Every tablet was inserted into a polyethylene case. The irradiated samples was transported in spectroscopy laboratory by pneumatic rabbit system during 5 s. The optimal working regime was for irradiation 5 min, decay time 1 min and accumulation of gamma spectra for 8 min.

The level of gamma radiation was checked by external device and dose rate of gamma on surface of samples was lower than 5 μGy/h (typically 2 μGy/h). Because the core of reactor VR-1 is small, the impact on reactivity was checked too and a change of reactivity was lower than +0,02 $\beta_{ef}$.

Gamma ray spectroscopy system including HPGe detector (FWHM 1,8 keV, rel. efficiency 25 %) was used. As elemental standards of iodine and bromine served water solution KI and KBr containing 30 mg iodine and 50 mg bromine for different size of samples.

Instead the gold monitors for checking output thermal power in a core neutron dose for every irradiated sample during the activation process served the time course of current measured by compensation ionisation chamber CC54B.

Determination of iodine in thyroid gland by short-term INAA was modified for irradiation in low level thermal neutron flux of training reactor VR-1. Values of concentration iodine in dry thyroid sample were between 1,5 – 3,5 mg I/g. Detection limit for determination of bromine is 0,3 mg Br/g dry weight thyroid matrix, while usual content of this element is lower then 0,1 mg Br/g.

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# Sensibility of the Fluoride Salts Flow Computations to the Selected Numerical Parameters

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Thermal-hydraulic analyses of reactor cores are important calculations of the currently designed nuclear reactors. This fact is the same in the case of new designes of Accelerator Driven Systems (ADS) blankets, which are proposed for a transmutation af radioactive wastes. The conception of ADS with molten salts, as coolant and liquid fuel at the same time, requires more accurate thermal-hydraulic analyses than the others types of nuclear reactors. The biggest difference lie in fact that the reactor neutronic characteristics, and consequent reactor control and nuclear safety as well, depend on the main thermal-hydraulic parameter, which is velocity and temperature of fuel-coolant flow. The velocity has impact on: escape of delayed neutrons and moving of fission products from the fission point and changes of mixture proportion in the fission point due to history of fuel flow. Furthermore, the thermal-hydraulic analyses of ADS determine heat removal from the core as well as in nuclear reactor with solid fuel. However, the heat from fission is generated directly in the coolant. It is evident that detailed and full hydraulic analyses of fuel-coolant flow is needed for a good design of the ADS blanket.

Appropriate simulation computer codes are needed to calculate a solution of flow in general geometry for liquids with volume changes as functions of temperature and movable heat sources. They are called Computational Fluid Dynamics (CFD) computer programmes. The two CFD codes are available at the Department of Nuclear Reactors for the above mentioned purposes: PHOENICS 3.2.0, based on the finite volume method, and the module FlowPlus for the programme package COSMOS 2.5, which is based on the finite element method.

Preliminary calculations have been done on the simple benchmark example as first. They showed some differences between results of both numerical codes, especially on boundaries of geometry. The differences could be explain in a different interpretation of the boundary conditions. [2]

It was chosen the more complicated geometry with two curves of angle 90 deg. and two blockages, which simulate neutron source and graphite moderator, in the new calculations. The example was modelled in cylindrical coordinate system (diameter 0,7m, high 1,8m) with gravitation force direction up stream of the fuel-coolant. The inlet conditions were: velocity 0.1m/s, temperature 888K. The volume heat source was constant, $1*10^8 W/m^3$ in the core of diameter 0,5m and hight 1m. The mentioned example accord with the central part of the proposed ADS blanket. The fuel-coolant mixture was chosen as the fluoride salt 44,5%LiF + 10,9%NaF + 43,5%KF + 1.1%$UF_4$ (with contamination of structure materials for the thermal conductivity property).

Works, which were made last year, were intend on the evaluation of influence of numerical method and numerical parameters choice on computation results. The mesh density influence was evaluated as the first by separated calculations with other parameters. The results show great differences among separate calculations, especially near central axis and boundary walls, when the small density was tested. A high mesh density is not necessary in the centre of

the flow volume, such that good problem solution is the variable mesh density in the volume with high values near central axis and walls.

The influence of a turbulence model choice was evaluated as the second. The rason of this tests was that the most used numerical code PHOENICS 3.2.0 offers twenty two turbulence models and [3] gives no answer which model is appropriate for various types of flow. It was tested only fourteen models (the others are intended for two-phase flow, chemical reacting, …) and compared mutually. The results of separate models showed great differences and it was difficult to say which model is appropriate. Only comparison with the code FlowPlus gives the sufficient answer on this problem that models of type K-Epsilon: RNG or Chen-Kim modified K-Epsilon are optimal.

The comparison of results from both numerical codes was made as last. It shows the biggest differences especially on boundaries of geometry. This result was obtained in [2], but the differences are globally greater in the more complicated geometry.

The achieved results show weak points of theoretical calculations. They determine limits of the CFD calculations precision and call attention to the critical points, e.g. mesh density, turbulence model, numerical model etc.. The results show two ways of solution this problems: experiments and the use of more CFD codes and comparison of theoretical results.

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# Innovation of Dosimetric System on Reactor VR-1 Sparrow

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After 13 years of use of the VR1 reactor it is necessary to approach partial steps of modernization of not only control system, but also an another important parts of our nuclear equipment. Dosimetry is one of these important parts. This effort, also due to big flood in summer 2002, has a support in a scope of MAAE projects and also Fund of Developing. The purpose is to modernize mainly personal dosimetry and stationar dosimetric system STADOS.

For the first phase, we decided for a new way of personal monitoring of reactor staff, students and visitors of the reactor, based on film (legal for staff only) and at a present termoluminiscent dosimetry. Existing TL dosimeters, used for staff and all visitors, will be step by step replaced by new DIS system. DIS (Direct ion storage) system is based on the combination of an ion chamber and a non-volatile electronic charge storage element. This system is excellent covering for the Hp(10) and Hp(0,07) photon and beta in the wide dose and energy range. DIS badge allows the wearer to instantly readout, by means of reader DBR-1, his/her accumulated doses whenever required. The values measured are immediately saved in the computer. Now a days DIS badges are used by staff, but since begining 2003 they will be in use for all of our students and visitors.

DIS-1 Specifications:

| | | |
|---|---|---|
| Dose Measurement Range: | Hp(10) | 1 uSv to 0.5 Sv (40Sv) |
| | Hp(0.07) | 10 uSv to 0.5 Sv (40Sv) |
| Energy Range Photons: | Hp(10) | $\pm$30% from 15 keV to 9 MeV |
| | Hp(0.07) | $\pm$30% from 6 keV to 9 MeV |
| Energy Range Beta: | Hp(0.07) | +10 … -50% from 240 keV to 2.2 MeV |
| Isotropy: | | $\pm$20% up to 60$^o$ at 65 keV |
| Temperature Range: | | -10 to +50 $^o$C |

Second phase of modernisation concern inside dosimetry, STADOS. Present system is based on one-channel analysers JLK201 and is designed to monitor environment of the reactor hall by using the measurement of dose rate of gamma (10 sensors), neutron radiation (2 sensors) and radioactive aerosols (2 sensors). New system will contain 12 new gamma sensors GMS3 (100nSv/h - 10mSv/h), 2 updated neutron monitors located close to radial and tangential chanel and also new $\alpha\beta$ aerosol monitors. Furthermore, it will be complemented by additional wide range probe to measure radiation situation outside reactor workplace. Whole new radiation monitoring system will contain control unit with microprocesor for data acquisition and memory, power supply system and will conected with control system of the reactor and with our web portal for public presentation.

New system will match up with requirements of relevant legislation, above all Act No. 18/1997 Coll. (the Atomic act) and regulation of the SÚJB No. 307/2002 Coll.

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Section 11

# CHEMISTRY

# Utilization of Ionizing Radiation for Removal of Some Toxic Heavy Metals from Aqueous Solutions

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Among the different contaminants contained in industrial wastewater the heavy metals belong to the most dangerous ones. Such metals can accumulate in living plants and then enter the animal and human food chain in form of their salts soluble in water. Therefore the removal of possibly present toxic metals before the releasing of wastewater to the environment appears to be one of the most actual tasks. In addition to the conventional chemical methods the ionizing radiation can be succesfully utilized for the reduction of various metal ions to insoluble metals [1, 2]. Our research was focused, first of all, on the lead ions and the seeking for optimum conditions for the effective removal of this metal from aqueous solutions using both gamma radiation and accelerated electrons.

The initial concentration of different soluble salts ( chloride, nitrate and acetate) varied from 20 to 200 mg $dm^{-3}$ of $Pb^{2+}$ ions. The solutions were prepared from both deaerated (bubbling with $N_2$ or He gas for 20 min.) and non-deaerated distilled water. The samples were irradiated in sealed thin-glass ampoules with $^{60}Co$ gamma rays ( dose rate of about 18 Gy $h^{-1}$ ) and by accelerated electrons of an average energy of 4 MeV from a highly frequency linear accelerator (dose rates of 0,5 and 1 kGy $s^{-1}$) at the doses ranging from 0 to 40 kGy. The Fricke and polymethylmetacrylate dosimeters were used for the gamma and electron beam dose estimation, respectively. The changes in lead concentration were determined by means of atomic absorption spectroscopy with a flame ionization. After exposure the ultrafiltration with Millipore filter ( 0.45 μm pore size) in the absence of oxygen or centrifugation ( 21 400 g) were used for the separation of product- finely dispersed metallic particles. In both cases the same quantitative separation was attained.

The preliminary results show that in the absence of substances scavenging the hydroxyl radicals the degree of radiation reduction is virtually negligible. From the various scavengers applied the admixture of $10^{-2}$ mol $dm^{-3}$ kalium formate appears to be most effective. The actual concentration of $Pb^{2+}$ ions decreased monotonously with increasing dose starting from 0.8 kGy. The total reduction was found at the dose of 3 kGy if the initial concentration of $Pb^{2+}$ ions was 20 mg $dm^{-3}$ . Substantially lower efficiency was reached in environment of different alcohols such as ethanol, 1- butyl and isobutyl alcohol. In the presence of these scavengers the doses indispensable for the attainment of given degree of reduction were higher achieving several tens of kGy. Moreover their effectiveness was found to be strongly dependent on concentration especially with higher alcohols. On the other hand no scavenging effect and consequently no reduction were found with acetic acid at different pH values ranging from 0.8 to 5.0.

It was proved in all cases investigated that at given dose of radiation the degree of reduction decreases with increasing initial concentration of lead ions. From the kinetic point of view it was found that the reduction proceeded as the pseudo-first-order process and the dose constant decreases with increasing initial concentration of lead. This probably gives evidence for the effects of some competition or recombination processes. In accordance with reductive

mechanism of the process under study the removal of lead occured more efficiently in deaerated ( nitrogen or helium bubbled) solutions. More detailed study in this field and influence of others effects such as dose rate, type of radiation etc. will continue in the future.

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# Reaction Order of Radiation Dechlorination of Some Aliphatic Hydrocarbons in Aqueous Solutions

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A remediation of ground- and wastewater seems to be very important task for our society [1]. Hence, new alternative methods suitable for removing of various pollutants from water are needed. One of them is a radiation treatment of water using the γ- or EB (electron beam)-irradiation. The application of this method is determined, of course, by a deep knowledge of radiation processes proceeding in the wastewater under irradiation. Therefore, systematic studies are needed in this field.

The radiation dechlorination of perchloroethylene (PCE), trichloroethylene (TCE) and chloroform in aqueous solutions (initial concentration from $5.3 \times 10^{-6}$ mol $dm^{-3}$ to $5.4 \times 10^{-4}$ mol $dm^{-3}$) initiated by gamma ($^{60}Co$ - Gammacell 220 AECL, dose rate 1.5 kGy $h^{-1}$)- or EB (linear accelerator – UR-4-1200, TESLA, MIKROEL, Ltd, power output in EB 500W, dose rate 1,5 kGy $s^{-1}$)-irradiation (doses from 0.1 kGy to 5.0 kGy) were studied. Some samples were prepared from water preliminary bubbled with nitrogen gas for 30 minutes or saturated with air/ozone-mixture or dinitrogen oxide gas. Other samples contained various amounts of sodium hydrocarbonate or sodium nitrate (0 mg $dm^{-3}$ – 200 mg $dm^{-3}$). The dosimetry was performed using the Fricke- or methylmethacrylate-dosimeter. The gas chromatograph CHROMPAC CP-9002 with a capillary column CP-SIL 5CB 10 m long and 0.25 mm in diameter equipped with EC-detector 902 B served for determination of hydrocarbons. The data collection and processing was done using the hardware and software of Data Apex comp., program Apex Integrator, version 3.1. Extra. The concentration of $Cl^-$-ions was determined electrochemically using the digital milivoltmeter RADIOMETER with the chloride ion selective electrode CRYTUR and the standard calomel electrode.

The characteristic dependences for dechlorination of all above-mentioned substances were published in a short form earlier [2], [3]. The reaction orders ω of dechlorination were estimated from the data presented there.

The dependences of actual concentrations c of hydrocarbons (or chloride-ions) on the dose D in various coordinates ($\ln c = f(D)$ for the first order, $c^{1-\omega} = f(D)$ for all other orders) were plotted and the straight lines were fitted. The least squares method was employed for determination of the regression factors of these straight lines. The dependences of the regression factors on the reaction orders were found to be non-monotonous functions with the pronounced maxima. The abscissa-coordinates of these maxima determined the reaction orders under given conditions. A standard deviation of this method was estimated to be having about ± 20 %. Reaction orders owing to the hydrocarbons of 1.7, 2.0 and 1.9 were found for dechlorination of chloroform, TCE and PCE, respectively. It means that the dechlorination of all hydrocarbons under study proceeds as the process of the second order, approximately. The order of dechlorination did not depend on the following parameters of the reaction: initial concentrations of hydrocarbons, manner of irradiation (γ or EB), presence of atmospheric oxygen, ozone, $N_2O$-oxide and both $HCO_3^-$- and $NO_3^-$-scavengers. The only exception was found for dechlorination of chloroform in presence of both $HCO_3^-$- and $NO_3^-$-ions: the reaction order decreased from 1.8 to 0.6 if the concentrations of $NaHCO_3$ and $NaNO_3$ increased from

0 to 184 mg $dm^{-3}$ and from 0 to 10 mg $dm^{-3}$, respectively. It means that both scavengers reduce the dependence of reaction rate on the concentration of chloroform. The formal "order of dechlorination" owing to the $Cl^-$ ions showed to be near to zero at various concentrations of $NO_3^-$-ions. It means that the main product of dechlorination, i. e. $Cl^-$-ions, did not affect the kinetic of dechlorination.

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# Remediation of Cs-137 Contaminated Soils

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Fission products and various other radionuclides released from nuclear installations contaminate currently large amounts of soils on large areas all over the world. The possible solution is not to shut down the important and relatively ecological nuclear technologies, but it is a development of new industrial techniques, safe disposal of the existing waste and also the decontamination of wasted areas.

$^{137}Cs$ is one of the major contaminants that were spread into the nature, where most of it was strongly sorbed onto soils. However, this mechanism causes a lot of trouble for living creatures, including the man. Contaminated soils are not usable for agriculture, breeding or anything else. Moreover, if the level of contamination is high, these soils must be collected to waste deposits and treated.

The sorbed caesium is chemically bound inside soil. Hence, there are several decontamination methods possible. It is necessary to break the bonds in the soil matrix (clay minerals) and so release the caesium from its crystalline detritus. Various decontamination methods were described in the literature [1-3], however none of them seems to be applicable generally and their efficiency is often questionable, namely in the case of old contaminations [4]. For our experiments, three methods were chosen: chemical attack with subsequent sorption; migration of caesium ions in electric field with parallel destruction of soil by ions “in statu nascenti”; and thermodesorption of caesium and partial destruction of the soil at high temperatures.

The first, purely chemical, method is based on replacement (ion exchange mechanism) of caesium in the soil by similar ions. The ions with similar properties and chemical behaviour are potassium, ammonium, and calcium ions that have almost the same ion size and also hydration energy. It was found that the ion exchange proceeds only on a very thin surface layer of the clay materials while the decontamination process deeper in the crystalline structure is driven mainly by diffusion. This results in a very slow rate of the process and long decontamination times. After equilibrium is achieved, the spent decontamination solution must be replaced by a fresh one and then it is possible to remove another small amount of caesium. However, generally, it was not possible to remove more than 25 % of the sorbed radionuclide. Better results could be achieved by strongly acidic solutions, where the $H^+$ ions destruct the minerals (even more than strong alkalis) and the crystalline “traps” for caesium open. The opened structure then enables better and faster diffusion and exchange processes. In strongly acidic solutions and in the presence of the above listed similar exchangeable ions, it was possible to obtain decontamination factors of almost 45 % during 14 days. The spent solutions can be treated by sorbents selective for caesium and in this way the waste volume can be reduced ten to hundred times.

The second, electrochemical, method is based on migration of ions in strong electric field to the electrode. In this method, it is supposed that caesium is bound in the soil only by electrostatic interactions as a partially free ion. In this case these ions migrate to the cathode compartment, where they concentrate. The next process, which runs in parallel to the

migration, is the destruction of the soil minerals (their respective crystalline structure) by the very aggressive agents created during the electrolysis of the background electrolyte. The soil can be "electrolysed" very close to anode, in harsh acidic and ionic conditions, which makes this process similar to the strongly acidic leaching, but it is more efficient. As in the leaching methods, the solution can be treated (caesium removed and concentrated) by a suitable selective sorbent. In the real system, the background solution is pumped from the cathode into a column with the sorbent and then – after "sorption cleaning" – to the anodic part of the device. This continuous system was shown to be more efficient than the leaching, because it also reduces the problems with phases separation.

The third, thermodesorption, method is based on the volatility of caesium at relatively low temperatures (boiling point 705°C) and also on the possibility to break the crystalline traps and the bonds of caesium at high temperatures. The desorbed caesium condenses on the cooled cover of the heated crucible and from there it can be desorbed by standard decontamination solutions. Only preliminary test experiments were performed by now. The first results show that some caesium is released at temperatures higher than 900°C. In the conditions tested, the amount of caesium released onto the cooled cover increased from the background value almost two hundred times. However, the overall decontamination factor could not be determined because it was still too small. The experiments at higher temperature range will be performed in the near future. However, predictions of the desorption trends at higher temperatures cannot be easily done.

In the future experiments new possibilities in the thermodesorption and electrochemical methods will be tested. Their mechanism and potential great waste volume reduction factor promises high decontamination efficiency and possibility to decontaminate the soil down to the limits for free release to the environment.

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# Study of Cobalt and Europium Interaction with Humic Acid by Gel Chromatography

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Speciation of radionuclides in natural systems is strongly influenced by their interaction with humic substances and therefore studies of complexation equilibria of radionuclides with humic and fulvic acids have attracted much scientific attention recently. Various methods were applied, but most of them were used in static (batchwise) equilibrium arrangement.

As a part of systematic study of experimental methods for evaluating radionuclide – humate interactions we studied an application of a gel chromatographic (SEC) variant of Hummel–Dreyer dynamic equilibrium method [1]. Aldrich Humic Acid (AHA) was used as a standard humic acid, europium (model for studies of americium migrations) and cobalt were chosen as important trivalent and divalent metals. The method aims at determination of the ratio of moles of metal bound with humic acid ($Q_{MAHA}$) to the amount of humic acid present ($Q_{AHA}$, in large excess). Interaction constants for metal M are defined by

$$ {}^{c}K = \frac{[MAHA]}{[M^{n+}]\,(AHA)_{tot}} = \frac{Q_{MAHA}}{[M^{n+}]\,Q_{AHA}} $$

$[M^{n+}]$ … buffered conc. of "free" metal (calculated by PHREEQC [2] )
$(AHA)_{tot}$. . . . total conc. of AHA (g/l), large excess relative to $[M^{n+}]$
[MAHA] , $Q_{MAHA}$ . . . concentration and amount of metal-humic acid complex in sample (mol/l and mol), $Q_{MAHA}$ determined indirectly by SEC / AAS
$Q_{AHA}$ . . . amount of humic acid in sample (g)

The chromatographic system consisted of X-Act Jour Research mobile phase degassing unit, HPLC pump DeltaChrom SDS030, syringe loading sample injector Rheodyne 7725i, Sephadex G-15 column (340 x 10 mm) for Eu or Ultrahydrogel 120 (300 x 4,8 mm; 6 μm) for Co, the Hewlett-Packard UV/VIS 1100 detector and fraction collector Lab PRO. The concentration of "free" metals and pH of the mobile phase was buffered by citric acid buffer; ionic strength was adjusted by $NaClO_4$ to 0.01 and 0.1. Samples with the same amount of AHA and various total metal content (internal standards) were injected. Individual fractions of eluent were collected and their total metal concentration analyzed by AAS on Varian SpectrAA – 200 device.

Hummel–Dreyer method has a unique advantage over the conventional static equilibrium methods in that metal concentration (and pH) can be kept (buffered) at a desired and predetermined value throughout the experiment, so metal complex concentration and humate concentration are adjusted to be in dynamic equilibrium with metal concentration throughout the process of their chromatographic separation. Another often proclaimed advantage of the method is the mechanism of the gel separation itself, which is in ideal case governed only by the size of molecules separated and therefore the equilibrium is believed to be unperturbed by interactions with gel phase. Macromolecules (AHA and MAHA complexes)

should elute at interstitial volume of column, low molecular weight species (citrate complexes and "free" metal ions) at total liquid volume of the column.

The study revealed that it is not the case. On all chromatographic columns studied (above mentioned columns and also glycidylmethacrylate column (GMB 200, 125x4 mm, 5µm) and TSK-GEL column (G3000SWXL, 300x7 mm)) low molecular weight metal complexes showed much smaller elution volumes. This resulted in some cases in poor separation.

In order to elucidate this experimental result speciation of low molecular weight Co and Eu forms was calculated by PHREEQC [2] and the results compared with the separation efficiency. Calculations revealed that in the range of pH 4 – 7 negatively charged metal citrate complexes prevail. Concentration of neutral or positively charged species increases with lowering of pH from pH 7 to pH 4 (this results in better separation and larger amount of complex MAHA formed), but solubility of AHA and MAHA decreases (this causes sorption on the column). The same trend is with lowering of buffer concentration, but at citrate concentration lower than $10^{-3}$ mol/l the buffering capacity is insufficient. It is therefore concluded that the efficiency of the separation depends on the charge and concentration of low MW forms because ionic exclusion (interaction with negatively charged gel) accelerates negatively charged citrate complexes. This acceleration (lowering of elution volume) results in poor separation.

The main shortcoming of the method thus consists in fairly narrow range of experimental conditions usable for effective chromatographic separation of MAHA (macromolecular forms) from low molecular weight metal species (for Eu and Co three citrate complexes predominate). The best separation of Eu was achieved at pH 5, I=0.01 ($NaClO_4$), for Co at pH 6, I=0.1 ($NaClO_4$), for both metals in 0.001 mol/l citrate buffer and $5x10^{-5}$ mol/l total metal concentration. Specific limitations of the method are due to AAS analysis. Eu concentration changes (relative to Eu conc. in the mobile phase) are close to Eu determination limit and overall uncertainty of the $^{c}K$ determination is 9-16 % (for Co it is 3 – 5 %).

Another shortcoming of the method is that the values of interaction constants depend on calculated buffered concentration of „free" metals and accordingly on metal–citrate complexation constants and citric acid acidity constants used [3]. The values of interaction constants obtained – for Eu (1.1 ± 0.1) x $10^5$ l/g (pH 5, I=0.01) and (2.4 ± 0.4) x $10^5$ l/g (pH 5.5, I=0.01); for Co (1.4 ± 0.05) x $10^3$ l/g (pH 5, I=0.1) and (7.1 ± 0.3) x $10^3$ l/g (pH 6, I=0.1) - are in fairly good agreement with the results found in literature for other humic acids [4]. Chromatographic study of Hummel–Dreyer method with radioactive tracers is in progress.

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# Using XRFA for Analysis of Corroded Bronze Objects

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This research deals with corrosion study of old bronze objects. Ancient bronze statues, tools, and arms constitute valuable objects of the cultural heritage. Although bronze is a noble alloy, corrosion causes its damage. The preservation requires detail information on corrosion processes and chemical composition of involved objects. The non-destructive analytical method, X-ray fluorescence analysis (XRFA), was used to examine its applicability to corroded bronze study. Firstly, the analysis of 15 bronze objects was performed with XRFA. Secondly, one sample was analyzed in detail to determine the surface and bulk composition. Basic description of corrosion processes is presented.

Bronze, copper and tin alloy, is one of the most important materials in history. First mentions date back to 4000 BC. Since then the bronze has been used as a fundamental alloy for production of tools, statues, arms, and religious objects. The importance of bronze decreased after iron began to be used. Many objects which were discovered during archaeological excavations fall to this time period. It is evident that they were deposited a long time in clay, affected by the environment causing their corrosion. If the objects were deposited in a soil with high humidity, the corrosion was able to affect all the bulk. The corrosion products make the bronze less resistant to further influences. If corrosion exceeds a certain value, the object is completely destroyed.

Corrosion acts on bronze not only in clay, but in the air as well. Therefore the ancient objects in museums are not preserved, and corrosion may cause their damage within next centuries. Now, historians and museum conservators try to develop new techniques to stop further degradation of bronze. To do this, they require information on principles of corrosion and chemical composition of the involved objects. This is a task for XRFA.

XRFA is a non-destructive analytical method making use of X-rays or gamma rays to invoke emission of characteristic X-rays in the investigated object. The analysis is restricted to surface due to strong attenuation of characteristic X-rays in measured objects, i.e. in bronze. Fifteen corroded bronze objects, dating from 200 BC until 200 AD, were studied by this method. The experimental device consists of an X-ray tube with rhodium target operated at a voltage of 35 kV and a current of 0.7 mA. Characteristic X-rays were detected by semiconductor detector (Amptek XR-100CR). A narrow aluminum collimator was placed between the X-ray tube and an object to achieve a small beam spot. The small object-detector distance allowed to identify all elements with an atomic number higher than 16. The detection limit was close to 0.1 %. It was higher for light elements and elements corresponding to overlapping peaks in X-ray spectra. The experimental data were evaluated with Canberra WinAxil software package. The quantitative analysis was made by the fundamental parameter method that is the most versatile method for quantification in XRFA. To do this, a set of standards was used for energy calibration and calculation of instrumental constants required in the fundamental parameter method.

The analysis of several ancient bronze objects showed that the element concentrations in their surface layers differ considerably from the typical bronze composition. Although there

are many types of bronze differing in element concentration, copper is the main constituent whose concentrations vary from 75% to 95% (except special alloys). The concentration of tin, the second major element in bronze, usually do not exceed 20%. The rest complements other elements, e.g. zinc, lead, iron, and nickel. In comparison to these typical values, the most of our measurements showed lower copper and higher tin concentrations. This phenomenon was more significant for more corroded object.

One piece of corroded bronze was analyzed in detail to demonstrate corrosion influence on surface composition. The surface layers were gradually removed and the rest of the piece of bronze was analyzed. Extremely high tin and low copper concentrations were observed on the surface. Contrariwise, the element concentrations inside the piece correspond to “true” bronze. This is very important information for understanding corrosion processes in bronze. It seems that corrosion protects tin and removes copper from the surface.

It has been shown that XRFA can be successfully used for corrosion study. In addition, other important information concerning the origin and the utilization of studied objects are obtainable.

This research was carried out in cooperation with the ISIB-Haute Ecole Paul Henry Spaak (Brussels, Belgium) and the Museé Royal de Mariemont (Morlanwelz, Belgium).

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# Role of Kinetic Processes for Sorption Dynamics

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Environmental contamination resulting from the extensive use of harmful substances of different origin in industry, in agriculture, and in manufactured products has magnified the threat of toxicity for society. Since soils and sediments have a large capacity for sorbing great part of these substances, an understanding of reaction mechanisms of them with natural materials is critical. Results from the studies describing various aspects of contaminant sorption have been used to develop regulations, devise cleanup strategies, and develop models that predict the fate of the contaminants in the environment [1]. Various experimental and computation techniques have been used in such studies, among those the flow-through experiments and the modelling of them are of the significant importance. In the flow-through systems, particularly using packed soil columns, is studied (in the case of the use of sorbing filling) so-called sorption dynamics, e.g. the dynamical interaction of the contaminant diluted in the flowing solution with the stagnant filling material. This type of experiment serves not only as the physical model of sorption dynamics in the real system in the environment but also as the source of model parameters, gained by means of a fitting procedure, of processes affecting spreading of contaminants in the environment.

The so-called equilibrium sorption dynamics is reached if sufficient time contact of solution with the sorbent is allowed; this state is characterised by the same amount of sorption at different flow velocities. On the contrary we speak about the nonequilibrium sorption dynamics if the increasing flow velocity causes the decreasing sorption in the layer of the stagnant sorbent. This nonequilibrium state in the sorption dynamics, which can be experimentally distinguished also using flow-interruption experiment, are affected by kinetic processes of different physical and/or chemical nature. Sorption nonequilibrium may arise due to the sorption reaction itself being slow (chemical kinetics), or if the soil solution is not well mixed (physical nonequilibrium described, e.g., by double-porosity or “two-region” model), or both. Time-dependence of contaminant sorption during transport might be due to film or intrapartical diffusion, or diffusive transport between mobile and immobile portions of the flow domain. A comparison of the sorption and desorption flanks of the breakthrough curves can provide clues about the reversibility of solute sorption during transport. Nonlinearity of sorption isotherm and kinetics of sorption/desorption reactions can influence the shape of sorption and desorption flanks of a breakthrough curve. Partial reversibility of sorption will influence the desorption flank markedly.

The non-ideal shape of a breakthrough curve can be further caused by the dispersion in the column filling. This effect can be, for the modelling, eliminated by means of an independent experiment with a non-reacting tracer. The independent batch experiments, which can give information about the shape of both sorption equilibrium isotherm and sorption kinetics, are also of great importance.

The dynamic behaviour of sorption columns and the sorption dynamics in real systems can be modelled by a transport code that has to include the appropriate description of both equilibrium and kinetic phenomena. Codes based on an analytical approach of the solution of

the transport equation include obviously a simple description of kinetics [2], and should not be therefore used as a tool for the description of a specific kinetic phenomenom. On the contrary their use for the predictive modelling of the behaviour of a sorption system can be recommended in many cases. The more adequate description of kinetics needs mostly a more sophisticated code that is obviously partly [3] or fully based on a numerical approach to the solution of the transport equation.

The own system of evaluation of experimental data and modelling of sorption processes was developed. The code KINET serves as a tool to the choice of the best model of sorption kinetics; it uses Runge-Kutta method of solution of the ordinary differential equation. The code MIV1D solves the 1D-transport equation in the saturated layer by the finite difference method. The incorporation of sorption equilibrium and kinetics is global implicit, therefore the computation proved a good efficiency.

The numerical studies performed by codes available demonstrated the possibility of them to separate various influences causing the non-ideal shape of the breakthrough curves, which also in the case of dominating kinetic condition can serve for the choice of the most suitable experimental conditions. The simple transport code CXTFIT [2], which enables the determination of model parameters by fitting the experimental breakthrough curves, was also used with a success for the prediction of the dynamic behaviour of an industrial sorption column using evaluation of results of a set of laboratory experiments performed in the kinetic regime [4]. The more sophisticated numerical approach mentioned above proved to enable the discussion about the role of various phenomena inducing kinetic behaviour of sorption system.

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# Elemental Composition of Aerosol in the Region of Příbram Mines

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External environment has an influence on living organisms, which live in it. Beside others, solid aerosol floating in the air contains many elements, which can be risky for health of living beings. The aerosol may be of natural origin or produced by human activity. Human activity can also carry out an underground material to the surface, where it decays and is eroded on dumps. Also a geogas or water vapour can transport fine particles of the material out of the dumping ground [1]. Elevated by wind it contributes to the air pollution. Such situation can be found in region of mines, where the underground material is exposed to atmosphere on mine dumps, which become sources of aerosol. Tiny grains of the aerosol are transported far from the source and pollute all the region.

In connection with medical investigations of environmental impacts on health characteristics, several series of samples of a respirable aerosol has been taken in the Příbram mine region. Two simultaneous series were taken in small towns Milín and Bohutín. The samples were picked up near the schools, where the health characteristics were formerly measured. Also, two other simultaneous sample series were taken at mine dumps No. 15 and No. 19 in the region. Collecting probes where placed leeword of the mine dumps at their foot.

To obtain the respirable aerosol samples two identical probes were used. Fine fraction of the aerosol was deposited on Milliprobe membrane filters, while coars fraction was separated in the impactor before. The fine fraction deposit on the filter presented the sample. Particulates of the aerodynamic diameter less than 2 μm (i.e. PM2) were collected in the towns, and particulate matter PM5 was collected at the mine dumps. Respirable aerosol from several cubic meters of air has been cought in each sample.

To analyse the sample by PIXE [2], protons of energy E = 2.105 MeV were used. The acquired x-ray spectra have been analysed with the use of GUPIX program [3]. The detection setup has been calibrated using Micromatter XRF calibration standards. Contents of elements in pure membrane filter has also been determined, to be subtracted from the yield of exposed sample. Nineteen elements have been followed: Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Sb, Br, Sr, Zr and Pb.

It is interesting to compare abundance and composition of aerosol in samples from the two towns or from the two mine dumps, as they were taken at the same time under essentially the same conditions. There is no remarkable difference between samples from the two towns.

The most pronounced is sulphur concentration, nearly the same at both places. Besides common natural elements like Si, K and Ca protrude also Fe, Zn, Ti, Mn, Cu and Pb. Other elements has been found in concentrations about their limit of detection or lower. The aerosols from the mine dumps are different. Not as for their composition but for their amount. Elemental concentrations in aerosol from dump No. 15 are quite similar to those from the towns. Also aerosol from the dump No. 19 has similar composition but is several times as abundant as that from the dump No. 15. It may be in accord with overall appearance of the dump No. 19, which is at first sight much more dusty than the other one.

Our measurements showed nearly the same composition of aerosol at all four measured places. However, the aerosol near the mine dump No. 19 had remarkably higher density. This mine dump can certainly be a local source of aerosol contamination in the region.

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# Analysis of trace elements in wood-rotting fungi by PIXE method

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Wood-rotting fungi, so as fungi, lichens and tree rings, can also serve as bioindicators and biomonitors to detect pollution of the environment [1]. One of the methods used to measure concentration of trace elements in these fungi is the PIXE (Particle Induced X-Ray Emission) method [2].

Using the PIXE method to measure such samples several problems occur : selecting of the methods of sample preparation, charge accumulation in these non-conducting samples, selection of proper filter in front of the detector, changing concentration of elements in the sample during analysis because of mass loss and heat radiation damage during analysis. In the first three cases, various solutions can be taken from literature on analyses of organic samples [3,4]. These solutions can influent concentration of some elements in the samples as well as quantity and quality of resulting information. It has to be considered when choosing the right measuring method.

Fruits of wood-rotting fungi *Ganoderma applanatum* (taken from the polluted Prague environment) were cut into rectangular samples 1-2 mm thick and 1,5 $cm^2$ in area [5]. These samples were used as the targets in preliminary experiments to find the conditions of analysis. PIXE method with 2 MeV proton beam was applied to determine the trace-elements concentration. Spectra were accumulated during exposition of the sample to proton beam. Analyses were performed with proton beams of different current (1-25 nA in area of 28 $mm^2$). Dependencies of the element concentration changes in the targets on exposition value (μC) below given current of proton beam were obtained. Observed changes were smaller than the uncertainty of the measurement. Also, values of currents were found out for which visible sample damages were not occurred.

The samples of most frequent species of wood-rotting fungi (*Ganoderma applanatum, Fomes fomentarius, Fomitopsi pinicola*) were collected in several locations with varying degree of environmental pollution. Concentrations of elements (K, Ca, Mn, Fe, Ni, Cu, Zn, Rb, Sr, Cd, Pb) in these samples were determined by using the PIXE method with 2,905 MeV proton beam of the current 25 nA. Mutual dependencies were analysed in detail. Concentration ratios for some elements remained unvarying with regard to species or location. It would explain, in some circumstances, the origin of trace elements in the fungi fruits [6].

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Section 12

# BIOMEDICAL ENGINEERING

# The Creation of Models of Biocybernetics Systems for Education

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The article describes biological data measurement and processing [1] and creation of models. The innovation is made in creation software for hearing signal processing, in creation methods for biological data processing [2], in creation of models of bio system:

- Influence of mental load on heart beat rate, blood pressure, skin response and EMG
- Auditory organ
- Circulation of the blood
- Cardiac activity
- Digestive system

and creation of learning text:

- Measurement of anthropometrics value
- Cybernetics system in biology and medicine
- Processing of information in central nervous system
- Audiometry
- Processing of anthropometrics value
- Audiometry measurement and software processing
- Software diagnostic of hearing

There is made software for hearing signal processing. Input is hearing signal and output is value hearing loss and proposition competent hearing aid for correction hearing loss. Software make possibility set measured audiogram and set audiogram from file and save measured audiogram to file. Software make possibility edit audiogram and contain database of patient and hearing aid. Software calculate intensity of hearing loss for left and right ear. Software make proposition competent hearing aid included set of hearing aid for assigned hearing loss.

Software have a few odds:

- Audiogram and curve of gain hearing aid are in one graph
- Consumer have possibility manual set hearing aid
- Instant set hearing aid on the screen.

Measured data was processed artificial intelligence methods:

- Expert system [3]
- Fuzzy
- Learning machine [4]
- Neural network.

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# College Licence of Matlab for CTU in Prague, MU in Brno and UWB in Plzeň

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10 years ago was established a very useful cooperation among the Czech Technical University in Prague, Masaryk University in Brno and University in West Bohemia concerning with the utilizing of so called "college" license of Matlab. Every student or worker of the above-mentioned universities has full 24 hours access to this license of Matlab via Internet. Release of Matlab can be installed at any computer within the above-mentioned universities but the number of contemporaneous processes depends on a number of licenses of Matlab kernel and additional toolboxes. Based on the financial support of FRVŠ project there was performed an upgrade of the Matlab licenses at the March of this year. This update consisted of 25 licenses of the Image Processing Toolbox and 25 licenses of the Communications Toolbox with 1-year maintenance. There are 3 license redundant servers. There is also possible to set up a utilizing of any number of Matlab kernel licenses or Matlab toolbox license for a specific day, e.g. The current "college" license of Matlab is in version 6.5 (release 13). There are 150 licenses of Matlab and Simulink kernels and 50 licenses from each toolbox, excluding Image Processing and Communications Toolboxes having 25 licenses. The detailed list of installed items is the following:

| | |
|---|---|
| MATLAB Toolbox | Simulink |
| Communications Toolbox | Communications Blockset |
| Control System Toolbox | DSP Blockset |
| Fuzzy Logic Toolbox | System Identification Toolbox |
| Image Processing Toolbox | Neural Network Toolbox |
| Optimization Toolbox | Partial Differential Equation Toolbox |
| SB2SL (converts SystemBuild to Simulink) | |
| Signal Processing Toolbox | Spline Toolbox |
| Statistics Toolbox | Symbolic Math Toolbox |

Because of MATLAB is very powerful tool follows the detailed description of the Image Processing Toolbox and Communications Toolbox integrated within the MATLAB from The MathWorks [3].

Key Features of the Image Processing Toolbox:

- Linear filtering and filter design,
- Image analysis, including pixel, region, and feature statistics and measurement,
- Image enhancement,
- Binary and grayscale morphology,
- Image segmentation,
- Spatial transformation,
- Image registration,
- Image deblurring

- FFT, DCT, and Radon transform,
- Region-of-interest (ROI) processing,
- Multidimensional image processing,
- DICOM import in addition to supported file formats in MATLAB®.

We use this Image Processing Toolbox within the exercises of the subjects Medical Imaging Systems 1 and 2 (see [2], [3], [4]), Image Processing and Photonics for students at CTU in Prague and Imaging Technology for students at Medical Faculty of Charles's University as well.

Key Features of the Communications Toolbox:

- Signal generator functions for creating test signals,
- Display functions, such as eye diagram and scatter plot, to visualize modulated signals,
- Source coding, including quantizers, differential pulse code modulation (DPCM), μ-law and A-law companders,
- Block coding with Reed-Solomon, Hamming, BCH, general cyclic, and linear codes,
- Convolutional coding, including Viterbi decoders,
- Baseband and passband digital modulation functions, including amplitude shift keying (ASK), phase shift keying (PSK), and frequency shift keying (FSK),
- Baseband and passband analog modulation libraries, including analog modulation (AM), frequency modulation (FM), and phase modulation (PM),
- An additive white Gaussian noise (AWGN) channel,
- Galois field object for easy manipulation and representation of algebraic codes.

Our experiences with a utilizing of "college" license of Matlab are very good and we are suggesting this approach to all the rest of Matlab users at the above mentioned universities. Despite a very effective and relatively low-cost financing of the upgrade in question. I believe that this mentioned approach is the best for the next upgrading and utilizing of this "college" licence of Matlab at the three above mentioned universities (see [1]).

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# Gas Exchange Modelling During Artificial Lung Ventilation with Tracheal Gas Insufflation

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There are many techniques of conventional artificial lung ventilation (CV) of patients with acute respiratory failure that are widely used in the clinical practice, but there are still some limiting factors of their usage, many of adverse effects and there are also frequent cases when the artificial lung ventilation fails. Therefore, new unconventional ventilatory techniques have been developed. Some of them, e.g. high frequency ventilation (HFV), have been introduced into the clinical use recently.

Conventional artificial lung ventilation uses physiological breathing frequency and also physiological tidal volumes $V_T$ that can be too big in some severe lung diseases. Ventilation with high $V_T$ leads to additional ventilation-induced lung injuries. The main advantage of high frequency ventilation is reduction of tidal volume and pressure amplitude in the airways. In order to maintain constant gas exchange with reduced tidal volumes, the ventilatory frequency must increase rapidly. Typical ventilatory frequency during HFV is 5 -25 Hz in newborns and 2 - 10 Hz in adults. Very small tidal volumes $V_T$ are used during HFV. They are very often comparable with volume of the anatomic dead space $V_D$. According to the standard ventilation equation there should not be sufficient gas exchange for $V_T/V_D$ ratio near 1, but thanks to the very complicated gas transport mechanisms during HFV, sufficient alveolar ventilation can be reached for $V_T/V_D$ ratio even less then 1. The $V_T/V_D$ ratio plays a very important role in efficiency of HFV. Even a very small change of the $V_T/V_D$ ratio evokes a very rapid change of alveolar ventilation and consequently significant changes of arterial blood gas pressures of oxygen ($P_aO_2$) and carbon dioxide ($P_aCO_2$). This effects and functionality of ventilation when $V_T < V_D$ cannot be explained without exact description of gas flow including all possible gas transport mechanisms.

Some ventilatory techniques are still examined by researchers and they are not yet used for ventilation of patients. Tracheal gas insufflation (TGI) is one of these ventilatory techniques providing additional ventilatory support to conventional or high frequency ventilation leading to improved oxygenation and $CO_2$ removal without increase in tidal volume or pressure amplitude in the respiratory system.

Tracheal gas insufflation is a method within the array of supporting unconventional ventilation techniques. TGI is based on fresh air delivery to the endotracheal tube or to the airways using a thin TGI catheter with a constant TGI flow of fresh air. The distal end of the TGI catheter ends several centimetres above carina. TGI is used as a conjugate technique to conventional artificial lung ventilation [1]. Expired gas in the trachea, endotracheal tube and in some main bronchi is washed out and replaced by fresh air delivered from the TGI catheter. This principle partly protects lung from the re-inspiration of already expired gas. The effect is equivalent to the anatomic dead space reduction.

A new method of ventilation based on combination of TGI with HFV has been documented in one experimental study [3]. Considering the effect of $V_D$ in HFV and effect of $V_D$ reduction during TGI, the combination of HFV and TGI may offer a surprising result. Understanding and exact evaluation of TGI effect is very important task for future clinical introduction of the method and they cannot be carried out without modelling of gas flow in the

respiratory system. This is not easy task because of complex behaviour of gas during its movement and because of complexity of the respiratory system.

The aim of the study is to model gas flow and its effects during both conventional and high frequency ventilation in the respiratory system. Furthermore, introduction of tracheal gas insufflation into the model is carried out so that final mathematical model could predict clinical outcomes of the conjugate applications of CV + TGI and HFV + TGI.

Bases of the gas flow modelling during artificial ventilation are described by Jongh [4] where convection-diffusion equation is presented. Unfortunately many simplifications have been applied and several incorrect principles not respecting physiological processes have been introduced into the computation. Therefore it was necessary to make changes in the model and employ simulation of regional oxygen consumption, regional velocity calculation, etc. The TGI ventilation is modelled as a additional source of gas mixture, situated in the respiratory system.

Very important part of modelling is testing of the TGI gas flow model validity. Two results were compared: 1) results of the mathematical simulation by the created model, 2) results of animal experiment [2]. Only one is made with exactly defined conditions. Unfortunately the results are obtained for different objects: simulation is carried out using the model of an adult (78 kg), but the experimental results come from animal experiment on a group of rabbits (2.5 kg). However different the examined objects are, the results still can be compared. Some appropriate anatomical and ventilatory parameters are proportional to the body weight. The fact that they are measured in human being or in different animal species does not play a very significant role. Some essential ventilatory parameters are equal in both cases.

The last difference between the theoretical and experimental approaches is that mathematical modelling produces values of alveolar partial oxygen pressure $P_AO_2$ whereas the animal experiment provides values of arterial partial oxygen pressure $P_aO_2$. There is a small physiological difference between these two values in healthy objects. But when studying only changes of these values, there are always proportional and they have to be very similar.

Results of the animal experiment confirmed that TGI is more efficient during HFV then during CV. The difference in increased oxygenation is $\Delta P_aO_{2\,\mathrm{HFV+TGI}} - \Delta P_aO_{2\,\mathrm{CV+TGI}} = 11.2 \pm 3.6$ % and for mathematical simulation $\Delta P_AO_{2\,\mathrm{HFV+TGI}} - \Delta P_AO_{2\,\mathrm{CV+TGI}} = 14.4$ %. Alveolar $P_AO_2$ is calculated as steady-state alveolar oxygen fraction multiplied by atmospheric pressure. The presented results show a good agreement of the theoretical simulation with the animal experiment.

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# Three-Dimensional Dosimetry Using Gel Dosimeters

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In modern radiation therapy more and more complex dose distributions are used to conformaly cover target volume to asure normal tissue sparing. Thereby, for example, dose escalation to target volume which can improve tumor control is allowed. To realize such complex dose distributions, dosimetricaly difficult dose delivery techniques are used. IMRT (Intensity Modulated RadioTherapy) is such a modern method of dose delivery using relatively large number of small and very irregular shaped radiation fields associated with increased dosimetric complexity. Therefore there is a need of dosimetric tools able to verify both the absolute dose and relative dose distribution as calculated by clinical treatment planning systems.

A relatively new and promising tool, able to measure dose distribution in all three dimensions is a 3D gel dosimeter evaluated by, generally, 3D imaging method and based on either radiation induced oxidation (Fricke infused gel) or polymerization (polymer gel). A 3D gel dosimeter itself forms a tissue equivalent phantom in which a dose distribution is recorded. Reading of such recorded dose distribution can be performed by dosimeter's magnetic resonance imaging (MRI) which is currently more and less established procedure. On the other hand, because of some technical difficulties (temperature dependence, spatial dependence and response reproducibility), difficult availability and high price of MRI technique, alternative, optical based evaluation methods become more important and favorite last years.

Purpose of this study has been to manufacture an optical computed tomography based device and perform first measurements with a 3D gel dosimeter to determine basic dosimetric characteristics such as dose response curve and investigate the influence of imaging parameters.

Manufactured optical computed tomography scanner (OCT) consists of uniform sources of light, water tank, fixation holders connected to computer controlled step motor and CCD camera as a detector of transmitted (scattered) light. Construction of OCT enables various illumination geometries using one or two sources of light. These luminaries are common white photographic sources with lenses and a condenser to assure homogeneity. A dosimeter is imaged in a water tank to minimize light refraction. Taking CCD images of a dosimeter being rotated is also computer controlled.

Basic dosimetric characteristic of every dosimeter is dose response dependence (curve) under various conditions. Therefore dependence of optical properties of both modified Fricke gel dosimeter (FXG) and polymer gel dosimeter (PG) on the dose was investigated..

FXG with xylenol orange (XO) (violet complex with $Fe^{3+}$) added was irradiated with the doses from 0 to 28 Gy. Absorbance of dosimeter samples was measured spectrophotometrically at various wavelenghts. Aftewards, identical samples were imaged with CCD camera in transmitted light. So called CCD absorbance was defined as a decadic

logarithm of the ratio of intensities corresponding to dose of 0 Gy and actual dose. Similarly, the film standard with known optical density was measured and the value of CCD absorbance was used to correct the instabilities of the scanning process. There was observed a good correlation between CCD absorbance derived from green compound of the image only and spectrophotometric absorbance at 440 and 580 nm.

Further, optical properties of the polymer gel dosimeter irradiated with various doses were evaluated by the measurement of CCD absorbances at transmission geometry and CCD intensities of the scattered (90°) light taken under rectangular illuminator-detector geometry. CCD absorbances determined were then compared with corresponding NMR relaxation rates 1/T2 obtained using the MRI scanner. The best correlation was observed for CCD absorbances derived from green compound as well. CCD intensities obtained at the scattering geometry of measurement were correlated with corresponding relaxation rates as well. Again, the best correlation was achieved taking just green compound of the image. In addition, there was observed saturation of CCD intensity at NMR relaxation rate of around 5 $s^{-1}$, followed by relatively steep fall off. This effect might be explained by multiple scattering processes taking probably place in case of samples of greater density (both physical and optical) and dose, respectively.

There was also performed first measurement dealing with the 3D use of the system. Five glass vessels (one bigger, four smaller) were filled with solutions of various concentrations of copper sulphate ($CuSO_4$). Sixteen CCD projection images in total were acquired in transmission geometry in the range of 0-180°. Central slice of each image was selected to test first version of reconstruction algorithm. In case of this solution, red compound of the response showed acceptable results. The algorithm tested was made as a procedure of MATLAB program using its intrinsic procedures. Program is based on simple backprojection algorithm to fully control image pixel intensities. The reconstructed image shows a lot of artefacts due to presence of impurities and scatter effects in the field of view during acquisition. Also CCD intensity of images of samples does not fully reflect various concentrations of copper sulphate.

Based on first results we can draw following:

- CCD absorbance seems to be a good parameter of radiation response of both Fricke and polymer type gel dosimeters.
- Better results were obtained using rather transmission than scattered light geometry of CCD imaging for polymer based gel dosimeter. The use of geometry of scattered light is difficult and requires fundamental modification of the system.
- Concerning tomographic reconstruction, it is necessary to optimize reconstruction algorithm with respect to its speed, supress artefacts associated with impurities and unwanted scatter of the light, investigate potential position errors as well as chose a proper mathematic filter.

Method of three-dimensional dosimetry has large potential in dose verification processes in radiation therapy. Optical based dosimeter evaluation provides some advantages with respect to MRI, namely low price and easier availability, but to introduce this method as a superior one, further studies are required.

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# Dependence of Opening Angle on Position in Aortic Tree

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There are two ways how arteries in human body are loaded. The first is loading by intraluminal pressure of the blood flow. Second is by residual stress. We can observe residual stress in two directions, in axial and circumferential direction respectively. This residual stress is still staying in the vessel wall in unloaded state (zero blood pressure). The most important for the wall mechanics and stress distribution is residual stress in circumferential direction. It was first time observed in the middle 80th by Chuong and Fung.

We can convince about it after excising an artery from human body. When we sliced a ring of artery, mount it and cut radialy. After radial cut a ring will open to the stress free configuration. This stress free configuration is characterized by opening angle. An opening angle we use to estiomation of residual strain. If constitutive law of an artery is known computing of values of residual stress is possible.

The role of residual stress in arterial mechanics is not known sharply. But results of our computions lead to decreasing of values of circumferential stress in arteris. So it is generally presume that residual stress in arteries is adaptation of vessel walls to loading. It causes redistribution of stress to less stressed state. But pathological values of opening angle were seen too. Thees lead to overloading of wall layers.

Significant dependence of opening angle on localization in aortic tree, sex, time after death and age was observed. Our experimantal measurement of opening angle of aortic specimens study just thees influences. Data are divided to six groups in according thees factors.

Experiments with human aortic specimens are performed in the Depertment of Forensic Medicine of Tecaching Hospital Na Královských vinohradech in Prague. Specimens from autopsy are used. 167 specimens were tested at present, 117 male specimens and 50 female. They were obtained from 39 male bodies and 16 female. Specimens are excised from thees position in aortic tree: aortic arcus, position just above diphragma and just below reanl arteries. Three specimens frem each body are obtined excepting a few cases. The problem is that threefold less autopsy of female than male caused by less controled death rate in women than in man.

Regression analysis of opening angle depended on sex, age and position in aortic tree is made. We make two-factroial regression analysis (age, time after death) too. Bodies with more than 30 hours death time are not included to our analysis. We are using regression functions in polynomial shapes to linear regressions (linear in coefficients of regression).

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# Estimation of Age Based on Ossification Ratio Male Thyroid Cartilage

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There are many methods to determine age of people with unknown identity (crime victims, etc). Morphological methods are based on for example survey of stage of dentition, prolongation of pithy cavities in femur and humerus in epiphysic and capitic directions, increasing of circumferece of thoracic and abdominal aorta, stage of symphysis, productive changes of upper extremity carpus dermining by X - ray.

Using of computing analysis of X – rays of thyroid cartilage to determining of ossification ratio as method to estimation of age was first time described by Leopold and Jagow in 1960. Both authors found degree of ossification ratio on thyroid cartilage by X – ray analysis of larynx samples. It was investigated 520 samples of thyroid cartialge, 281 male and 236 female samples 0 – 89 years aged. Experimental material was obtained from common autopsy. Relationship between ossification ratio of thyroid cartilage and age was shown directly by authors. Ossificaton ratio depend on age in thyroid cartilage, other cartilages of larynx have not thees relation with age. L. Schott used this method to estimation of age of old slavonic man in Gustavel. This theme was studied by E. Vlček in Czechoslovakia (1974 and 1980). He used X ray analysis of thyroid cartilage in his work with paleoantropological materials. He validated the theory of above described authors using less noumber of samples. At present is using computational X ray analysis of thyroid cartilage for example by Sugiyama et al. (1995).

We use the theory presented by Japanese authors to determine quantitative relationship between age and ossification ratio using computational X – ray analysis. Using measurements of controled samples (obtained from rutin autopsy) we pick up useful data for determining this relationship.

In Department of Forensic Medicine of 3rd Faculty of Medicine Charles University and University Hospital Na Královských vinohradech were studied 176 male samples obtained from sectional autopsies. Cartilages were prepare and fixed by usual methods. X – rays were performed by General Electrics apparatus using voltage 40 kV, electric current 100 mA, focuse 80 cm, exposure 0,12 s. This way obtained pictures were scanning by videocamera and treat by graphical software LUICA Screan Measurement LIM. Using computational analsis of scans was found area of all cartilage nad area of ossified parts. Now the ossification ratio was computed for each one.

Linear regression analysis with least square method was used to determine quantitative relationship between ossification ratio and age. We use linear regression (linear in coefficients of regression) with logarithmic shape of regression function:

$$y = a * \ln(x) + b$$

Where y is age and x is ossification ratio, a and b are regression coefficients. Values of a, b were determined by leastsquare method in this shape a = 54.0862 and b = -154.187. The coefficient of determination $r^2$ was computed also, $r^2 = 0.6054$. This value of coefficient can be think as good. This method for estimation of age do not give to good results before 20 years of age. Otherway are results satisfactory. Estimation of age based on ossification ratio of thyroid cartilage is an objective method independent on investigative person.

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# Influence of Anthropometric Parametrs on Maximum Aerobical Output

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The objective of this study is to find an influence of anthropometric parametrs on maximum aerobical output during clique ergometry and after it we would like to improve training methods (individual training load) in accordance with results of our measuremnts.

A fitness during ergometry in our laboratories is determining by physical units and bilogical parametrs as for example output, heart rate, oxygen consumption etc. Output is described in watt [W] or in watt per unit of body weight [W/kg]. Influence of anthropometric parametrs on body output during clique ergometry was studied by Aminoff (1996), Blimkie (1988) and Enders (1994) in the past. The relationship between anthropometric parametrs of upper extremities and body output was proved. Significant correlation between maximum oxygen consumption and proportion of upper extremity was shown.

32 male persons aged in range 19 – 30 years were included to our study. Nobody of them was impaired or other treatment method was used by him especially medicamentous during tests. Set of tested persons was divided into two groups under training and without trainig respectively. Objects were screened and anthropometric parametrs were measured. From thees data sets parametrs to finding relatinons and correlations were computed by Ulbichová method, Matiega method. Included and computed parametrs: muscles weight [kg], muscles quantity [%], lipids [%], upper extremity [kg], corrected upper extremity [kg], brachium [kg], corrected brachium [kg], anterbrachium [kg], corrected anterbrachium [kg]. Dependece on thees parametrs of output, output per unit of weight, oxygen consumption and oxygen consumption per unit of weight was measured by clique ergometry.

Tested persons were loaded by ergometry to maximum subjective output with warming-up period. KEW – 12 II ergometr (Medicor) was used. Heart rate and respiratory gases changing during ergometry were measured.

Results for nontraining persons we can summarize: the highest linear correlation was obtained for muslces [%] – oxygen consumption in [%] r = 0.6261, muscles [kg] – O2 [%] r = 0.6254, muslces [%] – output [W] r = 0.6971, muscles [kg] – output [W] r = 0.60. Other good correlation was obtained for muscles [%] – output [W/kg], lipids – output [%] (r = -0.601), muscles [%] – O2 [kg], lipids – O2 [%].

Results for training persons we can summarize: the highest linear correlation was obtained for muscles [kg] - output (P) [W] r = 0.572, upper extremity [kg] – P [W] r = 0.6982, corrected upper extremity [kg] – P [W] r = 0.6982, brachium [kg] – P [W] r = 0.7021, corrected brachium [kg] – P [W] r = 0.7022, anterbrachium [kg] – P [W] r = 0.6526, corrected anterbrachium [kg] - P [W] r = 0.697. Between oxygen consumption per unit of weight were obtained similary high linear correlations.

We can say that correlations are higher in the case of training persons than nontraining one. Noumber of all significant linear correlations is higher for training persons than non one too. But correlation is manifested especially for brachium and anterbrachium (case of training persons). It is because of their traning of upper extremities during their sport activities.

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# Oncology and Microwave Applicators

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Thermotherapy (Hyperthermia) is the one of the methods of complex cancer treatment. This method is based on the fact, that cancer cells are more temperature - sensitive than normal cells. In conjunction with others therapeutic methods, mainly with radiotherapy, it has very good benefit for patients. Goal of this project was realization of Evanescent Mode Waveguide Applicator for local Hyperthermia and its comparison with Waveguide Applicator, which is clinically used. Local Hyperthermia is mainly used for treatment tumors: Hand and neck, breast and sarcomas.

Applicator for microwave thermotherapy is an important part of every Thermotherapeutic system, because it determines the distribution of electromagnetic energy in the front of applicator's aperture. Applicator provides impedance adaptation between complex impedance of biological tissue and 50 Ω impedance of coaxial exciting line as well.

Waveguide and Evanescent waveguide applicators have aperture 18 x 12 cm and are operating at 434 MHz. Evanescent Mode Applicator is a waveguide, which is excited under cut off frequency. Entering capacity and inductive characteristic admittance of TE mode build up band pass filter for operating frequency. Reflection coefficient has to be lower then –13 dB on the operating frequency. Configuration of exciting elements must be devise in relation to exciting dominant mode and in relation to eliminate higher modes. It was done with adequate distance of elements from applicator's aperture. The most difficult part of the project is problem of exciting element. The theory of this one is not complete and consequently it is necessary to experiment.

Reference Waveguide Applicator is clinically used in Department of Radiation Oncology of Bulovka Hospital in Prague since 1993 for superficial and subsurface Hyperthermia. It is filled by dielectric with relative permitivity $\varepsilon_r$=5,8 for decreasing the cut off frequency. It is the reason, why this applicator is very weighty. For impedance adaptation is necessary to use external impedance transformator.

After verification of impedance adaptation is necessary to know the distribution of electromagnetic field or temperature profile in the front of aperture. Next equation applies to SAR (Specific Absorption Rate is defined as power absorbed in 1 kg of tissue). $SAR = c\frac{\Delta T}{t}$ [W/kg]

c…heat capacity of agar phantom (c = 3000 $J \cdot kg^{-1} \cdot K^{-1}$),
t…period of heating,
ΔT…thermal increment

For good knowledge of SAR distribution is necessary to measure thermal increments in high enough number of points in the front of aperture. It was done by Teflon probes with thermistory sensors. Power level: 185 W. The biological tissue with high volume of water (e.g. muscle tissue) was represented by agar phantom DUBLAGA. As the alternative, it is possible to use, water phantom with detector diode (LED).

For treatment planning is very convenient to use numeric methods. In our laboratory we have modern software products (e.g. FEMLAB, SEMCAD).

The both applicators allow homogenous effective heating to the depth 7 cm. Waveguide applicator can be used for heating larger tumors. Evanescent applicator protects superficial healthy tissue, because its SAR maximum is 3 cm below surface and. Also this one has higher efficiency (more than 2x approximately), because of the waveguide applicator's dielectric filling.

# Motion Analysis of Human Lower Jaw in 3D

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The range and pattern of human masticatory system movements during function are of considerable interest and they are a typical example of kinematically and mechanically indeterminate system. Two segments, the mandible and the skull, are able to move with respect to each other. These movements are guided by two temporomandibular joints. In each joint a mandibular condyle articulates incongruently with the articular surface of the temporal bone. The articular capsule is slack. Due to this construction both joints allow for movements with six degrees of freedom (Koolstra and van Eijden, 1999). The jaw movements are not limited to rotations about one or more axes defined by the joint (Andrews and Hay, 1983). If the joint surfaces are assumed to be undeformable and maintain contact all the time, the mandible still is able to move with four degrees of freedom. Jaw movements can be defined by the three dimensional path travelled by the lower central incisor (Lewin, 1985). This can be accomplished in various ways with the system that is able to move with at least four degrees of freedom. Consequently, the masticatory system must be considered as kinematically redundant.

In this study is used a method of motion analysis to record three dimensional movements of mandible. There were used three SONY DCR-TRV900E digital video camera recorders for lower jaw movement recording and commercial software APAS for video sequences processing, three dimensional reconstruction of lower jaw movement by the method of direct linear transformation and result evaluating. All these devices are properties of Laboratory of Biomechanics of Man.

Own experiment consists of several steps. First step is video cameras calibration, second step is marking of anatomically significant points onto cranium of patient, third step is recording of video sequences of mandibular movement during patient masticating of different kinds of nutriment with three video cameras at the same time, fourth step is measured data elaboration and evaluation with APAS software and the last step is statistical evaluation of outcomes.

Video cameras calibration was achieved by specially constructed calibrating cage. Three dimensional space was calibrated into Cartesian coordinates. The x coordinate represents lower jaw movement in lateral direction, y coordinate represents lower jaw movement in cranial direction and z coordinate represents lower jaw movement in ventral direction. The main goal of this project is statistical comparison of frequency of mandibular displacement in each direction.

The special pointer was rigidly fixed to patient lower dentition in order to measure lower jaw movement. Black marker was attached at the end of the pointer in order to read pointer coordinates with cameras. Other black markers were set at anatomically significant points of patient face in order to eliminate patient head movement during recording.

Each subject of experimental research was asked to masticate different nutrition e.g. bakery, nuts etc. This procedure was recorded by three video cameras. These cameras were placed at such a three different places, so all makers should be recorded at all cameras. The clappers were used for time synchronization of cameras. A cameras recording frequency was 50 half frames per second.

From video record of simultaneously recorded camera views were obtained coordinates of all markers during recorded lower jaw movement. The coordinates of markers were detected from video records in software APAS for all three camera views. The direct linear transformation method was used for markers displacement computation in x,y,z axes and other geometric and kinematics parameters of mandibiular movement. This method was used for camera calibration and the marker position computation and it is involved in APAS software.

The statistical analysis of this experiment will be performed in the future, because of low count of observed patients up to now. The analysis of contact pressures and bite forces during masticating will be also made concurrently with three dimensional motion analysis.

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# Accreditation of Mechanical Testing Laboratory in Accordance with the Standard ČSN EN ISO/IEC 17025:2001

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This research report deals about the accreditation process of Mechanical testing laboratory. Mechanical testing laboratory (MTL) resides at the Czech Technical University in Prague, Faculty of Mechanical Engineering, and is a part of Department of Mechanics, Laboratory of Biomechanics of Man.

The laboratory is equipped with the top test system MTS 858.02 Mini Bionix, that has two load channels and makes it possible to execute simultaneously tests in two axis - tension (thrust) and torsion. This system we can find in many other biomechanics laboratory, that cooperate with manufacturers of bioimplants not only for development own replacements, but also on development testing methodology. Therefore MTL provides area for testing of biomaterials according to international standards ISO, ASTM and EN.

In the year 2000, the idea originated from the cooperation with the firm Saint-Gobain Advanced Ceramics, Ltd. to accredit the laboratory for practice some special tests of ceramics.

Accreditation of laboratory understood an official recognition by Czech Accreditation Institute of the fact that subject is competent to carry out specific tests. Within the framework of the Accreditation System of the Czech Republic (ASCR) it is the Czech Accreditation Institute, Public Service Company (henceforth CAI), which is the national accreditation body of the Czech Republic and which ensures the accreditation of:

- testing laboratories
- calibration laboratories
- certification bodies for certification of: products, quality management systems, EMS, personnel,
- inspection bodies,
- environmental verifiers (EMAS programme),
- providers of proficiency testing schemes.

Accreditation is carried out on the basis of internationally recognized criteria and rules, contained in international standards, normative and further documents applicable to accreditation, respective Methodological Instructions for Accreditation (MIA) and EA, ILAC and IAF documents, issued by CAI in view of the general nature of international standards and normative documents applicable to accreditation and approved by CAI for implementation in the National Accreditation System of the Czech Republic. The purpose of the MIA is to interpret and refine the criteria contained in the above-mentioned international standards, normative and further documents applicable to accreditation.

Mechanical testing laboratory obtained the printed Basic Information on Accreditation and the application for assessment/audit together with two identification annexes and a questionnaire for the applicant for assessment/audit together with the instruction for filling in the application form.

MTL had to buy the international standards, normative and further documents applicable to accreditation. Then it composed the documents that are necessary for enter to the accreditation process. Among these documents appertain Quality Manual in that is being described the quality management system of laboratory, Procedures for the observance of particular criteria of the standard ČSN EN ISO/IEC 17025: General Requirements for the Competence of Testing and Calibration Laboratories, Metrology System in that is being described e.g. the handling with gauges of Mechanical testing laboratory, the documents of organization structure and its legal position, and so on.

At first Mechanical testing laboratory underwent the preaudit of the quality management system documentation, on the basis of which some significant non-conformities in the quality system documents were identified and subsequently eliminated. Within the preaudit the quality management system documentation was checked in details for its completeness, formal correctness and sufficiency for given purpose.

Then MTL entered into the accreditation process. The on-site assessment includes the assessment of the documentation and functionality of the quality system of the entity, assessment of all standards, regulations and procedures, whether they correspond to given type of assessment, whether they meet the requirements stated for testing. Laboratory must demonstrate some tests that it wants to accredit.

Mechanical testing laboratory was successful in the accreditation process and earned the Certificate of Accreditation in December 4$^{th}$, 2002. MTL can carry out the following test:

- **Biaxial flexural strength** according to international standards ISO 6474:1994 (for ceramics materials based on high purity aluminia) and ISO 13356:1997 (for ceramics materials based on yttria-stabilized tetragonal zirconia)
- **3-point bending** according to the standard ČSN EN 843-1:1997 for ceramics
- **Wear resistance – Ring On Disc** according to the international standard ISO 6474:1994 for ceramics materials based on high purity aluminia
- **Tensile properties of ceramics** according to the standard ČSN EN 658-1:1999 for advanced technical ceramics
- **Tensile test at room temperature** according to standard ČSN EN 10002-1:1997 for metallic materials

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# The Modelling of Interaction of Biomaterials

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This research project dealt with a study of an experimental methods using for description of musculoskeletal system behavior by various conditions. Was established several mathematical models of musculoskeletal system (lower and upper extremity, shoulder complex,...) for muscular activity simulations. Obtained data by experiments had been used as input data for simulations models.

On all experiments antropometric respectively palpation measurement of human body dimensions, 3D movement analysis of human movement, and telemetric surface electromyography for description of muscles activity was used. It was necessary, for objective results of these experiments, to exclude all pathology of experimental man. The antropometric measurement of experimental man was done before concrete experiment and was compared to literature for an eventual simulation of this concrete movement. For synchronization of cameras and EMG the clappers with microswitch was used. The experimental area was calibrated for 3D analysis and later movement simulations. The direct linear transformation (DLT method) for the camera calibration and marker position computation was used. The body of experimental man had installed paper markers on anatomical significant points and surface EMG electrodes for movement and muscular activity identification. Self-adhesive diagnostic surface electrodes Biotabs Ag (MIE, LTD., UK) were used. Electrodes were connected to preamplifiers EMG 4K. Preamplified signal led into an EMG transmitter. We used six channels for EMG signals and seventh channel for synchronization with cameras. A receiver was telemetric EMG MTR8 (MIE, LTD., UK). For video motion analysis a digital video cameras recorder Sony DCR-TRV 900E were used. The record frequency was 50 half frames per sec. From a videorecord were obtained coordinates of significant points and from this coordinates were computed other geometric and kinematics parameters of movement. Video camera analysis provides the visual information about motion. Both of these are being passed to create a correlation between body motion and EMG signals from muscles.

At first was created three mathematical models of lower extremity. In first model only kinematic, mass and inertia parameters was implicated. In second model EMG activity of major muscular groups (flexors, extensors,…) was implicated too. In third model concrete muscles was implicated. Was problem with computation of bones loading, because is not know how the skeletal muscle work for motion in joint is distributed. Accordingly was established mathematical model of elbow joint with relatively few muscles involved in it relatively simple movement, only flexion and extension. A behavior of flexors (m. biceps brachii – caput longum and caput breve, m. brachialis,) and extensors (m. triceps brachii – caput longum, laterale and mediale) of elbow joint was studied. A behavior of elbow joint muscles was studied in various normal and pathological conditions. The EMG activity of above mentioned muscles in slow and fast movement (flexion and extension) and without and with loading 5 kg weight in hand, and its combinations was studied. The same EMG activity and movement in elbow joint with spasm in m. biceps brachii (evocation of pathological situations) was studied too. Was established, the different EMG activity is in various loading and various movement (EMG activity is not only higher but its timing is different too). In mathematical model of elbow joint movement the experimentally established kinematic parameters was used. Basic on restrictive

conditions (optimizations criteria) as the EMG activity timing, minimum of wirtual work principle and position of global joint force the global force and moment in elbow from muscles was computed. Was established, if the upper extremity goes to the flexion in elbow joint, the m. triceps brachii (extensors) are working too, the force from extensors has stabilizing character especially in cases with higher loading.

The above mentioned experimental methods were used for muscles reactions observation from random movement impulses and for identification of cause of muscular ache. The muscles reactions from random movement impulses were observed on horse rider trunks during hipotherapy. Hipotherapy is method used for relaxation and balancing of trunk muscles, especially paravertebral postural muscles. We can characterize the change time depending of muscular activity and the trunk movement that is represented with anatomical significant points in relation to step phase of horse walk, as a reaction of stabilizing muscles on opposite lateral escape of rider's trunk that has been generated by movement pulses of horse trunk. There was apparent correlation between backward leaning and rising activity of abdominal muscles as well as lateral leaning and rising activity of contralateral trunk stabilizing muscles in this experiment. The identification of cause of muscular ache was studied on often and sophisticated sports movement – volleyball smach. Basic on correlation of the shoulder complex movement and the muscles involvement, the probably function of every muscle during analyzed movement was detected. A probably causes of lokated shoulder complex anguish have been a chronic overload of muscles, there are anchored with tendons into the anguish place. A cause of the muscles overload is probably the high activity of affected muscles during analyzed movement and short time for their regeneration and the high frequency of analyzed movement during match or training (m.deltoideus, m. supraspinatus). A next mechanism of chronic muscles overload have been the moment of "hitting action" (m. teres minor, m. suprascapularis, m. pectoralis major et minor, m. subscapularis) with the high frequency of analyzed movement. The last argument looks to be a repetitive effect of impact load (m. biceps brachii).

The aim of this research project was to analyse a human muscular activity and its influence on global musculo-skeletal system loading. Muscular activity was investigated both various human locomotion, and in various magnitudes of loading and pathological conditions. Was verified using of electromyography and 3D movement analysis. Was established optimization criterion for solving of muscles cooperation, with a future possibility of using adaptive methods solving per artificial neural networks. Acquired knowledge and data will be in future used for assembling of mathematical models of musculo-skeletal system loading and optimization of orthopaedics items design.

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# Modelling of the Respiratory System with Respect to its Anatomical Structure Using Electro-Acoustical Analogy

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Artificial lung ventilation is the most efficient method for treatment of acute respiratory failure. Despite the fact that artificial lung ventilation has been examined properly and new protective ventilatory modes have been introduced, there are still strong adverse effects of artificial ventilation upon patient's respiratory system. A quite new ventilatory strategy is called high frequency ventilation (HFV). HFV can be characterised by increased ventilatory frequency (up to 40 Hz) allowing a significant decrease in pressure amplitude and delivered tidal volume. Usage of the small pressure amplitudes in the airways and breathing with very low tidal volumes prevent the lungs from overdistension, barotrauma and volutrauma. These properties represent the most significant difference between HFV and conventional artificial lung ventilation (CV) and they identify unconventional ventilatory strategies.

Different effects of artificial ventilation can be observed when conventional ventilation (CV) or high frequency ventilation (HFV) are used. Unpredictable differences mainly in oxygenation, which have not been explained yet, can be observed in clinical practice. Many parameters can influence the oxygenation, but their effect is mostly impossible to study directly in the human body. Therefore, deriving a mathematical model of the respiratory system exactly corresponding with the reality can be the only possibility how to study influence of mechanical lung properties through the bronchial tree, distribution of tidal volume among generations of alveoli, etc. A unique modelling approach has been chosen in this study based on the respiratory system modelling according to its exact anatomical structure in this study and simulations using the model are used to describe unequal effects of both the ventilation modes upon various parameters characterising intrapulmonary conditions.

A mathematical model of the respiratory system has been developed as an electro-acoustic analogy of the respiratory system respecting its exact anatomical structure. The structure of the respiratory system is very complex. The system branches 23 times and contains more than 15 millions of the individual airways. A regular dichotomy of the respiratory system is considered in this model. All individual airways are represented by short acoustic wave-guides with parameters computed using the common acoustic principles and published lung morphometry measurements. Alveoli are represented by acoustic compliances computed from their dimensions and overall lung compliance. The final model has 23 airway generations and employs 67 108 859 individual components.

A special method has been developed so that such a complicated model could be used for simulations of the real situations. Ventilatory frequency of 0.25 Hz is considered for CV and 5 Hz for HFV. Distribution of tidal volume $V_T$ and pressure amplitude among generations of bronchial tree, total lung impedance *(TLI)* and other variables are studied under various conditions by modelling.

The influence of respiratory mechanics upon the *TLI* was studied for frequencies that correspond with ventilatory frequencies used during CV and HFV.

Changes of alveolar compliance have significant effect on *TLI* during CV while *TLI* changes during HFV are not essential (effect of airway inertances). Contribution of airway resistance changes is significant mainly during HFV. *TLI* is essential variable for pressure controlled ventilation modes. Results of simulations describe and explain clinical experience.

Reduced alveolar compliance causes an increase of pressure in distal regions of the lungs. This increase is substantial for HFV whereas for CV is not very significant. The pressure in the distal regions of the lungs becomes 4 times higher when considering typical decreased alveolar compliance in HFV.

Nevertheless, the developed algorithm and the model-based simulations have several restrictions. A harmonic signal of the ventilator is supposed to be applied in the airway opening. A Fourier analysis has to be implemented into the algorithm in order to cover all real ventilatory signal shapes. Another limitation is that the corresponding elements in each generation can't have different values. Therefore only homogeneous changes in lung mechanics can be simulated. For more detailed simulations will be necessary to subdivide the model into the compartments that will be computed independently.

In spite these restrictions it is possible to use the simulation results to explain the differences between CV and HFV usage. Therefore some essential effects observed in clinical practice can be studied and explained by this modelling technique.

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# Mechanical Properties of Mitral Annuloplasty Rings

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Mitral annuloplasty rings are prosthetic implants used in heart valve repair surgery for reshaping and supporting a dilated annulus of the mitral valve. There is a lack of quantitative data on the mechanical properties of mitral annuloplasty rings.

In heart valve surgery, the issue of an optimal annuloplasty ring is under heated discussion. Foremost, its mechanical properties are assumed to be of high importance for the optimal performance of the heart post-operatively. From the clinical point-of-view, an annuloplasty ring should allow the desired re-modeling of the valve orifice, while not - or as little as possible - opposing the natural behavior of the valve. Several researchers have studied the kinematics of normal mitral annuli [3, 4]. Therefore, the annuloplasty rings have been evaluated by comparing the displacements they exhibited in vivo to the corresponding displacements of the normal annuli. All of the tested models showed significantly lower displacements as compared to those of normal annuli. While all the available models allow a successful repair of a dilated mitral annulus, no model allows a complete recovery of the normal mitral annular dynamics. Consequently, the physical performance of the patients post-operatively remains limited.

Until now, the mechanical design of mitral annuloplasty rings has been rather intuitive. It has been based on knowledge of the displacements observed by normal mitral annuli. Apparently, this approach has resulted in an increased number of different models on the market, rather than in finding an optimal implant. We assume that design approach based on knowledge of the load imposed on the annuloplasty rings in vivo is more appropriate. The in vivo load can be calculated from the previously measured in vivo displacements of a particular valvular implant, and the force-displacement characteristics of the same implant in the corresponding directions. For mitral annuloplasty rings, no quantitative data on the mechanical properties have been published. In this experiment, we obtained force-displacement characteristics for most of the currently available mitral annuloplasty rings.

The experiments were executed in the Laboratory of Biomechanics of Man at the Czech Technical University in Prague, Faculty of Mechanics Engineering. Eleven different brands (total count 23 pieces) of mitral annuloplasty rings were tested. All models were of size 30 or comparable. One to three samples per model were available. Axial tensile tests were performed on the MTS 858 Mini Bionix tensile testing system equipped with 500N load cell and custom fixtures. Annuloplasty rings were tested in the commisure-to-commisure direction (C-C) and the septo-lateral direction (S-L). Annuloplasty bands were tested in the longitudinal axis direction (A-A). All models were tested under two loading regimes. Firstly, stepwise loading 0-2-1-4-1-6-1-8-1-10 N was applied to assess the general mechanical behavior of the models and the effect of pre-conditioning. Secondly, threefold full-range loading 0÷10 N was applied. For both regimes, the following measuring conditions were set: loading speed 0.1 $mm.s^{-1}$; unloading speed 0.5 $mm.s^{-1}$; sampling rate 20Hz. The data were processed using conventional software.

For all models, force-displacement data were obtained in the appropriate directions. The preliminary graphic representations of the data for all annuloplasty implants were acquired. From the obtained characteristics, the resultant in vivo forces corresponding to the displacements measured by others can directly be estimated. Except one model all annuloplasty rings show hyperelastic properties. The data can be fitted for use in finite-element (FE) modeling. Using the FE models, the mechanical stiffness of the annuloplasty rings can be calculated. Consequently, the in vivo load on the implants can be assessed.

The measurements were performed in cooperation with P. Havlík and P. V. Pištecký from Delft University of Technology, Faculty of Design, Engineering and Production, Mechanical Engineering (Netherlands). This study is part of the Delft Interfaculty Research Center on Medical Engineering (DIOC-9) - the research program "Minimally Invasive Surgery and Interventional Techniques (MISIT)".

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# Tubular Microsensor for Stress State Analysis in Living Bone

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. The exact determination of stress state in the bone of living subjects has great importance in biomedical research (remodelling of bones) as well in practical branches as orthopedics, reumatology and osteology. Parts of skeleton are changing their qualities during their life. These changes are joint with remodelling of the structure influenced by the stress field in the material of the bone. The only possibility how to estimate them is to use transducers.

Principal of the transducer is given by the distribution of stress field round cylindrical hole. As it is not possible to measure these stresses directly a transducer has to be inserted into the examined bone. But the rigidity of the embedded transducer must not influence considerably the stress field. From the medical reasons outer diameter of the hole cannot be greater than 3 mm.

Problems of biological compatibility and aseptic treatment (assumed time of transducer application in the bone is 6 – 8 months) have predetermined material used for injection needle. Theoretic and numerical calculations were performed so that we receive optimal distribution of the examined stress field in the bone. The outer diameter of the elastic body of the transducer is 2,8 mm, wall thickness 0,2 mm, total length according to medical demand was 5 mm.

As it was not possible to apply strain gages in the circumferential direction the only chance was to apply semiconductive strain gages orientated axially as they have several ten times higher sensitivity than metal one and thus they give sufficient signal. First tests were done with semiconductive gages available on market which had greater length (3 mm) than we needed. These tests proved great sensitivity to non-symmetric positioning of the transducer and to added bending out of plane. These tests were carried out in the photoelastic model and numerical simulation.

According to our wish the domestic producer of semiconductive strain gages - the company VTS/SGT Zlín prepared for us shorter base of the strain gage (2 mm) and applied one pair of the above mentioned gages on the inner surface in a half-bridge connection. This transducer does not suffer from not only additional influences (non-symmetry, bending, but also from temperature shifting).

Special attention was given to strain gage isolation which has to fulfill requirements of biocompatibility as well as resistance during sterilization by temperature, chemistry or radiation. Problems of glues for bonding is solved separately.

VTS/SGT producer prepared new types of semiconductive strain gages with the total length 2 mm and with the connecting wires leading to one side. It is prepared production of the semiconductive strain gage of the length 1,5 mm.

As in the living bone it may be expected temperature changes that intensively influence the signal relevant to pressure it is necessary to add semiconductive temperature. that gives relevant signal to temperature and by SW elimination of temperature can be carried out. In this way it is possible to use single strain gage in one circumferential position.

Numerical simulation of application [2] into a bone has been done and the experiment on bone is prepared. First on animal, later human one

During tests linearity of the signal due to the applied loading as well as sensitivity to angular orientation were performed by means of photoelastic model. A good agreement between numerically simulated results and experimental ones was found.

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# Estimation of Aortic Aneurysm Behaviour using Artificial Neuronal Network

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Diseases of cardiovascular system are the most frequent cause of death in mature countries. In Czech Republic it makes about 53% causes of death. Ones of the grave diseases of cardiovascular system is abdominal aortic aneurysm (AAA). Rupture of an AAA is tenth most frequent cause death at all in male population older 55 years in according to [1]. Occurrence AAA in male population older 60 years is about 2-6%. It is serious reasons to research biomechanical properties of an arterial wall with AAA.

Abdominal aortic aneurysm is usually manifested like balloon dilation of the distal aorta. This bulge is probably caused by degradation processes in an arterial wall. Sharp cause of this rising of arterial wall is not well known on the present. Mostly is attended by strong atherosclerotic damage of arterial wall. AAA is most often diagnosed below nephritic arteries. Arterial diameter cen ovegrow 6 – 7 cm. Mean value of aortal diameter below renal arteries is 2,5 cm adult man. It is seen that growth of aortic abdominal aneurysm can lead to really big values of diameter.

Presently, there is no reliable criterion to predict the behavior of AAA and the risk of rupture of abdominal aortic aneurysm. Eighty five percents patients with the rupture AAA is dying. So the risk of rupture of AAA is very grave problem. Most common surgical criterion is based on the values of arterial diamemeter only. Indication to surgery are values of diameter over the 5 cm. But this criterion can not include other important factors as for example arterial mechanics, strength of the wall etc. We suppose that our research will be support for the finding of this prediction criterion and will improve surgery indication.

There are lot of research departments in the world which are focused on problems of mechanics of AAA. But most of thees site investigate stress – strain questions in abdominal aortic aneurysm. But knowledge of AAA mechanics can not improve treatment of AAA patients by inself. Because we can not response general question this way: What is the prognosis of behaviour of AAA? Computing based methods in continuum mechanics (FEM,...) works with inexact datas for example constitutive laws of aneurysmatic artery. Second reason is that we have not any criterion of failure for aneurysmatic arteies at present. So we focuse our work to another objective.

Our method is based on using of artificial neuronal networks. Using this one we try to find respopnse to simply question: Will abdominal aortic aneurysm grow or not? Because in clinical medicine are known situations when AAA stoped its growth. (But never decrease). And using this method we can response second question: How much will aortic diameter increase per time unit. We think that this is the way which is more helpful than other one.

We cooperate with Department of Surgery of Teaching Hospital in Plzeň. We obtained set of 40 controled patients with small abdominal aortic aneurysm. Patients were under 2 or more measuring of abdominal aortic diameter using ultrasonography (USG). Cotroled qualities were risk factors and other: sex, age, smoking, hyprtension, diabetes melitus, ischemic heart disease, ICHDK, pulmonary disease and diameter values. We divided set of datas to to groups: learning data and control data. Leanrning data are use to find learned neuronal network and with control data we test degree of learning artificial neuronal network.

We use ANN (atrificial neuronal network) with one hidden layer and with self learning system – back propagation.

At present we can not say that we have found learned ANN forn the best prediction of the AAA behaviour. But we have to say that using of artificial neuronal networks to prediction of AAA behaviour is advanced way to aid surgery with solution of AAA problems.

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# Methods of Microwave Applicator Evaluation

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Microwave thermotherapy is the treatment method, when the biological tissue absorbs the microwave energy and warms. The applicator is an important part of every thermotherapeutic system, because it determinates distribution of electromagnetic energy in front of applicator's aperture into the tissue. Therefore every applicator must be thoroughly evaluated before it can be used in the therapy.

For these measurements we use some types of phantoms of the biological tissue. By the evaluating we can measure distribution of the electromagnetic field in the water phantom of the biological tissue (E-field distribution), or we can measure temperature distribution in the agar phantom.

Evaluation in the water phantom of the biological tissue means to measure the electromagnetic field power distribution in front of the aperture of evaluated microwave applicator in the media, which substitute the biological tissue.

The water phantom is the container, which is filled with solution NaCl in the water (strength of solution is 3 g/l). The complex permitivity of this solution is near to electrical characteristics of the biological tissue. The electric field strength is measured by the special probe. There is a dipole antenna as a base of this probe. The voltage induced in this antenna supply the next important part of the probe, the LED. The optical signal from the LED is leaded by the optical fiber outside the phantom to the optical detector.

The optical signal in this fiber is not influenceable by the measured electromagnetic field and the optical fiber affect minimally the measured field pattern. The output voltage from the optical detector can be measured by the voltmeter or can be converted by the ADC to the digital form and processed by the computer. The probe is moved in the container. The position of the probe is controlled by the movement control unit, which communicates with PC.

There are many factors that influence on the proposal of the probe. The most important of them are:

- the dimension of the probe,
- the sensitiveness and the dynamic range of the probe,
- the resistivity to the corrosive solution.

The overall dimension of the probe must be as small as possible. This is very important for easy probe mobility and for minimally influence on the measured field pattern. The length of the dipole antenna must be small in comparison with $\lambda$ ($\lambda$ is the wavelength of the measured field in the phantom media). The measured E – field strength is integrated along the dipole antenna. That can cause measured error and this error is dependent on the length of the dipole. The length must be less than $\lambda/4$.

The sensitiveness and the dynamic range of the probe depend upon the length of the dipole and upon the type of used LED and other used components. The sensitiveness and the dynamic range should be as large a possible. It is necessary for measurement accuracy and for the distributed electromagnetic field pattern detail representation.

The solution NaCl in the water is very corrosive and the probe must be resistant to this.

I used the antiparallel Schottky diode is to close the circuit. This diode is fast and it shows low resistance value in the conducting state. I chose it for its bushing shape (small) too.

The LED emits optical radiation, the wavelength of the radiation is 880 nm (infrared spectrum range). The fiber is multi-mode, the fiber core is compact of about 300 $SiO_2$ fibers, and the core diameter is 1.2 mm. This diameter is right for effective energy transfer from the LED to the optical fiber.

I realized two probes, they are similar themselves, and the different is only in dipole lengths. The dipole length of the first probe (P1) is 26 mm, the length of other probe dipole (P2) is 16 mm. For probe testing I used the waveguide applicator with rectangular aperture. On account of the input electromagnetic power (from the microwave power generator) I can calculate the E – field strength amplitude in the middle of the aperture. In this point I placed the tested probe.

The electromagnetic field distribution we can measure by the matrix of LEDs, which is placed in the water phantom. LEDs are supplied by small antennas (they are similar to antenna mentioned above). The emissivity of LED depends on the power of electromagnetic field in place. Thus we can see power distribution in the section of the phantom or we can make a photo using the camera.

For the measurement of the temperature distribution we can use the agar phantom of the biological tissue. This is mostly cylinder, which is made from agar gelatine. The dielectric parameters we can modify by some ingredients (i.e. aluminium powder). The phantom is exposed to the electromagnetic field from the applicator. Then the cylinder can be slited and the sections can be scanned by the infrared camera. The next possibility how to measure the temperature in the agar phantom is using temperature-sensitive elements.

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# The Possibilities of Tooth Bleaching with Laser Radiation

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Great emphasis during stomatologic treatment is shown not only to the functional but also to the aesthetic viewpoint. Tooth bleaching is one of the prevent stomatology methods. It serves to accomplish tooth colour brightening and tone arrangement. Preliminary tooth bleaching techniques reach back to 19. century. However, large development and expansion of tooth bleaching methods turn up in the end of 20. century, mainly in the USA. Risk minimization, great effectiveness and comfortable trends of new methods are followed. Laser-assisted tooth bleaching is one of the external methods of thermocatalic tooth whitening. External methods of tooth bleaching are used predominantly for discoloration treatment of vital tooth. The bleaching process itself consists of active medium (hydrogen peroxide or carbamid peroxide) ionization in the internal structure of tooth enamel and dentine tubules, where macromolecules of organic pigments are present. During the ionization, strong oxidative radicals are released. Oxidative radicals interact with organic macromolecules and change or break their conjugate bonds. The changes of light absorption spectrum of organic molecules are accomplished and visual effect is result of tissue whitening. The active medium ionization can be initialized by different ways. To start the thermocatalic reaction, the energy has to be delivered from an external source. By this procedure concentrate oxidative agents application time shortening is accomplished and safety of procedure is increased. Laser radiation can be one of the external energy sources. The basic advantage of laser light is its quasi-monochromaticity. A selective absorption of different wavelengths in tissue and active whitening medium can be performed. A portion of radiation which is not effectively absorbed in active medium is minimized. Temperature rise in peripheral tissue is low (less than 5°C) and structural changes in peripheral tissue or pulpal necrosis is not developed.

The basic procedure consists of several steps. First, gel substance with the active medium (hydrogen peroxide or carbamid peroxide in 35-50 % concentration) is placed on the facial surface of treated tooth. The reaction is rapidly activated by laser radiation. Laser radiation is characterized by the wavelength, pulse duration, energy and repetition rate. Photochemical reaction process depends on irradiated area size and application duration. Effective and safe procedure is achieved by suitable laser radiation parameters.

The objective of our experimental study was the investigation of different lasers effect on tooth whitening activation. Suitable wavelengths for application were evaluated from different bleaching agent's absorption spectrum. In the interaction process the radiation of CTE:YAG, Nd:YAG, Nd:YAG (SHG), and alexandrite laser was used. Two different commercial bleaching agents were used, HI-LITE (hydrogen peroxide in 35 % concentration) and QUICK START (carbamid peroxide in 35 % concentration). Bleaching agent was placed on one part of facial side surface of each tooth specimen in 2 mm thin layer. Second part of each tooth specimen was covered with an inactive wax to prevent the laser exposure on reference part.

In the first part of this study four tooth specimens covered by HI-LITE agent were irradiated by four above mentioned lasers with the following parameters: CTE:YAG – generated wavelength $\lambda_{CTE:YAG}$ = 2.7 μm, pulse energy $E_{CTE:YAG}$ = 20 mJ, length of pulse $\Delta t_{CTE:YAG}$ = 150 μs; Nd:YAG - $\lambda_{Nd:YAG}$ = 1.064 μm, $E_{Nd:YAG}$ = 27 mJ, $\Delta t_{Nd:YAG}$ = 25 ns; alexandrite - $\lambda_{alex}$ = 750 μm, $E_{alex}$ = 80 mJ, $\Delta t_{alex}$ = 100 μs; Nd:YAG SHG - $\lambda_{Nd:YAG\ SHG}$ = 0.532 μm, $E_{Nd:YAG\ SHG}$ = 7 mJ, $\Delta t_{Nd:YAG\ SHG}$ = 8 ns. The beam diameter of individual lasers was similar ~ 4 mm. Useful property of HI-LITE bleaching agent is based on color changes. Inactive agent colour is green and the completion of bleaching active process is followed by an agent discoloration. For effective and safe procedure the energy and number of laser pulses could be determined. During the interaction experiment the tooth specimens were irradiated by laser radiation up to the moment of the agent discoloration. The needed number of pulses required for used lasers were: CTE:YAG number of needed pulses for agent discoloration $n_{CTE:YAG}$ = 250, Nd:YAG – $n_{Nd:YAG}$ = 310, alexandrite - $n_{alex}$ = 2000, and Nd:YAG SHG $n_{Nd:YAG\ SHG}$ = 300.

In the second part of the investigation the other four tooth specimens were covered by QUICK START agent and irradiated by the number of pulses evaluated in the first part of our study. Comparison of the individual laser radiations and various bleaching agents were done. Last tooth specimen was treated only with the chemical agent HI-LITE without laser activation and comparison of traditional chemical treatment and laser-assisted bleaching method was performed.

The irradiated tooth color was investigated and the structural changes of its surface were evaluated by a Scanning Electron Microscope. As results it was found out that the application of Nd:YAG SHG laser radiation resulted in an ineffective treatment without significant tissue brightening. Enamel surface injury done by the ablation of tissue was initiated by very short pulse length of this radiation. Ineffective procedure without enamel surface damage was achieved also in the case in which Nd:YAG and CTE:YAG lasers were used. Good results were obtained for the alexandrite laser activation of bleaching process. Optical brightening in range 2-3 tones (in 24 tones scale) was achieved and no enamel surface injury was observed. The duration of this bleaching activation was 400 s. This time is significantly shorter when compared with chemical treatment without laser activation (this time is 630 s).

It can be summarized that the laser-assisted bleaching method is the perspective prevent stomatology method. Quasimonochromatic laser radiation matches selective absorption of bleaching agents and heat generation is limited. Temperature rise in peripheral tissue is much lower in comparison with other possible energy sources. Duration of application is shorter. Enamel brightening result is comparable with the traditional chemical treatment without laser activation.

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# Planar Shape Description by Means of Wavelet Transform

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## Introduction

Shape description and characterization of planar objects represents an essential procedure in biomedical image processing systems esp. for automated microscopy and diagnosis.

Recently, the multiscale approach (methods based on continuous and discrete wavelet transform of parameterized contour, curvature scale space etc.) in shape analysis has become accepted for the ability to decompose the shape in different global and local features [4]. This decomposition is straightforward and user has no opportunity to choose/balance the set of resulting features.

## Materials and Methods

We propose a method for planar shape description based on wavelet packets (WP) [1]. The method has advantages of non-redundant complete multiscale representation and in addition allows to select the set of representing features in accordance with their information contents. The different shape classes (e.g. neurites versus round cells) can be described in a most desirable manner. Obtained shape description can be used for similarity/dissimilarity quantification, classification, shape averaging, database retrieval etc. The proposed method is demonstrated on assessment of shape changes induced by xenobiotic agents in neurotoxicity testing [3].

The object is described by planar contour obtained from preprocessed image (gray-scale morphological filtering, thresholding, contour tracking). The wavelet packets description is non shift-invariant, accordingly the contour must be normalized with respect to starting point and orientation (by normalization of Fourier transform coefficients). The normalized contour is decomposed to binary tree of wavelet packets by means of hi-pass and low-pass filtering (quadrature mirror filters) and subsampling. The closed contour representation is periodic and a minimal periodic extension for dealing with wavelet packet transform border distortion can be used.

The binary tree contains redundant information; the resulting set of wavelet packets (shape descriptor) must be selected as a graph in tree (wavelet base). The selection process must satisfy the following requirements: interclass separation should be large, intraclass variance must be small.

The proposed variance-based automatic feature discrimination procedure can be described as follows:

1. Compute tree of wavelet packets for all contours
2. Evaluate appropriate discrimination measure for every wavelet packet (terminal nodes of tree are evaluated as a single node with sum of measures), the result is discrimination tree with single coefficient for every node
3. Prune the discrimination tree (according to discrimination effectiveness of using the wavelet packet in shape description) to obtain graph

The result of the described procedure is set of WP coefficients for non-redundant and complete description of shape optimal for classification.

**Conclusions**

The proposed descriptor possesses the properties required for general shape descriptor: invariance, uniqueness and stability. The performance of WP descriptor is comparable to discrete wavelet shape descriptor, in addition the WP descriptor allows to select more compact and efficient shape description [1].

The described method can be used also for shape averaging (process of extracting a typical representation from a group of shapes); the resulting descriptor obtained by averaging of corresponding coefficients is transformed to parameterized contour.

The proposed planar shape description method based on wavelet packet offers a richer range of possibilities for biomedical shape representation and analysis. The method allows to select different representing features according to different shape classes.

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# Methodology of Evaluation of Phonocardiograms in Measurement of Pulse Wave Velocity

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In a modern lifestyle there is a relatively high risk of damaging a human cardiovascular system. Therefore a determination of illnesses on the cardiovascular system is very important. Some kinds of diseases of the cardiovascular system can be found out by various methods, e.g. ultrasound methods that are commonly used in a clinical practice nowadays. Alternative ways are based on a principle of measuring a blood propagation velocity in arteries, especially the propagation of a pulse wave velocity, e.g. ultrasound techniques with Doppler effect or techniques with flow indicators of blood propagation in arteries. A measuring of blood pulse wave velocity using electronic stethoscopes is the other approach to this problem.

As one of an evaluative criterion for these methods can be used a medical endurance of patients during and after a treatment. From this point of view all ways of medical treatment may be divided into two main groups: invasive and non-invasive. Techniques with the principle of the flow indicators belong into the invasive group. To the second, non-invasive, group can be situated ultrasound and phonocardiographic methods.

The pulse wave of blood arises during a systolic phase of heart rather then the systole of a left heart ventricle. During this heart phase a small volume of blood is injected into arteries. The propagation of a small blood volume affects a value of several parameters of cardiovascular system. A term for this interference is pulse wave. Each of the pulse waves has different characteristics. Vascular distension creates a volume pulse wave, a fluctuation of a magnitude of blood pressure in vessels is a pressure pulse wave and a speed alternation of blood propagation forms a flow pulse wave.

A velocity of propagation of the first type of pulse wave – the volume pulse wave is much higher than the pulse wave velocity (thought velocity of the stream pulse wave) of blood along the vessel. The arterial distension is well observable on peripheral arteries. A method for a registration of volume changes is called a plethysmography.

The propagation of a short column of higher blood pressure – the pressure pulse wave can be measured only directly inside of the vessels. It means that invasive methods have to be used, e.g. a catheter with a pressure transducer. An acquired amplitude signal of blood pressure has two important extreme. The firs one, maximum value in one period, is a systolic pressure (the arterial pressure during the heart systole phase). The second one, minimum in the same period corresponds to diastolic blood pressure (the arterial pressure in the heart diastole phase).

The fluctuation of a velocity of blood propagation in arteries – the flow pulse wave can be detected by flow indicators or using the phonocardiographic methods. Flow indicators are not commonly used, because it is the invasive method. Phonocardiography is based on stethoscopes, i.e. the phonocardiography provides easy way to listen some sounds in a human body. In special cases, when some conditions are performed, this method can be used for sound data acquisition that has come up in arteries by the blood flow. These arteries have to be situated directly below the body surface.

The purpose of this work is a determination of blood pulse wave velocity of propagation in human cardiovascular system. The phonocardiographic method was chosen for the data acquisition. Although the phonocardiography is well known method this usage consists a new approach to the utilization of it.

The phonocardiography by two electronic stethoscopes was used for the data collection. Stethoscopes were fine fitted at the body surface where a palpation is possible. Data acquisition was performed simultaneously from two different places of a human body. Measured sound signals were digitized and transmitted into a computer for a subsequent analysis.

The analysis of all collected signals consists of three general parts. As the first and very substantial step a signal pre-processing is implemented. This part comprises a frequency analysis which results are utilised by parameters pre-setting of a filtering. In the next pre-processing phase a filtration is done to remove various disturb signals, e.g. an influence of respiration. The first phase is followed by a signal processing. The signal processing consists of correlation analysis of modified measured data and an analysis of computed signals, i.e. systolic-diastolic flowing. As the last part of the evaluating process is done a comparison of the results of previous analyses and the final pulse wave velocity of propagation in arteries is calculated.

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# Excentric Photorefraction in Clinical Practice

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Ophthalmology of the beginning of the 3rd millenium is facing new diagnostic and therapeutic challenges. Many of them are anyhow related to the refractive function of the human eye. Then the appropriate measurement of refractive state is vital. Besides many refractometric methods, the *excentric photorefraction* undergo the unprecendental development and wide usage.

The skiaskopy (retinocscopy) was the „gold standard" of the measurement of refractive error of the eye for almost a century (since *Cuignet*, 1873 to wide usage of the autorefractors). Some modern methods, including excentric photorefraction, have been derived from the *double pass reflection* (of the measuring light) principle of skiaskopy. Thanks to the contribution of sophisticated technologies (CCDs, PCs, image analytical software, etc.) we wittness the renaissance of this method.

According to the position of the measuring light source and the estimation algorithm of this light reflection from the eye, two principal subtypes of fotorefraction are distinguished. (1) ***Co-axial methods*** are based on the light source located on the axis of the camera lens. Four 70° pi-shaped cylinder lenses attached in front of the camera lens were typical for the (1a) **orthogonal modification** of the co-axial method [1], while the defocus of the camera lens is distinctive for (1b) **isotropic modification** of the method [2]. (2) **Excentric methods** are named after excentric position of the measuring light source in front of the camera lens on the shield occluding the part of the lens beneath the light source. The distance between the sharp edge of the shield and the source is called excentricity and is the crucial parameter of the method. The method was completely described by Bobier and Braddick in 1985 [3]. The ray-tracing analysis was performed by Howland five years before (1980). The principal methodological improvement was done by Schaeffel (1987) when the light source design was changed from point source to array of the point sources. The impractical measurement of light crescent of reflected measuring light in the pupila was changed to the measuring of the slope of the measurement light intensity in the pupila. Roorda (1997) showed that if the size of the light source is increased, the intensity profiles become more linear and the slope of the reflex changes linearly with the refractive state.

The clinical harwest of the improvements of the excentric photorefraction is mainly on the field of screening for the amblyogenid factors of the youngest children. It was stated by the American Academy of Ophthalmology that screening is perhaps the most important factor in the ocular health of infants and children. The advantage of the excentric photorefraction is that it is quick and remote making it useful for refraction measuring in children. The technique was used firstly for population-based screening by Kaakinen (1979) [4]. Nowadays, the *excentric photorefraction* is used widely and almost routinely. The effectivity of various screening devices based on this principle was tested extensively: MTI PS-100 Photoscreener (Medical Technology Inc., Riviera Beach, Fla, USA), ViVA videorefractor (Tomey, Waltham, Ma, USA), PowerRefractor (University Tüebingen, D), Auckland excentric photorefractor , Visiscreen OSS-C (Vision Research Corp., Birmingham, Ala, USA), iSceen LLC (iScreen, Memphis, Ten, USA), etc.

Thanks to the recent methodological improvements the excentric photorefraction methodology is applicable in laboratory settings.

We deal with diagnostic systems. The first one is for video measuring of the basic eye reactions (accommodance and convergence) in infants. As a noninvasive method for measurement we use excentric photorefraction and I. Purkynje image. Following image analysis from grabbed pictures gives us time curves of accomodation and convergence. The second diagnostic system is a photo screening system for infants. This system analyses obtained picture with the aim to catch anomal symptoms and warn on it.

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# Influence of Mechanical Loading on the Rise and Development of Osteoarthrosis in the Hip Joint

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Osteoarthrosis (OA) is a very serious hip joint disease, which is due to some of chemical, mechanical and genic reasons. One of OA frequent reasons is an excessive mechanical loading of articular cartilage. We suppose that its geometrical shape and mainly a mode of loading cause different stress and contact pressure magnitude and distribution in the hip joint. This paper specified contact stress and pressure distributions in the hip joint. Further, influence of changes in the loading modes and magnitudes on the contact pressure and stress distributions in the hip joint was evaluated.

Osteoarthrosis (OA) is a very serious hip joint disease, which attacks mainly older population. OA causes a significant damage of human health connected with important social and economic problems. An OA prevention would contribute to early diagnoses and subsequent treatment of this disorder. It appears that one of important factors influencing a rise and development of OA in hip joint is a magnitude and mainly a mode of its loading. The hip joint loading during walking has a cyclic character. This loading mode is for the articular cartilage advantageous not only from the mechanical, but as well as from the nutrition, viewpoints. Articular cartilage is nourished with the synovial fluid which is "sucked in" at unloading and "driven out" at loading. When this physiological situation is disrupted by a change of loading mode, a continuous local overloading of the articular cartilage occurs resulting in its primary and permanent damage since its physiological nutrition can not proceed. The primary degenerative region (PDR) occurs with every patient at different femur head areas depending on a way of his/her locomotion. Most often (60%) OA is found on the top of the femur head. At the PDR location, an increase of the articular cartilage stress and strain concentration occurs influenced with the multiplied mechanical loading. Thus the cartilage is again overloaded and its secondary degeneration occurs resulting in a progressive expansion of the degenerative area. The human organism tries to correct this adverse reaction by changes of its locomotion, but this causes further concentration of the mechanical loading into still smaller areas of the cartilage tissues, which results in a still more intensive overloading. Such an always developed cycle: *overloading – change of locomotion – overloading (OCO),* is one of main factors influencing a rise and development of osteoarthrosis of the hip joint.

From the analysis results obtained it is evident that, due to changes in the hip joint loading, a local permanent overloading of the articular cartilage takes place. Then in this locality, after a subsequent artificial change of the tissue material properties, an abrupt growth of stress and strain concentration occurs. This trend is increasing together with increasing area of the damaged tissue. Further it is evident, that due to a consequent change in the model loading direction, the stress concentrates progressively repeatedly in the local areas of degenerative changes.

Based on the evaluation of the analyses results, a hypothesis, expressing that magnitudes and modes of mechanical loading directly influence the articular cartilage nutrition, can be suggested. Just a disruption of the cartilage physiological nutrition is one of factors influencing directly the onset and development of osteoarthrosis in the hip joint.

With respect to an incomplete material model of tissue properties, it is not possible to consider the resulting absolute values of the computed stress and strain to be quite correct. Still the analyses executed approximate a real situation in the hip joint. A specified tissue material model is an objective of future work, along with confirming a hypothesis according which the osteoarthrosis development could be reduced by changing the patient locomotive stereotype.

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# Intelligent Medical Data Analysis

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Nowadays many real-world medical problems are being assessed with tools for automatic intelligent data analysis. Many different methods have been developed to improve the quality of analysis for specific domain. Application of method in specific domain requires special characteristics. For instance methods based on artificial neural network are capable of generalisation of nonlinearly separable problems but have poor explanatory power. Therefore we focused on methods which are capable of extracting knowledge in a form closer to human perception, e.g. methods that induce decision trees, classification rules, etc.

In the development we started with selection of knowledge representation. We decided to focus on decision trees. In that way we only narrowed down the potential set of methods. In order to find most appropriate classifier we tried different methods for decision tree induction. First we made analysis with widely known tools for decision tree induction C4.5 and C5/See5. Despite acceptable results we wanted to find alternative solutions, i.e. evolutionary and multimethod approach. Decision trees are easy understandable to the human and can be used even without a computer, but they have difficulties expressing complex nonlinear problem. On the other hand connectivistic approaches, that simulate cognitive abilities of the brain, can extract complex relation, but are not understandable to the humane, and therefore in such way not directly usable for data mining. There are many other approaches, like representation of the knowledge with rules, rough-sets, case based reasoning, support vector machines, different fuzzy methodologies, ensemble methods and all try to answer the question: How to find optimal solution i.e. learn how to learn.

Evolutionary approaches to knowledge extraction are also a good alternative, because they are not inherently limited to local solution. They are based on the evolutionary ideas of natural selection and genetic processes of biological organisms. As the natural populations evolve according to the principles of natural selection and "survival of the fittest", so by simulating this process, genetic algorithms are able to evolve solutions to real-world problems, if they have been suitably encoded. They are often capable of finding optimal solutions even in the most complex of search spaces or at least they offer significant benefits over other search and optimisation techniques. The hybrid approaches rest on the assumption that only in the synergetic combination of single models can unleash their full power. Each of the single method has its advantages but also inherent limitations and disadvantages, which must be taken into account when using the particular method. Therefore the logical step is to combine different methods to overcome the disadvantages and limitations of a single method.

Multimethod approach: While studying presented approaches we were inspired by the idea of hybrid approaches and evolutionary algorithms. Both approaches are very promising in achieving the goal to improve the quality of knowledge extraction and are not inherently limited to sub-optimal solutions. We also noticed that almost all attempts to combine different methods use loose coupling approach. The methods work almost independent of each other and therefore a lot of luck is needed to make them work as a team. Each of those methods uses its own internal knowledge representation (symbolic, connectivistic) that other methods cannot

reuse, because of the incompatibility of knowledge representations. That incompatibility presents a major obstacle when trying to combine different methods using conventional hybrids. Another aspect of knowledge exchange is that methods have to be able to accept already constructed knowledge representation and have to apply its operations with the objective to improve the quality of the already extracted knowledge or they have to be able to construct a knowledge representation from the scratch. Main concern of the multimethod approach is to find a way to enable dynamic combination of methodologies to the somehow quasi unified knowledge representation. Multiple equally qualitative solutions like in EA approach, where each solution is gained using application of different methodologies with different parameters was used. Therefore we introduced a population composed out of individuals/solutions that have the common goal to improve their classification abilities on a given environment/problem. We have also enabled coexistence of symbolic and cognitive representation in the same population. The most common knowledge representation models have to be standardized to support the use different methods on individuals. In that manner the transformation support between each individual method does not need to be provided. The action is based on assumption that it is highly improbable to find unified representation for all knowledge representations, therefore we decided to standardize the most popular representations like neural nets, decision trees, rules, etc. Standardization brings in general greater modularity and interchangeability, but it has following disadvantages - already existing methods cannot be directly integrated and have to be adjusted to the standardized representation. The modular design of the framework enables us to apply some subparts of a method to another method. For example, independent of the induction method used, universal pruning and error reducing operations can be applied on a decision tree. The aspects of individual representation and methods/operations on the individual are strictly separated.

The developed multimethod approach was tested on mitral valve prolapse (MVP) data. (MVP is one of the most prevalent cardiac conditions, which may affect from five up to ten percent of population and one of the most controversial one.) 631 patient records were used for testing, each was described by 103 parameters that could possibly indicate the presence of MVP. For comparison, the following basic purity metrics for greedy induction of decision trees were used: information gain ration (ID3), Chi square, Gini, J Measure, iBARET and Mgain metric. As evaluation criterion, average class accuracy was used because on unbalanced data sets it is more informative measure than overall accuracy. The multimethod approach achieved the best result (84.31% accuracy), followed by Grredy Chi square + ID3, Greedy Gini + Chi square, and iBARET (all three methods achieved 83.47% accuracy).

The future research will be focused on experiments with different data sets. The aim is to find out whether this approach will bring comparable results and thus will prove its quality.

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# Transducer for Pressure Distribution Measurement and Its Using in Biomechanics

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## 1. INTRODUCTION

The using possibilities are not only in orthopaedy, but in any others branches too, as e.g.: by the back-bone diseases determination (scolioses), in sports medicine, by robots stability determination, etc.

## 2. SIGNAL PROCESSING

Multisensor system can be realised on the area as large as 300 x 400 mm. The area's scanning is controlled by multiplexes (100 rows x 75 columns) by the 300 snaps per second. Being respected the medical safety precautions, the "safety" extra low voltage (SELV) has to be used for the sensing elements supplying (5 V DC), and no activated electrodes are grounded. The couple CMOS-unipolar transistors are used as switches. Microprocessor is controlling their activity ; and all logical controlling functions are programmed in PLA-memories. An analogue level of the output signal can be adapted, either by means of the output resistors (these ones are connected in series with sensors being realised voltage divider), and either by means of the amplifier. Its output is connected to the 8-bit A/D converter - supplying the I/O special interface unit. The mentioned electronic components are solved as the peripheral unit for PC-by SMD technology - with the high sampling frequency 2.5 MHz.

The communication with PC and the control signals generating for multiplexes is made by means of the control microprocessor, that is together with ultra fast 8 bits A/D converter and with 10 MB buffer in one special interface unit. This unit is connected with parallel port to PC. HDD can be included in this unit, too. On this HDD can be recorded long time measurements in real time. Having been measurements over, these data are transfered from interface unit to PC by parallel port. Besides that, this interface unit enables to be seen the measurements results on the PC monitor display in real time, too. The evaluation is provided on PC - with respect to the used SW-equipment (as e.g. : 2D-half tone view on the monitor, or the pressure-profile cuts of the activated loaded area etc.).

Briefly the others technical features:

| | |
|---|---|
| sensor element dimensions | 2x2 mm |
| digital output | 256 levels |
| supposed pressure range to be caught the balance centre | 12 – 90 kPa |
| snap frequency | 300 Hz |
| sampling frequency | 2,5 MHz |

## 3. SOFTWARE TOOLS

The transducer pressure assembly consists of the following parts:

- matrix pressure transducer,
- operating electronics,
- interface and PC with driver and SW.

Being used operating system Win98/ME/NT/2000 in PC, our driver is installed there too, to be realised the communication activity between interface and operating software. Operating software has been developed in MS Visual Studio 6.0 and is divided on operating and analytical part. It is possible, to be seen the preview of an immediate load of the sensor, by speed frequency - up to 15 snaps per second. For measurements, the dialog window is prepared, where you can adjust: the measurements duration, snapshot frequency, and the noise level. It is possible to view the immediate changes of the pressure load in frequency 15 snaps per second, too. For an exact measurement, no possibility is to be seen the snaps in real time, due to the fact – that the data are stored in buffer in interface with the high speed scanning frequency (up to 300 Hz).
The next one dialog window is prepared for the measurement start adjusting:

- from SW by button click,
- by clicking keyboard,
- by touching external switch, or
- by auto detection of contact with pressure sensor (level is also adjustable).

There are possibilities - to save the measured data in several different formats (*.dat – working format, *.xls – Excel, *.bmp – 256 colours bitmap). For the data processing, the several dialog windows are prepared, which allow to be evaluated the snaps through:

1) Centre Of Pressure (COP) movement,
2) Region Of Interest (ROI),
3) Vertical and horizontal sections – “cuts”

For analysis of the COP movements, as results can be set - stabilometry parameters:

MV [Mean Velocity] – computed by means COP coordinates and time, CEA [95% Confidence Ellipse Area], and FD [Fractal Dimension].

ROI creation – it is possible create “infinite” number of ROIs. Each ROI can be evaluated by computing of its own COP, by histogram of values of weight, or by computing the typical values for this region (sum, average, etc.).

The last evaluating possibility is creation the number of the various horizontal or vertical “cuts” – sections, to be seen the loading curve – see.

From technical point of view, now we are preparing enlargement of the buffer memory in interface by connecting dynamic memory (SIMM 64 Mb), instead of the temporary 1Mb static memory. We established that 1Mb of memory it means 135 snaps and 3,5 seconds is not sufficient for the long stabilometry measurements.

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# Carbon Dioxide Laser Thermokeratoplasty

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The irregular corneal astigmatism is the refractive eye defect that cannot be treated by prescription of eyeglasses. It is possible to use special contact lenses but it is very difficult and only partial solution of the problem. Correction of the irregular astigmatism by surgical procedure is not easy and it is complicated with uncertain prognosis of the final result. The most frequent causes leading to the irregular astigmatism are eye injuries, corneal deformities after inflammation and situations after corneal transplantations (keratoplasty). Theoretically it is possible to evoke stresses in corneal tissue by application of the laser beam into the specific points with defined mutual distance. Then it should be possible to decrease or increase the curvature of the selected corneal areas. This could be applicable method of the correction of irregular astigmatism with positive effects.

Our analysis of the laser thermokeratoplasty effect on the corneal curvature together with porcine cornea absorbance measurement [1] and preliminary study of Chandonnet [2] has shown possibility of exploration of carbon dioxide laser at laser thermokeratoplasty instead of diode laser of 1.8 μm wavelength. Volume changes of corneal tissue caused by increased temperature in Ringer solution [3] together with computer simulation of corneal shape changes support thermal nature of laser thermokeratoplasty effect and correlation of model with diode laser experiment on porcine enucleated eyes proposed next direction of our research in the field of irregular corneal astigmatism correction.

The aim of this work was to study corneal tissue reaction on treatment by laser radiation with 10.6 μm wavelength ($CO_2$ laser) and to compare this reaction with reaction on diode laser radiation (1.8 μm). To be able to make necessary comparison it is a must of the both laser systems alignment to corresponding physical parameters: power 180 mW, time of exposition 4 s, focus alignment, the same patterns of coagulation points. We used Rodenstock diode laser system as a source of 1.8 μm radiation and home made carbon dioxide laser system based on Synrad 48 series as a source of 10.6 μm radiation.

Changes in top diffractivity, orientation of flat and sheer meridian and difference in optical density between min. and max. meridian after laser radiation application were observed. Six basic patterns of coagulation points were used: 3:3, 2:2, 3:1, 3:0, 8, and 16. Location of coagulation points into flat meridian reliably leads to change of orientation for individual meridian. In the case of coagulation points location into flat meridian it has been changed to sheer axis and vice versa sheer meridian changes into flat. Stable a lasted change of meridian orientation takes place.

From experiment results it is evident that $CO_2$ laser irradiation causes much higher changes in optical density of cornea. Also corneal diffractivity and meridian value are more considerably changed. Probably greater volume of corneal tissue is affected and higher traction

tension comes into existence between coagulation points. Usage of 180 mW power of $CO_2$ laser radiation causes ability to correct:

- Astigmatism in the range from 7.5 D to 12.2 D by points location 2:2
- Astigmatism in the range from 5.2 D to 7.3 D by points location 3:1
- Astigmatism in the range from 2.8 D to 5.4 D by points location 3:3
- Astigmatism in the range from 0.2 D to 2.2 D by points location 3:0
- Hyperopia in the range from 2.7 D to 3.4 D by symmetrical location of 8 points on circle with 6 mm diameter
- Hyperopia around 1.8 D by symmetrical location of twice 8 points on circles with 6 and 8 mm diameter

There is a question if caused corneal damage is not too large. Carbon dioxide laser spot on cornea surface is visibly grater than one from diode laser.

There is another question how high value of corneal optical density change is advisable. Experiments in vivo will be affected with wound healing and regression but 12 D regression is not probable. That is more convenient to use location 3:3, 3:1 a 3:0; regression from 0,2 D to 7 D is more probable.

Experiments with lower power (140 mW) have reflected in smaller changes of refractivity. Carbon dioxide laser spot with 140 mW power is comparable with diode laser spot and next conclusion can be done:

- Point location 2:2 corrects astigmatism around 3 D
- Point location 3:1 corrects astigmatism in the range of 5.0 to 8.2 D
- Point location 3:3 corrects astigmatism in the range of 1.7 D to 3.5 D
- Point location 3:0 corrects astigmatism in the range of 0.2 D to 2.2 D
- Hyperopia around 1.7 D can be correct by symmetrical location of 8 points on circle with 6 mm diameter

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# Bone Structure Analysis Using X-ray Computer Tomography and Development of a New Diagnostic Method for Osteoporosis

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Higher fracture risk in osteoporosis is a subject that still needs to be investigated in order to achieve more precise classification that would reduce costs in healthcare and inconvenience of patients suffering from osteoporosis and other osteopenia. Studies of fracture line have already been done using finite element modelling [1]. In other works some correlation has been revealed between trabecular bone density and fracture load in femoral neck [2]. This indicates that valuable information can be obtained when assessing the trabecular structure in detail.

Until now the research was focused almost exclusively on the study of the compact bone. Today the statistics shows that the risk of fracture during the pathological changes of the bone is high (and above all shows clinical complications) in the femoral neck and the body of vertebrae. The above mentioned bones have an extensive trabecular network that, although not proved yet, may be responsible for the overall mechanical characteristics of the bones. This idea is which leads us to orient our research towards the trabecular bone structure.

In this work, a preliminary study of the trabecular architecture of the femoral neck in the region of the fracture is presented. Structural analysis near fracture line is expected to improve preventive treatments.

For this purpose first we made studies of proximal rat femurs. The bones were examined by μCT machine in order to get valuable information about the trabecular features present. The spatial resolution we used in this approach was 10 μm, the consecutive slices were separated by 20 μm, hence using the best possible measurements the μCT in our lab has to offer. The trabecular network was assessed by means of structural parameters such as trabecular number, trabecular bone to total bone volume. Some recent papers [4,5] list the various parameters that undergo modification when the bone changes its mechanical properties. Nevertheless an agreement of which parameters are suitable for diagnostic is still missing in these papers. Our aim is to select those parameters that can be later used as a good indicator of osteoporotic bones in early stages. Therefore following the CT analysis the mechanical testing is scheduled using a selected method that can simulate the actual loading of the proximal part of the femur. The currently available textural parameters we hope to use in order to achieve a correlation between critical loading and the trabecular architecture.

Hence the number of imaged bone samples was too small we are unable to do statements indicating some general change patterns between different stages of the bone disease. However the results show that the tools we are using are likely to lead to new trabecular bone microarchitecture classification as far as the computer tomograph machine for big samples is installed.

As far as we take into account our primary intention that this study is done in order to bring new possibilities into clinical diagnostics we necessarily need to use samples of human femoral neck (some osteoporotic and some healthy) in this study. Unfortunately the equipment that was planned to be installed is delayed and the computer tomograph currently in service doesn't allow us to measure samples of volumes greater than 2x2 cm at the resolution 50 μm

and 0,5x0,5 at the resolution of 10 μm. However the above mentioned fact limited our work in a big extend, selected characteristics of the trabecular architecture could be obtained and the tools will be applied on discrimination of osteoporotic and healthy bones in our future work

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Section 13

# CIVIL ENGINEERING

# Experiments with Connections at High Temperature

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Under natural fire are the steel structures exposed to changes of material properties at high temperatures and to the forces due to elongation of heated members (under heating) and shortening (under cooling), see [1]. In the connections is mostly cumulated more mass and are designed in colder areas compare to the structural member. They are exposed to the redistribution of internal forces from to the non-linear behaviour of the structure under exceptional loading, see [2]. Presented experimental programme represents a part of activity aimed at the prediction of the behaviour of the connections under fire situation by means of the component approach. Particularly the programme was focused on describing the T stub component behaviour at high temperature and the temperature distribution.

The component method is one of the possibilities to predict the behaviour of a connection. It is based on the mechanical model consisting of the extensional springs and the rigid links, whereby the springs represent relevant components and their force deformation response. Under fire conditions, the method is influenced by the variation of the material properties of steel and bolts with temperature; by the prediction of time-temperature variation within the various connection components; by the differential elongation of the connection components under the increasing temperature and by definition of fire development models within the building envelope and subsequent time-temperature profiles reaching the connection. The tests of the header plate connections under fire conditions were carried out in laboratory of CTU.

The experimental programme was divided into two parts. The first part was carried out in the laboratory of CTU Prague and it consisted from a pilot test at the ambient temperature. The tests at the high temperature – the second part of the experimental programme – were carried out at test facility of the fire laboratory PAVUS, a.s. The beam cruciform test arrangement was used, which reflects the purpose of experiments and available laboratory equipment. Steel manufacturer provided three specimens in total. One was used for the ambient temperature test and two were used for the high temperature test. Two parts of beam connected together by a flexible end plate made a test specimen. The beam profile was IPE 200 and length of each part was *1100 mm*; end plates of dimensions *220 x 130 mm* were thick *10 mm* and four bolts M16 were applied in connection. The used bolts were grade 10.9 and the beams and end plates were grade S275 as shown the material tests, although they were designed as grade S235 originally.

In high temperature test only the area in immediate vicinity of the connection was left unprotected. The beams were protected with ceramic fibre blanket to prevent premature failure of the beams. The upper flange of the beam was protected along whole span to model the concrete slab acting as insulation and as a heat sink. In both test the specimens were loaded in midspan by a hydraulic jack. The pilot test at ambient temperature was controlled by deformation. The specimen was equipped by displacement transducers to measured deflection of the specimen and horizontal deformation of end plates. Strain gauges were fixed into centre line of the bolts to provide stress measuring. In high temperature tests the loading history adopted maintained a constant moment with different temperatures. This scenario gives a realistic representation of the temperature gradient across the connection at high temperatures. The specimens were loaded in different moment capacity levels respectively *70%* and *20%*.

These levels were based on the experimentally derived value from the ambient test. The heating regime followed the linear temperature ramp achieving *900°C* in *45 minutes*. Specimens were instrumented by thermocouples to provide data about temperature profile at compartment as well as at connection. The overall deflections were recorded using displacement transducers. The obtained results are well defining the asked goals: failure mechanism of the connection, moment-rotation curves for the connections and connection temperature profile.

A similar failure mode was observed in all tests. In each case a deformation at bottom of the end plate occurred with formation of the plastic hinges close to the beam web. A rupture of one or both bolts followed the initial mechanism. In one case rupture of the weld ware observed instead the bolt one only. It represents a characteristic example of the second failure mode of the T stub (plate and bolt failure) of the tension zone. In compression zone of the thermal affected specimens a localised deformation of the beam web and the upper flanges occurred at position of the load. In general the high temperature test produced failure modes, which were expected based on the prediction and the test at ambient temperature. In both cases the degradation was small up to about *500°C* beyond which there was a progressive increase of degradation in accordance to the load level.

The average relative temperature profiles for high temperature specimens were recorded. The relative temperature difference between connection elements is linear up to *400°C* in bottom flange and then is nearly constant. In general the end plate is cooler compare to the connected beam. The hottest element is bottom flange and the coolest element is upper part of end plate. The temperature across the depth of the beam is nearly linear where the difference between bottom and upper flange is about *90°C* only, see [3]. In case of end plate connection it seems to be realistic to represent the T stub temperature as uniform, because the difference between end plate and bolt temperature is negligible. The lower bolt row is about *30°C* hotter than the top one.

The obtained experimental results will be utilised for précising of the tensile part of the joint at high temperature and prediction of the temperature distribution inside this type of connection. The work is focused into the improvement of the structural safety, see [4], by eliminating the potential progressive collapse of the structure.

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# Welded Joints in Aluminium Structures

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In the structural aluminium is the progress in technology followed by new knowledge in the design of trapezoidal sheeting's, in the behaviour of structures under high temperatures in case of fire and in connecting technology. The welding of aluminium structures is common technology of last ten years, see [1]. The utilization is supported by new generation of the structural aluminium alloys, by the welding robots keeping the temperature of heated material in sharp tolerances, and by improvements of prediction of the structural elements and connections with material degradation by temperature round the welds, see [2]. The presented work is focused on development of the design models of welded joints and welded elements.

In the vicinity of the weld is the material property depredated by temperature. The engineering definition of heated affected zone (HAZ) helps the prediction models to take into account the material softening and variation of resistance. Two different quantities in the HAZ can be observed: severity of HAZ softening and extent of the softened zone. The severity of softening in the HAZ is expressed in terms of softening factor $\rho_{HAZ}$. Factor $\rho_{HAZ}$ represents ratio of the HAZ strength to parent metal strength. At the current state of the art, it is possible to predict values for this factor only. The well-defined coupon HAZ experiments employ hardness surveys. The actual stress in the softened area is more complex. It was approved that hardness ratio correlates better with the tensile strength compare to the proof stress. Hardness ratio obtained from the survey is often scattered between specimens. In prediction of the behaviour at the level of member design, extent of the softened zone needs to be studied [3]. The total softened area at any critical cross-section has to be determined.

Based on the present knowledge published in Europe and overseas as well as own prediction simulations the experimental research project was carried out in laboratories at the Faculty of Civil Engineering at CTU in Prague. There were two sets of experiments: the test of welds itself and the test of the real structural members made by welding technology. The tests of welds were divided into two series before and after the structural member.

The tests of the welded aluminium T-stubs were prepared to analyse the extent of the softened zone. Two sets with a different thickness were welded up. Each set had three T-stubs. For the test coupons were made following the standard coupon test. Each T-stub was cut up for ten coupons. Test to determine the actual modulus of elasticity and ultimate strength were made. A loading hydraulic machine with an extensometer was used in order to record strain. From each set the behaviour of the severity of HAZ softening and the extent of the softened zone was plotted on the graph. The residual stresses ware checked by the deformation of micro-raster of points. For the simple detailing and well-applied technology, which was used for T stubs, are the residual stresses negligible in range of the stresses ration till 10%, as was expected based on literature survey.

The main part of the experimental project was the test of two full-scale girders. First set was two parallel lattice girders in 1,0 meter distance and 6,0 meter span. The girders were braced at the supports and in the middle of the span, where was applied the load. The same set was used with the modified HAZ zones. The quarter welds were prepared at each parallel upper chord. The test peaces were loaded step by step to the collapse. The universal loading

hydraulic machine was used. Load was applied proportionally to both upper chords through a scale beam. The load forces, the vertical and horizontal deformations and main stresses in the observing welds were recorded during the experiment. The stresses were monitored at major points in order to recognize the influence of the material softening to the stability in the compressed upper chord. All strain gangues were doubled in order to record stress in every plane.

After the test the lattice girders was cut up at the specimens to prepare the parts for the tensile tests. It allows specifying material properties of used aluminium alloys. The major evaluated material properties were proportional and ultimate strength and modulus of elasticity.

The test results confirm the prediction models with good accuracy, if is the calculation based on measured material properties. In case of application of the characteristic design values the accuracy of prediction is good as well. The softening of material needs to be taken into account under design in case of the today utilized alloys and the progressive welding technology. The application of précised prediction procedure brings the improvements into safety as well as a substantial savings [4].

The data of the experimental tests are used in theoretical part of the research project. The finite element model of the tested T-stubs as well as of the lattice girders are under progress based on 2D and 3D simulation. The model is calibrated according to experimental results on T-stub and based on well defined as well as standard imperfections is the structure modelled including the material local softening. The sensitivity study allows to precise the prediction models of compressed members, which are till now based on tests with elements without HAZ only. The improvements of the analytical prediction model will be offered as a background material to the conversion of the European pre-standard into the European standard for aluminium structures.

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# Protection of Buildings against Ground Moisture - Efficiency and Reliability of Selected Remediation Means

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Protection of building against moisture is a fundamental part of preventive measures avoiding their deterioration. Increasing moisture content in building materials is considered to be among the most frequent causes of low physical durability, occurance of failures and devaluation of buildings.

During last decade renovation and reconstruction od a wide range of buildings increased and evoked a need for extensive application of new remedial materials and techniques. But the implementation of a number of new, insufficiently tested materials and unsuitable use of some technological processes without aquired knowledge and disrespect for behaviour of building materials in various conditions could cause serious failures and succesive damage. For this reason the reliability assesment of selected remediation means has been presently subject of special attention in area of research.

The main approaches of the grant project include creation of a self-contained database of remediation methods and materials and creation of the cataloque of faulty remediation procedures obtained by survey in situ.

The grant project developed methodology and recommendations concerning laboratory verification and testing of injection materials. Further in next stage in 2003 the project will include laboratory and experimental investigation of injection material samples and redevelopment plasters exposed to various impacts (salt, moisture, temperature), testing and evaluation of remediatial procedures applied under various condition. Experiment will be carried out according to the WTA code to achieve a comparison with results of measurements of collaborating departments of TU Wien and TU Liepzig.

Within the partial task of the grant project special attention was paied to evaluation of methods dealing with measurement of moisture in brickwork. Various non-destructive methods used for measurement were studied with special focus on the brickwork under salt loading. Based on the experiments it was proved that suitability of the respective method strongly depends on the content of moisture and salts in brickwork. These results will be applied within next experiment.

The results achieved within the work on the grant project, based on a relatively extensive field and laboratory investigation, contribute to the recommendation and methodological instructions for damage-prevention in processes of renovation and reconstruction. Limiting conditions for use of selected remediation means are formulated as well.

The grant project was carried out in collaboration with foreign project partner – Department of Building Physics, Technical University Wien.

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# Relaxation Qualities of Asphalt Mixes

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The relaxation test is a test method that evaluates properties of compacted asphalt mixes at low temperatures. Simultaneously, the low temperature bending test is performed to find out the flexural strength of the mix. The both methods use the same test equipment setup and the same type of the test sample (beam 50x50x300 mm). The test is performed in a special climatized bowl at the temperature of 0±1°C.

**Flexural strength.** In order to determine the flexural strength, the sample is loaded till its rupture, the maximum bending stress (load) and the corresponding strain being recorded. The loading rate (the rate of the movement of the loading press) is an imortant factor seriously influencing the stress value, for this test the value 1,25 mm/min is prescribed. The resulting flexural strength (or modulus of rupture) $R_i$ (MPa) is computed from the formula

$$R = \frac{3}{2}\frac{P \cdot l}{b \cdot h^2}, \tag{1}$$

where $P$ is the maximum reached (failure) load in N, $l$, $b$ and $h$ are the length (between supports), width and height of the beam, respectively (in mm). This test allows us also to determine modulus of stiffness in bending $E$ (MPa) and strain $\varepsilon_s$

$$E = \frac{1}{4Y_s}\frac{P \cdot l^3}{b \cdot h^3}, \tag{2}$$

$$\varepsilon_s = \frac{600h}{l^2} Y_s \tag{3}$$

where $Y_s$ is the beam midspan deflection.

**The relaxation test.** The test is performed in two phases. The first, the preparation stage, serves for determination of the flexural strength. In this stage, the loading rate should reached maximum allowed value in order to minimize adverse influence of the mix relaxation. Our testing machine allow the rate 50 mm/min of the loading press shift. In the second phase, the sample is loaded (in the shortest possible time period) by the load reaching 2/3 of the load maximum recorded in the first stage. Then the the load (stress) decrease in time is monitored (under constant sample deformation), the bending stress being computed from (1). The formula

$$\sigma_r(t) = \frac{P_r(t)}{P_r(t_0)} \tag{4}$$

then serves for determination of the relative relaxation stress $\sigma_r(t)$, showing the decrease of the stressing level in time in %. The relaxation value then indicates the time (in seconds) necessary for reaching 50% level (alternatively 30% or 15%) of stressing.

**Testing programme.** In the Road Laboratory of the Faculty of Civil Engineering, the large number of tests at low temperature were conducted. Two types of mixes were thoroughly tested: the SAL and VMT mixes. The SAL (Stress Absorbing Layers) mixes are mixes with high content of asphalt and smaller grain size aggregates, intended to prevent crack reflection and propagation through the pavement structure. The VMT (high stiffness modulus) mixes are used to prolong service life of the flexible pavements by minimizing occurrence of the permanent strains (rutting). These mixes show high fatigue resistance nad increased resistance against negative moisture effects. The samples, of both mix types, were prepared with broad spectrum of different types of asphalt binders, modified as well as unmodified. In the case of the SAL mixes, also the mixes with addition of arbocel fibers were tested.

**Evaluation of tests.** The selected results of the above described tests are shown in Tab. 1 and Tab. 2. The higher flextural strengths were observed for mixes with smaller grain size aggregates (mixes with higher homogeneity) and for mixes with modified asphalt binders. The addition of the arbocel fibers did not result in increased flexural strength. The same can be said for the relaxation properties: more homogeneous mixes and mixes with modified binders show better relaxation behaviour.

*Table 1: Flexural strenth of the asphalt mixes VMT and SAL*

| Mix type | Max. grain size | Binder | Flexural strength |
|---|---|---|---|
| SAL | 0/11 | AMe 65 A (3), arbocel 0,4% | 8,13 |
| SAL | 0/5 | 50/70 | 7,46 |
| VMT | 0/22 | AMe 65 (2) | 5,31 |
| VMT | 0/22 | 50/70 | 4,35 |

*Table 2: Relaxation properties of asphalt mixes VMT and SAL*

| Mix type | Max. grain size | Binder | Stress relaxation decrease to the 50% level at $T$= 0°C in (s) |
|---|---|---|---|
| SAL | 0/5 | 50/70 | 45,5 |
| SAL | 0/5 | 50/70 1% arbocel | 54,5 |
| VMT | 0/22 | AMe 65 (1) | 29,5 |
| VMT | 0/22 | 50/70 | 75 |

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# Assesment of Stream Ecological Status in Urban Watershed

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The purpose of this research was to compare the ecological status of few small urban watersheds and evaluate the environmental risk, which can be caused by different types of pollution.
The assessment of the ecological status of a stream is a very complicated process, and has to be done according to the Directive 2000/60/EC of the European Parliament and the framework for Community action in the field of water policy. The directive required a complex study of the stream ecosystem, it means that not only water and sediment quality are monitored, but the status of the aquatic organisms and changes in the morphology and hydraulics of the stream are observed.

The research was conducted in a few experimental Prague catchments each with different sources of pollution (industrial, residential), different sewer system (combined, separate) and with different hydraulic regimes for the recipient. The first observed stream- the Botič creek drains a residential and an industrial area both with busy traffic. The quality of water in the studied section of the Botič creek (length of 2.5 km) is influenced by two overflows from a combined sewer system serving both industrial and residential areas. The second observed watercourse- the Zatišský creek drains only residential areas (estate development) drained by separate sewer system. The quality of water in the creek is influenced by 8 storm sewers outlets and by 3 storm sedimentation basins. Although the Zatišský creek is a particularly small stream, there is a strong acute hydraulic impact due to the drainage of storm water. The third observed watershed is the Šárecký stream, the studied section is upstream and downstream from its tributary the Zlodějka creek (length of 1km). The Zlodějka creek drains the new highway on the Evropská street and it is impacted by pollution originating from traffic. A reference sampling site was selected on the Komořanský (Cholupecký) stream in its upstream part, where significant anthropogenic activities do not occur.

The ecological status and the environmental risk was assessed by the monitoring of different parts of the stream's ecosystems (water and sediment quality, stage of the macrozoobenthos community, morphological and hydraulic parameters).

Water and sediment samples were collected every two months. In all types of samples concentrations of heavy metals (Cd, Pb, Cu, Cr, Zn) were detected, additionally the basic physical and chemical parameters were measured in water samples. The sediment sampling was done in shorter intervals after the flooding, to monitor the remobilization of heavy metals from sediment and discover the time period, which the sediment required to return to the same level of contamination that existed before the flooding.

The biological assessment of macrozoobenthos was carried out according to two biotic indexes: The saprobic index and the ASPT index, whose higher value means worse resp. better quality of the aquatic environment. The computer program HOBENT was also used to assess the benthic community. This program evaluates the differences between a benthic community in the study stream and the target benthic community in a reference stream according to the

database. The result, index B, indicates how the study stream varies from the natural stage. The concentration of heavy metals in different species of benthic organisms was also detected.

The assessment of environmental risk in an aquatic environment is a very complicated and complex process. We try to estimate environmental risk by using two different coefficients (toxicological units and distribution coefficient), which are based on monitored data. None of these factors can by itself be used for assessment of environmental risk or give a complete picture about environmental hazard, the combination of both factors can significantly increase our knowledge about potential or actual environmental risk.

The comparison of the impacted streams with a referential stream showed that the aquatic environment in all three streams is modified compare to the reference stream. The Botič and the Šarecký streams are influenced mostly by the chemical stress, which is caused especially by the chronic risk of heavy metals accumulated in sediments. The concentration of monitored heavy metals in the water during dry weather flow is low. It corresponds with the first or the second class of ČSN 75 7221. On the Botič creek, during rain, when overflows haven't been in operation yet, Pb concentration is increased under the storm sewer outlets. When overflows are operating, the concentrations of all monitored heavy metals are similar to those within the sediment of a combined sewer system. We can say that outlets of combined sewer system in the Botič creek degrade water quality and consequently make the biological indicators worse.

In the Zátišský creek the hydraulic stress is most significant for affecting the stream ecosystem. Monitored concentrations of heavy metals haven't created any ecological risk for aquatic environment yet, with an exception of one site, where a problem exists due to black outlets. The comparison of the Zátišský creek with the referential stream (the Komořanský creek) demonstrates the strong hydraulic impact caused by storm sewer outlets. It induces frequent changes of the watercourse morphology. These changes are reflected in both the composition and representation of benthic macroorganisms.

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# Inverse Modeling of Heat and Moisture Transport Processes in a Building Envelope with Interior Thermal Insulation System

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Mathematical models of heat and moisture transport are very effective tools in the prediction of hygrothermal performance of building envelopes, which are frequently used in envelope design at present. However, any model can provide reliable information only in the case that the quality of input data is very good. This is not always true, because the standard lists of thermal and hygric parameters are usually far from complete and they often do not include the dependencies on basic state variables of heat and moisture transport. Therefore, the models have to be tested very thoroughly before they can be applied to serious service life prediction analyses based on modeling long-term hygrothermal performance.

At present, the mathematical models of heat and moisture transport are mostly tested using the measured data from selected test houses. This may not always be sufficient, particularly if some quite new hygrothermal problem is to be tested, which did not appear in exactly the same form in the previous test house measurements. In this respect, application of more flexible semi-scale testing systems can be considered as a reasonable solution for the improvement of the model validation and calibration procedure.

For the experimental analysis of hygrothermal performance of investigated building envelopes, the specially designed semi-scale device NONSTAT [1] was employed. The tested building envelope consisted from the exterior to the interior of a brick wall, water vapor retarder KAM on the cementitious basis developed by Sakret, capillary active mineral wool DU by Rockwool as thermal insulation and water vapor permeable plaster FFP also by Sakret. The hygrothermal parameters of particular materials employed in measured building envelope were experimentally determined in our laboratory in order to obtain necessary data for computational analysis (for details see [2], [3]).

The computational analysis of hygrothermal behavior of investigated building envelope was done using the computer code Delphin 4.3. It was developed by J. Grunewald at the Institute of Building Climatology of the Technical University of Dresden. Details on the code can be found in [4]. The climatic loading of the investigated structure during computational analysis was the same as in the semi-scale experiment.

The semi-scale measurements with NONSTAT device began with the real climatic data for October 1. The measurement took time of 165 days and was finished with the climatic data for the April 4. So, the whole winter period was simulated in the chambers. The measured results showed, that some overhygroscopic moisture appeared in the brick wall during the whole time of the experiment, and a part of it remained there until the end of the winter period. On the other hand, the capillary active mineral wool material DU remained dry during the whole critical part of the year, which is clearly a consequence of the high values of its moisture transport parameters. Therefore, taking into account all the negative and positive factors, the hygrothermal performance of the wall could be considered as relatively good in general.

The computational simulations have shown a not very good coincidence with experimental data. Therefore, we have started a process of inverse modeling to achieve a better coincidence. As the main problems were in water content and relative humidity profiles, we tried to modify hygric parameters, namely the water vapor diffusion resistance factor μ of the water vapor retarder KAM, moisture diffusivity κ of the water vapor retarder KAM and moisture diffusivity of ceramic brick. We have tested together 10 different combinations of the mentioned hygric parameters. The best results were achieved with the modified hygric parameters given in Table 1.

Table 1 Modified hygric parameters of used materials.

| Material | quantity | original data | modified data |
|---|---|---|---|
| Sakret KAM | μ [-] | 11.9 | 20.0 |
| Sakret KAM | κ [$m^2s^{-1}$] | 1.43e-09 | 1.43e-11 |
| Ceramic brick | κ [$m^2s^{-1}$] | 1.52e-07 | 2.00e-10 |

The comparison of experimental data from the semi-scale NONSTAT experiment with computational data obtained by Delphin computer code revealed the superior role of really complete determination of hygric and thermal properties used as input parameters of the model. This complete determination means primarily the dependence of all parameters on moisture and temperature in the whole ranges studied. The lack of these dependences for some of the parameters in this paper has led to difficulties in the process of inverse modeling because it was necessary to fit several parameters and too many combinations were available.

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# Semi-Scale Testing of Interior Thermal Insulation System on Mineral Wool Basis

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In this paper, semi-scale testing of hygrothermal performance of building envelopes in the conditions of difference climate was employed for testing two selected interior thermal insulation systems, namely the brick wall and calcareous marly limestone wall with newly developed capillary active mineral wool materials (Rockwool, SA) as thermal insulation. The semi-scale experiment was done using the measuring system NONSTAT [1], which consists of two climatic chambers, connected by a specially developed tunnel for testing of specimens in large scale, devices for measuring relative humidity and temperature and devices for measurements of moisture content, salt content and capillary pressure. In the testing process, the thickness of the specimens of building envelopes is the same as in the practical application on building site, the applied exterior climatic data correspond to the reference year data for Munich, Germany, for the interior climate common data for residential houses are chosen.

The developed interior thermal insulation system was firstly applied on brick wall of width 450 mm and secondly on calcareous marly limestone wall with the same width. In the case of the brick wall, MU thermal insulation boards were used, and for insulation of calcareous marly limestone, DU boards were employed. For fixing the boards on the base construction, the retarder B2 on principle of the cement glue from Karlomix was used. For details of basic thermal and hygric material parameters of applied materials in the tested structure see [2], [3].

The measurements were firstly performed continuously for 65 days on non-insulated brick wall. The boundary conditions in the chambers were as follows: internal temperature $20.5^0$C, internal relative humidity 50%, external temperature $2^0$C, external relative humidity 90%. The temperature initial conditions in the brick wall were the same as the conditions in the laboratory, i.e., $22^0$C, the initial relative humidity was higher than in the laboratory, typically between 70% and 90% due to the fact that the brick wall was freshly walled. After the 65 days measurement, there was applied our thermal insulation system, which applicability was tested for the most unfavorable external climatic conditions. The boundary conditions for temperatures and relative humidities on the external side were chosen according to the data from TRY Munchen (data for TRY Prague were not yet available in the time of measurements), the measurements began with the climatic data for January 1. Internal climate was the same as for the non-insulated brick wall. The measurements were performed for 62 days.

The measured results have shown, that the relative humidities in the brick wall decreased with time, so that after 60 days these achieved a value around 75% and no overhygroscopic moisture was observed. The relative humidities in the thermal insulation layer were significantly lower. Apparently, the capillary active thermal insulation layer exhibited a very positive effect on the hygrothermal behavior of the wall even in the most critical part of the year from the point of view of water condensation.

The testing of calcareous marly limestone wall was performed for 38 days on non-insulated wall, and then there was applied the thermal insulation system. The boundary conditions for temperatures and relative humidities on the external side were chosen according to the data from TRY Munchen, the measurements began with the climatic data for December 1. Internal climate was the same as for the brick wall. The experiment on insulated calcareous marly limestone wall was performed for 55 days.

In this case, the results were not very prospective, the overhygroscopic moisture was in the whole limestone wall during the whole time period, and only in the thermal insulation layer it was missing, the relative humidity being between 90% and 50%. However, it should be noted that this worst possible case will very unlikely occur in the practice. Our application of a severe combination of initial and boundary conditions, where initially the sample is on room temperature and on one of its ends there is applied suddenly temperature close to $0^0$C, which is maintained then for several months, was in fact very artificial, so that this case can be considered as only theoretical. On the other hand, even this very theoretical case documented well the capabilities of the system, which was its main purpose, and has shown again the necessity to handle stone walls very carefully.

The measured results show a very good function of the capillary active thermal insulation material, which remains dry during the most critical part of the year. These also reveal a critical role of the water vapor retarder, which should have the water vapor resistance factor high enough to moderate water vapor transport from the interior to the load bearing structure and prevent condensation there. From this point of view, the employed water vapor retarder B2 (Karlomix, Ltd.) was suitable for the brick wall but it failed for the calcareous marly limestone wall.

From the point of view of applicability of NONSTAT system for testing hygrothermal performance of multi-layered building constructions it is possible to conclude that the system is suitable both for monitoring heat and moisture transport in buildings envelopes and for providing experimental support in the process of design of new technological solutions in building structures.

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# Risk Assessment of Urban Drainage Impact on Small Streams

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Impact of urbanization on small streams is evident in the different part of the ecosystem. The goal of this research was to observe urban drainage effect on water quality of small streams. The main attention was focused on macro-invertebrates living in the streams. The biological assessment of streams is still underestimated, although organisms living in the water are able to reflect very sensitively the environmental changes from the long term view.

Stream water quality is directly impacted by urban drainage outlets and storms sewers outlets. The main risk of combine sewer outlets is in introducing pollutants to the aquatic ecosystem (heavy metals, organic pollutants etc.). The part of these pollutants remains dissolved in the water and part of them is bound to the sediment. Both of these environments provide living conditions for aquatic organisms. The storm sewer outlets cause mainly hydraulic stress. These effects influence stream morphology, and cause changes in biotopes acceptability for different kinds of organisms. The another consequence of hydraulic stress is organisms wash out. Benthic community needs certain time for its restoration and.

The studied stream was the Botič creek (134, 84 $km^2$, 34,5 km), which is the main Prague tributary of the Vltava River. The section of interest (length 2,5km) is located below the Hostivař reservoir. In this section is the Botič creek protected as "Práčské meandry Botič". The Botič creek drains residential as well as industrial areas, both with busy traffic. The quality of water of the Botič creek is influenced by two combined overflows in the studied section.

The biological assessment of makrozoobentos has been done by two biotic indexes: The saprobity index and the ASPT index, whose higher value means worst resp. better quality of the aquatic environment. To assess the benthic community the program HOBENT was used. This program evaluates the differences between parameters of benthic community in the study stream and the reference parameters found in the database. The comparison is based on environmental parameters (altitude, latitude, substrates characteristics, discharges etc.) The target benthic community is the community present on non-affected or minimally affected locality. The result, index B, indicates how the study stream varies from the natural state. The B index is equal 1 in the ideal case.

The artificial substrate was used as other method of environment quality monitoring. Advantages of the artificial substrate are in possibility to use it in locality with bad access and it provides uniform habitat for colonization, thereby reduce valuation benthic density variability. The artificial substrate reduces problems with unsuitable benhtic habitats by creating uniform islands of hard-bottom habitat that can be placed wherever they are needed. Samplers with the artificial substrate had been placed on the stream bottom and colonized by benthos. Samplers were taken out each weak and organisms were determinated. The influence of outlets was assessed by comparison of community composition up and bellow outlets. The colonization is influenced by season and fraction size of used.

The concentrations of heavy metals (Cd, Zn, Pb, Cu, Cr and Ni) in different species of benthic organisms were detected. Organisms were freeze-dry in freezedrier. After that organisms were digested by microwave system. The concentrations of heavy metals were determinated by atomic absorption spectrophotometer.

The assessment shows, that the best water quality is in B0 profile, which is not influenced by the outlets. Below the outlets (especially outlet CSO1, which drainages industrial areas) the quality decreases. The influence of CSO2 is not so significant. The number of tolerant species increase, whereas sensitive species decrease below CSOs.

We have to use carefully B index, because the observed urban catchment is very small and stream is strongly influenced by anthropogenic activities. Values of B index are very low in all monitored profiles and it means that these localities are away from natural state.

For the artificial substrate assessment was used 6 samplers (4776 $cm^3$) in each profiles. The samplers were placed on beginning of August 2002. Unfortunately the flood washed out the samplers. Another sampler's set was made and will be placed during spring.

The results of heavy metals show that they are significant differences in content of heavy metals in various species of benthical organisms. The organisms below the outlets are more contaminated than the same species above the outlets.

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# Test House for Validation of Hygrothermal Performance of Interior Thermal Insulation System on Mineral Wool Basis

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The application of interior thermal insulation systems on building envelopes is not a natural solution but sometimes there is no other option available. A typical example is a historical building, where the facade has to be kept in its original appearance mostly, and the exterior insulation systems are excluded for that reason. In that case the utilization of such an insulation system would allow to prevent moisture damages and to upgrade the thermal properties of the envelope as the only reasonable option. In this paper, we present the final stage of development of interior insulation system on the mineral wool basis.

The materials for this thermal insulation system were proposed using the numerical simulation program Delphin 4.1 [1]. The thermal and hygric parameters of these materials were determined by laboratory methods [2]. The application of the whole thermal insulation system was then verified using the semi-scale NONSTAT system in difference climate conditions [3]. The final stage of verification of the system was its application in a test house.

The Kindergarten in Prague 5-Hlubočepy, Hlubočepská 90/40 was chosen as a test house for this verification. The object is about 100 years old. In this object, the necessary thermal insulation had to be performed from inside because the façade had to be maintained in its original appearance. The purpose of the construction work was the increase of thermal resistance of the building envelope. This increase was achieved by installation of INROCK interior thermal insulation system. At the same time the ceiling below the roof was thermally insulated in an ordinary way using an external insulation.

The preliminary works consisted in careful scaling of all painting coats. Incoherent plaster places were repaired with lime – cement plaster with stuke surface finish. The inside wooden walls facing was displaced.

The additional interior thermal insulation INROCK produced by Rockwool was placed on the external walls of all rooms, where the children stay most of the time (playrooms, cabinets, bedrooms and in the neighboring staff cloak-rooms). The insulation was designed in the thickness 80 mm. The value of the thermal resistance of this insulation was determined by laboratory experiments and amounts R = 1.43 $m^2K/W$ (for 95 % relative humidity). The total thermal resistance of the construction is higher than the thermal resistance required by the Czech standards with the preservation of the current thickness of the brick-built external walls 600 mm. The thermal resistance of the construction with additional thermal insulation in the parapet location and with the thickness of the walls 450 mm achieves the standard requirements.

The thermal insulation boards INROCK are made from mineral wool. They consist of 2 layers of different density, which are connected compactly. The HARD layer is harder and its thickness is 30 mm. It is intended for the final design of the wall. The thickness of the SOFT layer is 50 mm and it is softer. It serves as the main insulation material. The SOFT layer of the boards should always be put towards the wall. The dimension of the boards is 600 x 1000 mm, the thickness is 80 mm.

SAKRET KAM leveling render was designed for glueing of the boards to the wall surface, and plays the role of water vapor retarder as well. The elements perforating the basis and the steel consoles for the radiators were carefully sealed with KAM leveling render.

The boards were assembled from the bottom upwards. The vertical board connections were alternating over one half of the board width in order to bond them and the boards were pinned hard upon on. Disk plugs EJOT IDK – T 8/60 x 155 were used for board mooring. There was always 1 piece used on 1 board in its center. The binding assembling foam was applied to a plug recessing location before its insertion. This acquisition provides compactness of the gummy leveling render surface.

The internal plaster was designed from the leveling render SAKRET FFP and has the following structure: layer of the leveling render FFP 3 mm thick on the boards, netting, layer of the leveling render FFP covering 1.5 mm thick, final layer of the leveling render FFP 1.5 mm thick. The final layer was painted with 2 layers of KARLOMIX painting.

Distribution and instrument boxes for electrical installations were placed into the prepared outlets in the insulation layer using gypsum mixture. It was also necessary to remove the window lining plaster before the application of the thermal insulating system. A curtailed hard layer of INROCK boards in the thickness of 30 mm was used for the thermal insulation of the window heads and window reveals. Wooden facing of the thermal insulating walls was recessed on a supporting structure made from lathes 40/18 mm. This structure was glued with PUR-65 (WURTH) foam 4 mm thick. It was glued only vertically on FFP final leveling render. This layout is used to guarantee the aeration between the thermal insulating surface and the wooden wall facing. All the windows of the southern, western and eastern facade (apart from yard facade) were repaired. The enlargement of the current wooden window stools over the added INROCK thermal insulation was performed.

Rockmin mineral wool boards were laid on the cleansed loft floor. The total thickness of this mineral wool layer was 160 mm.

The building reconstruction was completed between June and August 2002. After the reconstruction, probes for measuring temperature and relative humidity on the surfaces and in critical places within the wall were positioned in several locations for monitoring the hygrothermal performance of the reconstructed wall. As the same data were determined during the last winter before the reconstruction, the effectiveness of the system can be directly assessed in this way.

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# Experimental Research of Structural Materials and Technologies

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In the year 2002, the research activities under the project MSM 210000004 were conducted by the research teams from the FCE departments: Physics, Building Structures, Structural Mechanics, Concrete Structures and Bridges, Steel Structures, Geotechnics, Road Structures, Experimental Center, Center of Experimental Geotechnics as well as by the researchers from the Klokner Institute.

The research project scope covers the whole spectrum of scientific activities at the Faculty of Civil Engineering and at the Klokner Institute of CTU, the following areas being most important:

- aging and durability of concrete,
- micromechanical properties of the concrete structures and concrete reinforced by fibres,
- self-compacting concrete,
- experimental research in steel, timber and composite materials and their technologies,
- research on bentonit and its mixtures for application in construction of underground radioactive vastes deposit,
- biological degradation of structural materials,
- geotechnical characteristics and stability of mixtures of soils and brown coal combustion fallouts,
- rheological properties of road materials.

The aim of the project is to stimulate research in materials based on our natural resources in order to develop innovative construction materials for advanced engineering structures. The research is focussed on minimization of the energy consumption, recycling and use of vaste materials.

In the year 2002, the most notable contributions are the following:

1. The comparison of new experimental methods applicable for determination of the moisture conductivity proved that the best results are provided by the non-stationary method in integral form. The method was used for testing of calcium silicate materials and porous concretes.
2. The timber degradation by the biotic factors was studied, partial attention being given to the stabilization of the fungicides in the timber by the organosilicate hydrophobic coatings.
3. The thermal properties of cementitious composites under conditions of either thermal or mechanical load were monitored. The effect of thermal load was studied both in the conditions of direct exposition of the analyzed samples to elevated temperatures and after the high

temperature exposure to assess their possible applicability in structures after exposure to thermal loading.
4. The effects of the microscopic and submicroscopic structure of timber on its mechanical properties were studied and first results were obtained on the influence of the fibril inclination in the timbre cell wall on its strength.
5. The effect of various types of admixtures based on carboxyl ethers on properties of the self-compacted concrete were studied with emphasis placed on properties of the fresh concrete mixtures, as well as on the strength characteristics and modulus of elasticity time evolution. Also the long-time effects of different sorts of cement and microfillers at different conditions of treetment during a hardening process were studied.
6. The physical and mathematical modelling of the heat transfer in the surroundings of the radioactive waste container was accomplished.
7. The rheological and relaxation properties of asphaltic compacted layers were studied both for SAL type materials used in crack reflection prevention and for VMT materials with very high stiffness modulus used as base and bedding layers with potential generalization of the procedure for purposes of the design method innovation.
8. The new type of the dipping compass based on stringed strain-gauges was constructed and verified as well as the new type of the boiling bowl for determination of the moisture expansivity of ceramics. Several diagnostics methods were evaluated in order to improve process of detection of the ceilings with dangerous cracks formation.
9. The problems associated with volume changes in ceramics and in composite ceramics-concrete elements were studied. A concentrated attention was given to assessment of the structural reliability of buildings in flooded areas.
10. The method of the nitrogen and krypton adsorption was used to measure porous structure of selected structural materials with the conclusion that the cheaper nitrogen method provides sufficiently accurate results. This method was then used to monitor the nano-pore changes in concrete under different temperature conditions in order to correlate these results with changes in strength and fracture toughness of concrete caused by the same temperature conditions.

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# The Effect of Extreme Rainfall on the Function of Overflows

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Extreme hydrological phenomena are an effect of extraordinary course of certain natural processes. These are influenced not only by geographical conditions, but also the human activity. The main cause of occuring these phenomena in drainage areas is the presence of abnormal meteorological situations and other relating phenomena (downpour rains, sudden snow-melting). The occurance and course of extraordinary hydrological phenomena are however influenced also by geographical conditions of the relief, vegetation, climatic, pedology, geological, hydrogeology and hydrogeographical relations.

The results of extreme rainfalls are floods. The floods and other destroying effects of water from extreme rainfalls can't be prevented. Their negative effects can be, however, successfully reduced by suitable behaviour in the countryside and take out effective technical measures. Recent floods involving nearly the whole area of our republic have shown the acute need for being involved in these problems even when talking about sewerage. Not only when suggesting, but also when running sewerage systems and sewage treatment works.

The sewers can be damaged by pulling down or partial or total wash away and blocking of pipeline profile. Sewerage system are not design for extreme rainfalls and therefore during these extreme rainfalls are overloaded. Such overloaded pipeline can result in dangerous backwaves to service connection and flood of underground rooms of houses. As a protection against backwaves through sewerage system itś necessary to secure sewage treatment works as will the areas with flood protection. This-year-floods have proven out that the clap valves of sewerage systems could not renot the high pressure of water.

There are many objects in the sewerage system. The most endangered one are the sewer outlet structure of rain overflow. Other very often endangered objects are sewer syphons, rain overflow and storm-water stand-by tank. With regard to water-level in flooded areas the sewerage systems could be pressurized. In areas, where the pipeline and it could lead to sink down of roads. Pressure cars are used for sewerage purification and service connection purification. After this sewerage purification the monitoring of the whole system is highly recommended.

When constructing the overflow and outlets and establishing their positions (heights), itś necessary to take into account the water-level during floods. When the back-wave flood from the river threatens, itś necessary to protect the overflow and the sewerage system against water penetration. This protection is usually made by clap valve inserted into outlet. The clap valve must be inserted into outlet in special building, only in extra-small profiles itś possible to insert it directly sewer outlet structure. In this case itś also necessary to secure itś protective feature – tightness.

The inundation areas built up with various short-term and permanent buildings and bad maintainance of bank and surrounding vegetation play also very negative role during all floods. The main risky factor when speaking about flood-protection as well as floods themselves is the human behaviour. People could be informed, could be educated, a lot of things be ordered to him, but the most effective is their own experience.

After the evaluation of losses caused by floods on sewerage systems and sewage treatment works we have found out, that previous experience have substantion influence over minimization of losses. The question of floods must be taken into account already when designing.

The measures for sewerage system and sewage treatment works protection must be solved not only in the branch of sanitary engineering, but this problem of extreme rainfalls must be solved within the framework of the whole drainage area.

Also the attitude of state institutions can help with minimizing of losses (for example: construction permissions in flooded areas).

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# Research into Non-force Effects and Aggressive Environment Affecting the Ageing of Historical Structures with Special Emphasis on Charles Bridge in Prague.

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Following the completion of large repairs of Charles Bridge, a number of faults appeared in the bridge structure. The dug holes made right after the completion of the repairs in arches III, IV, IX and XIII in 1983 proved continued leakage of rain water into the body of the bridge and high moisture content of fillers. The high moisture content of the bridge fillers and their contamination by salts cause chemical, biochemical and physical degradation processes gradually damaging the stone structure of the bridge and reducing its durability. Long-term monitoring of the stone structure of Charles Bridge and numerical analyses show that a number of mechanical failures, origination and development of cracks, which occur in the stone structure and individual stone blocks, are mostly caused by non-force effects of temperature and moisture changes. Some structural interventions performed within the large repairs of Charles Bridge had a negative impact on the bridge structure behaviour and contribute to its gradual mechanical degradation.

Long-term monitoring of Charles Bridge, together with laboratory and theoretical analyses, have proved that a number of failures, present in the structure and individual stone blocks are caused, above all, by the effects of temperature and moisture. As a consequence of interaction individual parts, liable to different primary volume changes (due to different moisture, temperature and different dilatometric properties), these effects cause the development of mechanical states of stress in the structure of Charles Bridge with variable intensity and the extent and size of registered failures prove intense interaction between the stone bridge structures and bridge body filling and, at last but not last, the three-dimensional action of the whole bridge structure. The interaction mechanism, which is manifested mainly through shear forces acting between the respective layers with mostly low ductility, is

characterised by a gradual growth of permanent deformations, decomposition of material texture, appearance and development of cracks. The reinforced concrete slab, accoupling the breast walls in a transversal direction and partially also the vault arches in a longitudinal direction, acts alternately as a pull rod and a spreader of the breast walls in the transversal direction depending on the temperature fluctuation, while in the longitudinal direction in acts as a structure preventing namely vertical deformation of the bridge vaulting due to the effect of volume changes. The appearance of structural crack, their development and subsequent failure of the material and structure due to cyclic effects of temperature and moisture are caused by reaching critical and limit deformation, but not by reaching limit strain values.

Among the most frequent causes of primary physical degradation of stone masonry there are migration and crystallization of salts, together with moisture penetration into the stone and frost cycles. The samples taken from the sandstone blocks of Charles Bridge were submitted to frost and re-crystallization cycles. The partial results obtained have proved that frost cycles are not extremely dangerous for the stability of the sandstone blocks of Charles Bridge. The failure of stone is only on the surface. No deeper changes have been observed.

Reliability assessment of rehabilitation and reconstruction measures requires a detailed analysis of the interaction of the external environment and degradation processes in time, including and taking into account namely the specificities of repeated and cyclic temperature and moisture effects. Protection of buildings against these effects is a fundamental part of preventative measures avoiding their degradation. Mechanical states of stress due to these effects very often exceed the stresses and deformations caused by force effects. In the case of moisture attention must be also paid to chemical and microbiological degradation processes.

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# Functional Qualification and Optimization of Building Structures

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The ultimate long-term objective of the research project is to increase the functional qualification and reliability of structures by lowering the risks of appearance of serious faults and failure of structures during their use. The European and world-wide development of methodology of designing structures and constructions, characterised by efficient exploitation of the load-bearing capacity of materials and constructions, with simultaneous minimisation of reserves in their ultimate strength, requires a systematic use of probability methods. The development of numerical methods, material engineering and theoretic models describing the behaviour of materials and constructions allows a highly efficient design of structures. Their full implementation, however, is still impeded by insufficient theoretic knowledge in both the reliability theory of time-related phenomena (effects of wind and other climatic loads, exceptional loads etc.), and the area of time-related properties of materials and constructions (durability and degradation).

In 2002, research work in keeping with the research project's objectives and strategy of their achievement were focused on the following partial tasks (topics):

- Occurrence of faults and reduction in the service life of structures prove an extreme effect of moisture on the degradation of structures. Research of the effect of moisture on significant physical and mechanical properties of building materials also included a study into the effect of moisture content on the failure mechanism of moulded masonry constructions. Theoretic research of residual structural safety of prefabricated wall systems was oriented on the analysis of structural safety of a bearing panel construction subjected to the effects of extreme loads. A numerical reliability analysis of contact padding systems applied on a sandwich panel construction of external skin, together with optimisation of rigidity and strength properties of thermal insulators and thin-layer plasters was carried out. The problems of optimisation of structures and their parts involve research in the area of structural physics, health safety, functional qualification of individual parts of structures and their effect on the environment. Design of methodology and simulation models for estimating the service life of pre-cast panel structures with random joint properties and with random distribution of temperature fields. Study also includes combinations of load effects. The problems of interaction of consolidating subbase with creeping superstructure was extended to include non-linear phenomena. Further study deals with the effect of groundwater level movement and related degree of material structure deterioration with the application of methodology of evaluation of accident situations in earth slopes. Creation of a computer model for the description of mesoscopic behaviour of composites with woven reinforcement and a polymer matrix, and composites with a cement matrix reinforced with short polymer fibres. Engineering applications include optimisation of reinforcement of deteriorated constructions by fibre composites. Identification of suitable computational models of concrete and masonry constructions with regard to their load-bearing capacity, applicability and durability. In terms of load-bearing

capacity, there are namely computational models of backfilled bridge structures, in terms of applicability and durability there are models which will determine the effects of volume changes with greater accuracy. New methods of strengthening concrete and masonry constructions by means of glued plates and fabrics of various materials (plates and fabrics using carbon, glass, aramide etc.). Implementation of obtained knowledge in developing and debating on European standards, as well as in organising seminars for specialists from practice.

- Theoretical and experimental research into steel, steel-concrete and timber constructions of buildings and bridges. Development, design and verification of new structural solutions, elements and calculation methods.
- Verification of numerical modelling of selected geotechnical problems using the MARC/MENTAT and PLAXIS systems. Preparation and implementation of a test hole in Dejvice, instrumentation, gauging and initial measurements. Experts' discussion and feedback for practice within specialized lectures of the course of life-long education. Geotechnical engineering.
- In order to ensure functional qualification of roads and increase road traffic safety, the following spheres are of importance: high-quality guidelines and instructions for designing, including active application of traffic calming principles, improved road quality, namely of pavement constructions, acceleration of construction of high-capacity roads respecting priorities set up on the basis of optimization and complex approach .
- Optimization of construction of railway tracks and track construction, optimization of long welded rail and its use in tram transport. The problems of construction and maintenance of track in the conditions of urban mass transport and enhancement of functional qualification of this construction. In terms of noise emissions into the environment, ecological aspects of new constructions applied in reconstruction projects of tram tracks in Prague are monitored and evaluated, together with contribution of new elements applied within track construction.
- Functional qualification of completed and operated buildings is significantly affected by the quality and reliability of engineering surveying processes. In 2002, research in this area was focused on completing the ČSN 73 0420-2 standard, Laying-out deviations, which was issued after a debate. Great attention was paid to quality assessment of surveying instruments applied for monitoring structures, both universal electronic theodolites and digital levelling devices. The function of instruments was also tested during the measurements of vertical displacements of a motorway bridge, the steel construction of RFE Prague and monitoring of St. George Basilica towers in Prague.
- Creation of a numerical and statistical method for use in reliability theory (investigation of the changes in stochastic behaviour of random characteristics, numerical solution of differential equations etc.).

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# Non-parametric Statistic Methods for Motorway Inspection Measurement

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Inspection of the geometric accuracy of a motorway is performed using geodesic methods. The positions and heights of points in the roadway and on the edges are determined using a special procedure - the principle has already been published in the work (1) before. At the same time, the accuracy of the measurement is specified by the standard ČSN 73 0212-1 where a limit error of the inspection measurement is 20 % of the constructional tolerance. Measurement standard deviation is determined in accordance with the principles stated in (2). The measured real co-ordinates and heights of these points are compared with the values according to the project and the real deviations are calculated. These deviations have to comply with the limit deviations specified by e.g. the standard ČSN 73 6123 for construction of roads. It means that geometric parameters of the motorway, i.e. plane rectangular co-ordinates, heights of points, inclination, etc. are inspected. At the same time, the geometric parameters are divided among the critical ones (e.g. directional curve cross inclination which is important for safe vehicle driving) and the other important parameters (e.g. road location in exterior). Other possible division is among functional geometric parameters (e.g. evenness of road covering layer) and technological ones (e.g. thickness of any of the base structural layers). The inspection is performed either as a hundred-percent one or as a selective one while statistic regulation is also used besides the methods of statistic analysis and acceptance. From the viewpoint of time arrangement of the inspection of geometric accuracy, we classify it as input, operative, output or acceptance inspection. The input inspection is applied by the contractor when taking building materials or components over. The operative check is performed by the contractor of constructional works after completing individual technological operations. The output inspection is also provided by the contractor before submitting the supply of constructional works to the investor. The investor executes the acceptance inspection both in the course of construction for selected structures (for important structural layers in case of motorways) - so called partial acceptance inspection and after completing the construction as a (general) acceptance inspection (for covering layer in case of motorways).

We dealt with assessment of the results of the inspection of the heights of the reconstructed motorway D11 at km 26 - 40.2 with the objective to determine further directions in utilisation of statistic methods within the framework of the partial research task “New methods of engineering geodesy when ensuring the high quality of constructions” and in co-operation with the geodesic company Pragema, s.r.o. The properties of the files created from real height deviations of the cement-concrete covering layer determined by the geodesic methods, namely on the edges of the road and in the middle of the roadway, were studied. The road was laid down using the Wirtgen SP 1600 finisher while the company Dopravní stavby, a.s. Uherské hradiště was the supplier. The investigation was divided among three fields - statistic analysis, statistic acceptance inspection concept and tolerance limits.

Individual real height deviations were assessed, selective characteristics were calculated and comparison with the required values was made within the statistic analysis. It was revealed

that the given production process is satisfactory and that the limit deviation has been observed with a high probability.

The hypothesis on normal distribution of the monitored file of the real deviations was also tested, namely using the tests according to ČSN ISO 5479. This hypothesis was refused also by the other tests (3). An opinion was expressed that the normality of the files of the real deviations could not be assumed a priori. Unfortunately, many methods of applied statistics such as acceptance inspection by measuring, regulation by measuring or specification of tolerance limits are based on the assumption of the normal distribution of probabilities and preferred in engineering practice.

That is why we propose to classify the inspected real deviations between the consistent and non-consistent ones (with respect to the limit deviation) and to use the non-parametric methods of statistic acceptance inspection (i.e. inspection by comparing) and statistic regulation advantageously. In such cases, it does not depend on the type of distribution of probabilities. In spite of somehow larger extents of selections, numerous advantages exist here - testing of normality which complicates the task already from the beginning is eliminated, selection characteristics are not calculated, the acceptance inspection procedure is clear and the check of geometric parameters of the motorway is terminated as soon as the first non-conformity is met when selecting the acceptance plans of the type "no non-conformity in the selection".

We also dealt with non-parametric tolerance limits according to ČSN 01 0253 which we determined from the file of the real height deviations. These limits do not assume any specific division of probabilities and their numerical values were compared with the limits given by the standard ČSN 73 6123.

This also resolved the question of whether the limits specified in ČSN 73 6123 correspond to the possibilities of constructional production in case of a given progressive technology (it was found out that they do).

It is also necessary to note that harmonisation of standpoints at selection of the appropriate probabilities so that they could correspond to the probabilities used for inspection of geometric accuracy of constructions (e.g. probability of exceeding of the limit deviation according to (2)) will be the next direction of research.

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# Horizontally curved composite steel and concrete bridges

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## Introduction

Composite steel and concrete bridges are a progressive way of designing bridge structures. Their main advantages are simple assembly and construction, simple fabrication of the steel structure and using of natural properties of materials (steel-tension, concrete-compression). Approximately one third of them are horizontally curved and their number still rises. The main reasons are higher importance of traffic solution than structural configuration, increasing traffic and limited area for structures, especially in urban areas. This curvature must be considered in the structural analysis.

The modern solution for horizontally curved composite bridges with I-shaped main girders is curvature of main girders. This curvature deduces additional loads, which must be considered in the structural analysis. The influence of this load rises with decreasing radius of curvature and can be reduced by using of appropriate number of cross frames. There are many questions, which are difficult to answer, such as: the radius of curvature, when cross frames are necessary, how many cross frames should be used according to the curvature and how high the additional stress is.

The aim of this work is to develop a new method, which will determine the warping to bending stress ratio and lateral flange deflection. They will be calculated from several parameters, such as the span L, the radius of curvature R, the number of cross frames intervals N and the cross section properties of the main girder.

The next output will be practical recommendations for the choice of the computer models of different structures and for modeling of horizontally curved composite steel and concrete bridges for structural static and dynamic analysis. The solution will be made for the Service Limit State (SLS). The project is divided to four parts.

## Experimental part – Theoretical verification of the computer modeling by modal analysis

The modal analysis can be used for verification and calibration of computer models of structures. The result is a verified computer model of a structure, which can be used for structural static or dynamic analysis. The composite steel and concrete bridge in Vráž near Beroun was chosen for the experimental verification of modeling. It is a straight continuous beam with three spans. The aim was to verify the computer model and check the chosen way of modeling of cross section, which is the same for straight and curved bridges. The mode shapes and natural frequencies were measured in cooperation with the Department of Structural Mechanics and The Central Laboratories of Faculty of Civil Engineering, Czech Technical University in Prague.

The 3D computer FEM model was created in NEXIS 32 software by using of shell and beam elements. Calculated mode shapes and natural frequencies were compared with experiment. MAC coefficient was used to compare mode shapes (Tab. 1).

| Experiment | | $\Delta f_{(i)}$ | Theory | | Description of a shape | MAC |
|---|---|---|---|---|---|---|
| Shape No. | $f_{(i)}$ (Hz) | % | Shape No. | $f_{(i)}$ (Hz) | | Exp/Theory |
| 1 | 3,38 | -3,3 | 1 | 3,27 | 1st bending | 0,9822 |
| 2 | 3,65 | 0,3 | 2 | 3,66 | 1st torsional | 0,9611 |
| 3 | 8,54 | -5,7 | 3 | 8,08 | 2nd bending | 0,9647 |
| 4 | 8,95 | -8,0 | 4 | 8,29 | 2nd torsional | 0,8912 |
| 5 | 10,86 | -11,5 | 5 | 9,74 | 2nd torsional in antiphase | 0,8731 |
| 6 | 11,39 | -13,3 | 6 | 10,05 | 2nd bending with shorter span in antiphase | 0,6427 |
| 7 | 14,18 | -5,9 | 10 | 13,39 | Torsional of longer span | 0,9017 |

**Tab. 1)** Comparison of mode shapes and natural frequencies

**Parametrical FEM study**

The objective of the parametrical study, which is currently in progress, is to determinate an influence of several different parameters on warping to bending stress ratio $\sigma_w/\sigma_b$. A number of 3D models of horizontally curved bridges were created. These models are based on the same technique, which was used in the experimental part. The basic parameters are the span $L$ (L = 20 - 50m), the radius of curvature $R$ (R = 75 - 2000m), the number of cross frame intervals $N$ (1 – 10), the depth of a web $h_w$ (1.5 - 3.0m), the thickness of a web $t_w$ (15 - 30 mm), the width of a bottom flange $b_f$ and the number of girders.

**Analytical derivation of a new method and calibration**

The new method is based on an assumption, that the bottom flange act as a continuous beam, which has fixed supports at cross frames locations and is elastically supported between cross frames. This beam is loaded by a lateral component of normal stresses. The bottom flange acts then as a continuous beam on elastic supports. The behavior of this beam can be described by a differential equation. After solving this equation, the deflection line and bending moments can be obtained. The results from this method will be compared with the parametrical study and method will be calibrated.

**Creation of a computer program**

The computer program, based on an analytical method, will be created. The program will compute the $\sigma_w/\sigma_b$ ratio and lateral deflection along the beam from the above mentioned parameters. The manual will also recommend the suitable computer model.

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# Prediction of Temperature and Velocity Fields in Glazed Entrance Hall

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The main task set in this paper is to predict temperature and velocity fields in glazed entrance hall. The entrance hall is integrated into building on Evropska str. 178, Prague 6.
The building has five floors which are adapted for administration and underground car park (three floors).
All the administrative floors are designed for open-plan offices with all necessary backgrounds (toilets, technology rooms).
The entrance hall is designed all over the five overground floors. Front wall is completely glazed and is shaded by inside automatic sunblind. Height of this hall is over 19 meters.

The ventilation system was projected with forced inlet of air. Outflow of air is provided through the portlights situated on the roof.
The airconditioning system works only during summer period. In winter period incoming air is isothermic, all heat losses are covered by heating system.
The airconditioning system is projected to keep condition of inside space:
- indoor temperature $t_i = 26 \pm 1 °C$,
- relative humidity: $\varphi = 30 - 60\ \%$

Heat gain was computed by ČSN 730548 (solar radiation, lighting, electric devices, human heat gain).
Air inlet is realized by two symmetric air tubes. The tubes are taken vertically along all overgrounds floors. Air inlet was provided by a distribution element (nozzles) placed on the tubes. The nozzles are spacing uniformly (distance $d = 0,5\ m$).
Constant temperature and mass flow of inlet air will be kept by a two air-conditioning units.

Main goals of this research is to predict temperature and velocity fields in the glazed entrance hall by means of CFD.
3D model of the hall was created in software GAMBIT. By reason of symmetry of hall and air inlet was created only left half of the entrance hall. Circular surface of the inlet nozzles was converted to quadratic surface. All space was divided into several volumes (for simplify meshing).

Computation of temperature and velocity fields of air was provided in software FLUENT. In this software is necessary entry a correct boundary conditions:
- velocity inlet boundary conditions (direction, size),
- outflow boundary conditions,
- wall boundary conditions (material, heat flux, surface temperature, roughness)
- symmetry boundary conditions

The results obtained by CFD for summer period, external temperature $t_e = 30°C$:
- indoor temperature of the air is 26±1°C, all over the hall, increase with height

- air velocity in comfort zone is less or equal 0,5 m/s
- in space of the entrance hall exists macro-vortices. Vortices intensively mixing-up the air. It is the reason, that the indoor temperature does not increase more then 3K per 19 meters.

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# Fatigue of Asphalt Mixes

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Asphalt mix represents a complex heterogeneous construction material, containing a number of components, its material properties being dependent on temperature. Temperature changes cause shifts in its physical status, behaviour and properties. Under low temperature, the behaviour of asphalt mix is close to that of brittle materials, at temperatures over 60°C asphalt mix behaves like plastic (ductile) materials. Linear theory of fracture fails for asphalt mixes. One of the reasons for this failing is the fact, that in the case of ashpalt mixes the characteristics of the damage process of this theory cannot be determined with sufficient accuracy. In consequence of long-term repeated loading, the structure of asphalt mixes is changing, the changes taking place in a completely hidden way. The fatigue process is an irreversible deformation process characterized by growth of the permanent deformation and by gradual damage of material microstructure.

In theoretical part of the solution, it is foreseen that the principles of damage initiation and growth pertinent to composites of the asphalt mix type will be combined with the model of viscoelastic Boltzman's body. The damage growth in the bitumen bridges between aggregates will be modelled through the approach based on multivolume enhancement of the Aboudi's micromechanical procedure.

The experimental part of the project, the monitoring of fatigue and other material properties of the asphalt mixes, will be accomplished with the aid of the NAT (Nottingham Asphalt Tester) device. The NAT device is a unique testing equipment, allowing monitoring of selected rheological properties of asphalt mixes (stiffness modulus, creep, fatigue). The fatigue testing is conducted under controlled (constant) level of the applied stress. During the experiment, the growth of the deformation and decrease of the stiffness modulus are monitored untill the complete damage of the test sample. The constant value of the test temperature is kept at the value chosen in dependance of the analyzed asphalt mix stiffness (27 ºC or 15 ºC).

The fatigue of asphalt mixes is presently under research in two projects: in the presented GA ČR project No. GA 103/02/0396 „Fatigue of asphalt mixes and pavement design optimization" and also in the project MDS ČR 803/120/117 „Asphalt pavements of new generation in the Czech Republic". Both projects aim at obtaining new knowledge on fatigue processes taking place in asphaltic layers of flexible pavements through combination of experimental research and computer modelling and to make use of it in the revision of the design method. The use will be made of the microstructural modelling of the asphalt mix components having viscoelastic and viscoplatic behaviour in order to model the evolution of their interaction in the crack initiation stage as well as in the propagation stage.

In the year 2002, the GA ČR project was concentrated on:

- monitoring of fatigue resistance of selected types of compacted asfalt mixes (VMT, AB, SAL) at the temperature 15 °C or 27 °C ,
- monitoring of relaxation properties of asphalt mixes at low temperatures,

- transformation of fatigue results obtained at the FCE in the 1970s using trapezoidal test setting by comparison with NAT results.

For the sake of completeness, the sets of fatigue characteristics of all the tested mixes have been complemented by information on their stiffness modulus – temperature relationship as well as by the value of their temperature sensitivity (defined as ratio of stiffness moduli determined at the temperatures 0 °C and 40 °C) and by their creep curves obtained at 40 °C.

Close attention has been also paid to the practical application of the obtained research results in pavement reconstruction design – the reconstructions of the road I/6 in the Dubí – frontier section and of the road I/8 in the Karlovy Vary district can be given as examples.

The experimental results obtained on fatigue processes in the course of the project solution will be analysed using computational modelling based on:

- microstucture of the composite material,
- viscoelastic (viscoplastic) constitutive laws of a binder component,
- unilateral damage model (simulating opening and closing of microcracks), regeneration of material properties being taken into account,
- probabilistic nature of the fatigue.

In Tabs. 1. and 2, the results on rheological properties of the VMT (HSM – high stiffness modulus) type asphalt mixes are presented, the first table showing the stiffness modulus vs. temperature relationship, the second one presenting data from the fatigue test.

Table 1. Stiffness modulus vs. temperature relationship

| Temperature | 40 | 27 | 15 | 0 |
|---|---|---|---|---|
| Stiffness modulus [GPa] | 2.426 | 6.496 | 14.411 | 20.448 |

Table 2. Applied stress vs. number of load repetitions untill failure

| Applied stress [kPa] | 350 | 300 | 280 | 250 | 240 |
|---|---|---|---|---|---|
| Number of load repetitions | 473 | 731 | 1620 | 3250 | 6855 |

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# Measurement of Temperature during Deformation Monitoring of Historical Buildings

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Some objects are monitored by geodetical methods in area of the Prague Castle. Observed points are mostly placed on pillars of historical buildings, f. e. in the St. Vitus's Cathedral, the Old Royal Palace or the Royal Summer Palace. Deformation measurement is carried out with period three or six months. At the same time, temperature of air is measured. Shape changes of a pillar are interacted by their temperature during a year, which has to be eliminated to find out settlement of a pillar. The material coefficient of thermal linear dilatation which describes stone of a pillar can be computed via linear interdependence between temperature and thermal linear dilatation. This computed coefficient can be compared with the known tabular coefficient (see [4]). In this case, pillars are made from sandstone, which coefficient is $11.74 \times 10^{-6}$ °C$^{-1}$ (see [2]). Temperature of air was used for computation, although temperature of material must be measured. This substitution was caused by no suitable device for measurement of material temperature available at Department of Special Geodesy. Now, new thermometer Ahlborn AMIR 7811-50 was purchased in November 2001. This device is non-contact thermometer with circular laser sighting. Infrared thermometers measure the surface temperature of an opaque object. The optics of thermometer sense emitted, reflected and transmitted energy, which are collected and focused onto a detector. The electronics of thermometer translate the information into a temperature reading which is displayed on the unit. The laser is used for aiming purposes only. Accuracy of infrared measurement indicated by the producer is depend on a value of measured temperature. Although display resolution is 0.1°C, accuracy of this type of thermometers is not too proper. This is +-2°C in interval of temperature (-18°C to +23°C) and +-1°C for temperature above 23°C or 1% of reading, whichever is greater. Range of measured temperature is (-32°C to +760°C), because the device is rather used in engineering or smelting industry. More precise device was not found in this price range and in this type of non-contact thermometers. The non-contact thermometer is very important for measurement of inaccessible high-placed observed points on the pillars. Measurement is quick, comfort and easy, which is useful for effective deformation monitoring of buildings.

Verification of AMIR accuracy was started. Only one thermometer usable for measurement of material temperature is available in laboratories of branch Geodesy in Faculty of Civil Engineering, which is the unit of automatic atmospheric corrections LA 410 equipped with some atmospheric and six material sensors. This device is very precise, unfortunately quite old and often inactive, that is why its usage failed. Regarding to malfunction of LA 410, searching of other available thermometer was started to compare with AMIR. The following laboratory devices were found at Department of Special Geodesy. Ahlborn THERM 3280-8M is a device for measurement of air temperature with ten sensors "NTC thermistors". Ahlborn ALMEMO 2290-3 is equipped with a sensor NTC too, which performs only for measurement of air temperature. This device is the modular system, which contains another units for measurement of humidity or press of air. Completion of a contact sensor would be possible, but it is not available at this department now. Therefore, this NTC sensor was used for

experimental measurement of material temperature as a contact sensor. THERM sensors are not suitable in the design aspect, because sensors are contact-proof with plastic collars. Thus the ALMEMO NTC sensor was used. Regarding to unsatisfactory results another experiment was carried out, f. e. the sensor was placed into a cavity in material.

Next, Prof. Toman from Department of Physics lent their thermometer COMMETER NZ4 and COMMETER THPZ METEO, whereas THPZ METEO is a thermometer usable for measurement atmospheric parameters, such as humidity, temperature and press. The more interest thermometer is NZ4, which is equipped with various types of probes or sensors: f. e. contact straight or square probes, an immersion sensor and a fast space sensor 0100-60. The NZ4 was alone available device, which was used to compare with AMIR for measurement temperature of material.

Various types of material were used, f. e. brick, concrete, wood, formica, iron or other metal. Behaviour of patterns were examined during various temperature, which was indicated by conditions: indoor lab climate or outdoor weather. Higher temperatures were simulated by heating of patterns. Each material is described with own value of emissivity (energy-emitting characteristic of material), which has to set in thermometer AMIR according to tabular values. Experiments with AMIR included also measurement from various distances and angles of sight on an observed point. The spot size depends on the distance from the object. Regarding to, the size of the target has to be larger than the spot size. Inaccurate reading can result from measuring shiny or polished metal surfaces. To compensate for this, except setting of emissivity, the surface of a pattern has to be covered with a masking tape or flat black paint. In some time, the tape or paint reach the same temperature as the material under it.

Owing to difficulties during collecting of comparable devices, amount of experiments is deficient. Despite of all, accuracy of tested device AMIR accords to the mentioned factory value in keeping asked conditions (setting of emissivity and appropriate surface). Further possibilities to experiments with AMIR are f. e. temperature measurement of patterns heated to known value by the special electric furnace available at Department of Physics and next the contact probe of the system ALMEMO is available at Department of Geotechnics (Assistant Prof. Záleský).

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# Sustainability through Optimised Structures Using Recycled Waste

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An accelerating development of technology and production during the last two centuries has been accompanied by a devastating process of exhausting non-renewable raw material sources, and an escalating pollution and amount of wastes. The material and energy resources are limited with respect to the increasing population and human needs. The regeneration ability of renewable resources is limited, non-renewable sources are irreplaceably exhaustible. The construction industry and its products (buildings) represent the crucial consumer of natural resources, a heavy polluter and waste producer. Among basic actions towards sustainability specified in Agenda 21 are: minimisation of non-renewable resources use, minimisation of total waste, and maximisation of environmentally sound waste reuse and recycling.

The basic aim of the research project performed at the CTU in Prague was the environmentally based optimisation of RC floor slabs, including verification of suitability of using recycled waste materials in the building construction. Recycled industrial and/or municipal waste was analysed and experimentally used for production of light fillers for waffle or ribbed RC floor slabs [1]. The research have proved the acceptability of replacement of silicate fillers by fillers from recycled materials, namely from recycled plastics and recycled laminated beverage cartoons.

The analysis of secondary raw materials with regard to their possible use as fillers in waffle and ribbed composite RC slabs was the first step of the research. Then, performance, reliability and durability of the composite structure with fillers from recycled waste materials were analysed. Special attention was given to the problem of fire safety and health aspects of the new composite structure.

The utilisation of the scrap-based secondary raw materials for the production of building elements represents a severe technological problem from the hygienical point of view. Namely, the initial material being used for recycling is contaminated with a variety of organic materials considerably in some cases. In addition, the building materials which are produced by recycling may cause the escapes of volatile components which are inadvisable and improper for the people that are to stay in a microclimate in question for a longer time.

The hitherto results of evaluations of the ecotoxicity of recycled building materials obtained by means of specially developed bioindicators have also brought evidence of a considerable dependence between the building element age and the quantity and/or rate of toxicity of single volatiles. It is obvious that in case of recycled building materials it will be necessary to define the time interval elapsed since the production, in which the people may stay in the interior space for a long time. Therefore, the detailed and reliable evaluation of the ecotoxicity of new materials made of the recycled plastics is a problem of principal importance.

Several structural alternatives of composite waffle and ribbed slabs were designed, analysed, evaluated and compared. The shape of fillers was determined by the results of

multicriterion optimisation with regard to environmental criteria as well as to structural parameters of the resulting composite structure. The investigation was focused on reuse of municipal waste that is often disposed of or burned with corresponding negative impacts on the environment. Three selected alternatives of waffle and ribbed slabs with fillers from recycled waste materials were experimentally produced and tested.

The shapes of fillers from recycled plastics were developed and optimised by the first author. Fillers from recycled waste plastic were experimentally produced by recyling company Transform Lázně Bohdaneč. Two alternatives of fillers were tested in CTU laboratories and the other alternative: installaion fillers from recycled waste plastic for composite concrete slabs was experimentally used in situ in the construction of Senior-Centre in Moravany, East Bohemia. The experimental verification of all alternatives has shown compatibility of materials (concrete and elements from recycled waste) in the composite section during the whole service life of the structure. The suitability of further recycling of demolished composite slab structures with fillers from recycled plastics was proved by the test in the recycling crusher.

Two types of recycled waste materials (non-sorted plastic and laminated cartoons) have been experimentally tested and their suitability for the production of fillers to be used in waffle or ribbed RC slabs has been verified. Using recycled materials and the optimised filler shape, it was possible to reduce consumption of non-renewable silicate materials, the resulting production of $CO_2$, $SO_2$ and consumption of energy. The performed case studies supported preliminary assumptions about the undisputed significance of (i) the selection of materials, including recycled materials and (ii) optimisation of the shape of the structure [2], [3].

The results of the research have proved the possibility of the use of recycled components of municipal waste (plastic, laminated cartoons) for production of light fillers for waffle and ribbed RC slabs. The performance, environmental quality, reliability and durability of composite structures were theoretically analysed and experimentally verified. The results of environmental assessment of developed floor structures and their comparison with traditional alternatives supported preliminary assumptions considering environmental advantages of the use of recycled waste materials in the building construction. The experimental use of fillers from recycled plastics in situ in the construction of the Centre for Seniors in Moravany is also presented on the poster.

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# Fatigue of Girders With Undulating Web

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The contribution deals with the fatigue resistance of WT girders. These girders have thin-walled undulating web. Their web is from 500 to 1500 mm in depth and 2, 2.5 and 3 mm thick. The slenderness ratio is up to 500. Web of girders is made of steel St37-2G (fy = 215 MPa) and the wave amplitude is 20 mm. Flanges are made of standard steel. Considering high resistance of web in shear buckling we can save up-to 30% of material in comparison with traditional girders.

Aim of this research was to specify fatigue category of WT girders under i) predominating shear and ii) local cyclic loading. This classification is essential for designing WT girders as crane beams.

Research was divided into two main parts: experimental and theoretical one. There were two basic sets of experiments in the experimental part. Set of 10 girders under predominating shear and set of 10 girders under local loading with transverse eccentricity 20 mm. These experiments started in 2001 and finished during 2002. Tested girders were WTA type (2 mm thick web) with depth of web 500 mm and flanges 200x10 mm made of S235 steel. The span of the former set of experiments was 1700 mm and of the latter 850 mm.

All tests were finished when visible crack has appeared. In case a crack did not appear before reaching 3 millions cycles the stress range was considered as under fatigue limit.

There were two kinds of cracks in the web of the first set girders. Three cracks have appeared at the flange-web weld and the rest of them at the vicinity of mid-span stiffener. Cracks grew rapidly in both cases.

Only one kind of cracks has appeared during tests of the second set. It was at the top of the web under load location. Speed of all cracks decreased when being exposed to loading after crack appearance.

Standard statistical evaluation procedure was used in accordance with Annex Z of Eurocode 3 for both types of loading. The aim of the evaluation was to classify fatigue category or to establish a new fatigue strength curve applicable for design.

Design function of fatigue shear range $\Delta\tau$ was taken in accordance with recommendations of Eurocode 3:

$$r_t = \Delta\tau = \sqrt[m]{\frac{a}{N}},$$

and with the help of regression analysis the characteristic detail category was determined as 40 MPa with non-standard slope of S-N curve $m$ = 9.445. In comparison the Eurocode recommends standard category 100 for one-side welded plane web without stiffeners and category 36* for welds.

Elastic and elastic-plastic analysis of the girder with crane rail was needed to evaluate elastic resistance and fatigue under local loading. The stresses and strains at “hot spot”, i.e. at points along the weld toe where their values $\sigma_z$, $\varepsilon_{pl}$ in the vertical direction are maximal were found. One half of the girder was analysed with respect to overall symmetry. Web and flanges were modelled using isoparametric elements *SHELL 43* (elastic-plastic large-deflection elements), while rail elements *SOLID 45* (with he same capabilities) were connected with upper flange via nonlinear contact elements *CONTAC52*.

*WT* girders were analysed with various positions of loading and the one giving the maximum stress was found at amplitude of the web wave, with eccentricity 20 mm. Extensive parametrical study of girders under such loading for all produced web and flange thicknesses and six types of rails was evaluated by regression analysis, leading to formula for effective length:

$$l_{eff.2} = -32.5 + 1.195 \cdot \sqrt[3]{I_R} + 6.45 * t_f \qquad \text{[mm]}$$

$$l_{eff} = l_{eff.2} \cdot e^{-0.1865 \cdot (t_w - 2)} \qquad \text{[mm].}$$

Agreement between FEM results and results acquired employing above mentioned formulas is good.

Distribution of vertical stress $\sigma_z$ at flange-web weld root of tested girder loaded at amplitude of the web wave was enumerated too.

Fatigue cracks which appeared under local loading grew in parts, which are nominally in compression, however in the area affected by residual stresses due to welding. Mentioned theoretical analysis proved plasticity regions under loading leading to fatigue. The values of total and plastic mid-plane strains at top of the web were enumerated for both first reach of $F_{\max}$ and after unloading. It is showed that cyclic plastic strains are low.

Instead of using Manson-Coffin's approach and to ease practical design an attempt to use the stress range was investigated. The double values of Langer's pseudo-stress $S$ calculated from cyclic strain values by formula:

$$\Delta S = 2\, S = E\, \Delta\varepsilon_{tot}\,,$$

were in good agreement with fictitious elastic stresses evaluated simply with help of formula for $l_{eff}$.

The statistical evaluation followed again Annex Z of EC 3 procedure (here for pseudo-stress $\Delta S$):

$$r_t = \Delta S = \sqrt[m]{\frac{a}{N}}$$

Regression analysis for $n$ = 10 tests gave $m$ = 7.401 and $a$ = 6.378x10$^{25}$. Experimental mean value of the fatigue category corresponding to 2 million cycles is 431.7 MPa.

The evaluation of pseudo-stress lead to a fatigue strength curve 316 with the slope 7.401. Reasonable pseudo-stress values are easily available using formula for $l_{eff}$.

Apparently the practical design of crane *WT* girders in accordance with Eurocode 3 (Part 6) will be governed by elastic stress $\sigma_z$ along effective length $l_{eff}$ or fatigue in shear.

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# Simulations of Erosion Effect of Extreme Precipitation Events by the Help of EROSION 3D Model – Validation of Model Input Parameters

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Water erosion on agricultural soils is grown to be one of the phenomena in which are interested not only scientists but also agriculturists, water reservoir operators or city managers. Erosion is caused by extreme rainfall events and its size or danger is influenced by circumstances of soil, canopy cover and surface runoff.

In recent time the Dept. of Drainage, Irrigation and Landscape Engineering concerns on investigation in field of rainfall-runoff processes in catchments, possibilities of extreme runoff prediction and related flood protection. At the same time the erosion hazard and sediment transport from catchment to recipients is solved. This problem is handled in regional approach (large areas over $10^3$ km$^2$) and local approach (small catchments with area about 10 km$^2$). Both of these approaches have its different tasks and also different tools for work. Physically based mathematical models are connected with local one and Erosion 3D is one of them.

Erosion 3D is physically based mathematical model which computes soil loss and total runoff from catchment caused by single precipitation event. It was developed in 1992-96 in TU Bergakademie Freiberg, Germany. This model has limited number of input parameters. Input parameters describe relief characteristics of investigated area (digital elevation model), soil characteristics (map of grain size distribution, database of soil properties and map of land-use) and intensity and duration of rainfall. The raster background of model means that model includes spatial variability of input parameters. The simulation is computed in time steps what allows some inclusion of time variability. In last ten years model was tested in many different projects. In Germany this software is commonly used as a land-use scenario investigation tool. In Dept. of Drainage Irrigation and Landscape Engineering is model Erosion 3D tested as a tool for rainfall-runoff processes description and flood prevention.

The global project task was to validate the model for practical use in conditions of Czech Republic. The first step for this is input parameters testing and examination of input data sources. In the frame of other grants and this project there were made some basic investigations. Erosion 3D model parameters could be divided into four basic groups which have its specific input data.

- Digital elevation model can be made from digitized paper maps, regular point grid DMR 2 (Army Topographical Institute in Dobruška), vector contours layer ZABAGED (Czech Cartographical Institute) or vector contours layer DMU 25 (ATI Dobruška).
- Land-use maps could be obtained from different vector layers (ZABAGED, DMU 25), aerial photographs, satellite pictures or CORINE database.
- Information about soil grain size distribution could be gained from Map of Complex soil Investigation (KPP) or derived from soil samples taken in situ.

- Rainfall intensities can be obtained from direct measurements or from Czech Hydro-meteorological Institute observations.

Large number of simulations and associated testing works showed that it is not possible to choose the definitely best source of particular input data. Every time it is necessary to define detail goals of any project with budget and result resolution specification. For example satellite pictures have quite large resolution and possibility of easy reclassification during land-use map creation, but usually are very expensive. On the other hand maps created from CORINE database are simply available but the consequential map is very rough.

During this internal project soil samples for parameter catalog validation were taken. As an experiment area was chosen agricultural area around Praha - Sobin. Nine sites in arable land with different soils and different crops were chosen. Soils samples were taken approximately every 14 days from 3.4. to 12.6.2002. Mostly the undisturbed samples were taken. Only on plough-land early in spring the disturbed samples were taken. In laboratory of soil science in Dept. of Drainage, Irrigation and Landscape Engineering were determined some basic soil characteristics. In case of undisturbed samples it was:

- Density [kg/m$^2$]
- Organic carbon content [%]
- Soil moisture [%]

The analyses of laboratory results showed, that there are no simple two parameter relations (for example vegetation stage – soil density) in agricultural land, which is used in German soil parameter catalogue. There is always impact of soil moisture and other soil conditions. For more detailed results would be necessary to make much more investigations, take more accurate samples and take into account more boundary conditions.

During this project and also some other grant the new version, which is able to simulate long term effect of rainfall events on soil loss was testing. This submodul increase possibilities of Erosion 3D usage in field of soil loss prevention, because its result is possible to compare with results from other methods (Geographical Information System in connection to the Universal Soil Loss Equation). In this task the necessity of further determination of rainfall data, mainly to generate some reference long term sequence was shown.

In autumn 2002 H. Novakova was on four month study stay in TU Freiberg. She took part in some projects to get more experience with usage of Erosion 3D model. One of it was enlargement, improving and digitalization of soil parameter database. This was created in Germany using results from terrain experiments with rainfall simulator.

Work on field of computer model simulations of soil erosion and validation of model Erosion 3D should continue in next year.

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# Determination of morphological characteristics of natural stream channels as basic data for revitalization of watercourses design

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In past decades drainage systems have been done on a large area. These systems have been built during intensification of agriculture in order to get new arable land. Building of the drainage systems meant big changes of natural hydrological conditions (straightening of streams; reduction of lag time; reduction of underground water level = reduction of water supply in soil; rise in period of frequency of flood flow and low flow events). This process had caused changes of ecological systems or even damage of them.

Nowadays there is an effort to make these regulated streams more natural (to rehabilitate them), to improve their natural functions (flood, transformation, water retention of the watershed, habitat for organisms,….) In last ten years there have been realized many revitalization projects with better or worse effect. The variable success is caused mainly by small experience in the young branch of revitalizations of small watercourses. One of basic problems is indefinite interpretation of even the keyword „revitalization“ and its purpose. Its aim is surely returning the watercourse to more natural condition, but it is not easy to define this condition. There is possible to define it as condition which is acceptable for native living organisms in chosen locality. In fact it is important to raise the diversity of environment the way that fits its needs. Start and support an independent natural evolution. That all must be done together with preserving all other functions of anropogenized landscape (adequate level of flood protection, stabilization of watercourse, sustainable sediment transport, ...). Because the natural stream and its surroundings are dynamic system, the revitalized stream must be understood only as the firs stage of the whole rehabilitation process.

Project should define morphological characteristics of natural streams, so that these characteristics then might be use as source materials for designing and projection of revitalizations. It becomes to be evident that to find a natural (untouched) stream in the Czech Republic is very difficult. Little influenced streams can be found nearly only within the national parks situated in border areas of our republic. Because of very specific morphology of these areas (higher elevation, average catchment slopes, climatic and hydrological conditions) it would not be possible extrapolate project results to whole Czech Republic, but only to small areas with similar conditions. Therefore the project finally focused only to examination of quality and functionality of already implemented revitalizations on 20 small watercourses in the first step. Further work is planned for next years. Streams were chosen in the most variable range of regions and according the time of realization i.e. to evaluate different “engineer’s schools“, stages of development, etc. Results and knowledge get from this examination were then used in designing of revitalization of Jedlový stream in Šumava National Park.

Within assessment of 20 revitalized streams following characteristics were controlled – stream channel line, bank slope, character and diversity of a bed, passability of stream by low gage, stability of built objects, composition and condition of surrounding vegetation, quality of implementation to local landscape, appropriateness of a stream for revitalization. Based on terrain survey were developed following recommendations.

- **Water quality:** Water quality is a first necessary and required condition for successful revitalization. Stream witch has got a lot of organic pollution can not be revitalized because basic requirement of revitalization (native natural of stream) is denied. Therefore a study of catchment would be before final decision of stream revitalization. The study of catchment would include study of point and diffuse pollution sources.
- **Stream channel line**: Present ideal and synonym of natural stream channel line is a meandering stream. But meandering is native only for specific group of streams which is characteristic by rate of flow (dimensions of a channel) and especially by character (longitudinal slope and cross section) of floodplain. Meandering is native rather on low slope area with wide floodplain. Radius of meanders used to be rather small than big. When a stream is meandering on low slope area destruction of a channel is only a question of time. Rate of stream sinuosity (meandering) would by design commensurate with stability of stream channel without stabilization cascade or forced channel lining. A channel also would not be silted. Channel line ant its length can be uniquely determined by longitudinal slope which corresponds with requests above. The definition of optimal parameters of stream-line is the topic of literature overview, done during the project and will be actualized during next year.
- **Channel:** Dimensions of channel would be corresponded with characteristic of locality and rate of flow. Channel needs to be designed on minimum flow and evaluated on flow $Q_{355}$. Stream training would be functional by this flow $Q_{355}$. If a channel is designed on low capacity than water overflow sooner water velocity is not too big and do not cause devastation. In practice some designers use design flow so called $Q_{1/2}$ (half a year flow) or $Q_m = Q_1$ (one day flow). Definition of flow $Q_1$ is similar like one year flow but its value extrapolated from basic hydrological data is ten times lower.
- **Stabilization:** Removing of original hard channel lining (concrete blocks, grass-concrete blocks) should be necessary request for successful revitalization as well as making of new channel line with ability to reform. Therefore the channel lining should be as flexible as possible. Appropriate channel lining is stone riprap but it is necessary to choose accurate dimensions of stones. Often the riprap is too big and water disappears between these stones. Insertion of hard lateral objects seems to be unfit and nearly always causes problems (leaking, banks erosion, ...).
- **Shore vegetation:** Making of 10-m-width grass strips along streams on each bank is another condition of successful revitalization. When surrounding area is very steep and intensively managed, enlarging of these grass strips is recommended. Main function of the grass strips is to reduce amount of sediment and nutrients transported by surface runoff to a stream. Planting of shore vegetation should be realised on the grass strips. Only autochthonous species should be planted. Ratio between trees and bushes should be less than 1:1 (more bushes than trees).

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# Impact of Landscape Retention on Rainfall-Runoff Regime and Transport Processes

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Landscape retention capacity significantly influences formation of surface runoff within a watershed. Natural and technical elements that could slow down the runoff or store water form landscape retention capacity. Landscape retention capacity also influences transport of sediments and chemicals detached by erosion process. The landscape retention capacity is determined as temporary stored water by vegetation cover, in a soil cover (mulch), soil profile and surface depressions, in polders and reservoirs. The structural soil conservation measures, like broad base terraces, conservation bunds, ditches, and wetlands, etc. should be also included. The actual retention capacity is influenced by rainfall type and actual physical and technical conditions of elements.

Activities of a research team have been focused on validation of various methods and tools for estimation of impact of existing and/or planned retention elements on rainfall-runoff regime and soil erosion process in catchments of different size and various land use system

The activity of the research team has been focused on

1. definition of natural and technical elements for retention, accumulation and control of surface runoff and their identification by remote sensing methods;
2. analysis of behaviour and efficiency of retention, accumulation and control elements under various rainfall pattern using mathematical simulation models with support of GIS technology;
3. case studies - simulation of runoff, erosion and transport processes for different land use and planned control measures scenarios.

A structural approach is necessary for predicting surface runoff and erosion process formation in a watershed in order to determine potential risk areas in respect to a land use system and natural conditions of watershed.

A global scale approach should be used to define the most threatened subcatchments within a region. GIS combined with empirical methods is an appropriate and reliable approach. Various runoff models (CN method, rational formula, kinematic wave, etc.) and Universal Soil Loss Equation supported by GIS were intensively tested for this task.

A local scale approach is recommended for planning and evaluation of effect of conservation and retention measures in the targeted subcatchments. The EROSION 3D, WMS and AGNPS simulation models were tested in model framework of he project. A number of different scenarios and sensitivity analysis were tested within a local scale approach, e.g. the influence of input data or grid size input data layers, the influence of various actual and extreme land use scenarios, influence of soil improvement, impact of land consolidation on surface runoff and transport processes, etc.

The results of the project proved that tools of mathematical simulation and GIS could be used as an effective tool for assessment of risk of hydrologic extremes transport extremes in watersheds.

The research team has also cultivated a laboratory research for studies of mechanics of surface runoff and erosion formation. for water erosion process. Further, some parameters and input data such as soil erodibility can be effectively determined by laboratory research.. Laboratory rainfall simulator is required for this kind of research. Rainfall simulator applies water in a form similar to natural rainstorm so that the impact on runoff formation and soil surface can be studied. A research team has constructed the Norton Ladder Rainfall Simulator. The simulator is composed of mechanical and hydraulic parts, and a control unit. Two parallel pipe sections form the simulator, 5 m length each. The horizontal distance of pipes is 1 m. There are four special nozzles on each pipe (Vee Jet H3/8u-8100, discharge 0.06 – 790 l/min, pressure 0.3 – 35 bar, angle of sprinkling is 15 to $110^0$). Each section rotates independently so that the soil surface could be uniformly watered. The simulator is used for a tilting hydraulic flume and it is placed ca 2.5 m above its bottom. The sprinkling is computer controlled so that the rainfall intensity and its kinetic energy could be changed during experiments. The tested soil is placed in the hydraulic flume in a special container.

The first tests of the simulator have proved its applicability for the research and uniformity of simulated rain. Overland flow formation, soil erodibility, soil splash and relation between slope gradient and erosion intensity are the main characteristics of erosion mechanics that are being researched in the laboratory.

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# Models of wind actions on civil engineering structures and their applications

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The purpose of the project is to study the effect of wind on building structures designed in accordance with ČSN P ENV 1991-2-4 (hereinafter referred to as ENV). The project is aimed at verifying the wind loading models used, at studying the loading on model buildings in BLWT and at studying interference phenomena.

Of key importance to the design load is the value of the load factor, which is based on the required reliability of the designed building and which is directly related to the definition of the reference speed. Thanks to the cooperation of the Czech Hydrometeorological Institute it was possible to obtain from existing databases relatively reliable sets of maximum 10 minute wind speeds on Czech territory and to make estimates of reference wind speeds for both wind zones. According to existing experience, the calculated load as determined according to the ČSN 73 0035 has not caused any accident or damage to buildings. However, its reliability is incompatible with Eurocode requirements.

The construction of wind loading models under current standards is very similar; it differs only by the extent of simplification of experimental findings, in particular the power spectral densities of the wind speed fluctuation component, spatial and temporal load correlation, integral length of turbulence and the definition of pressure coefficients and force coefficients. The new definition of pressure coefficients, which is based on statistical analysis of BLWT measurements, should ensure the same extent of reliability of loading on the whole building. Their values for certain parts of the building are lower than the values used so far. According to the results of comparison calculations, the characteristic load (ENV)/standard load (ČSN) ratio for entire buildings situated up to elevation 700 m above sea level is 0.84 - 1.17 for local pressures in the 0.89 - 1.62 band (or 1.04 - 1.46 and 1.11 - 2.03 for the design load (ENV)/calculated load (ČSN) ratio). While for higher buildings lower values of loading on entire buildings hold, higher values hold for regular buildings. High local pressure values hold for the area with higher reference wind speed and terrain roughness.

Pressure and force coefficients tables according to ENV cannot cover all types of buildings or the effect of neighbouring buildings and terrain configuration. That is why the possibility of determining these coefficients by measurement in the BLWT was examined. The aim of the model measurement was to determine the mean and the fluctuation component of loading by measuring the aeroelastic model response of defined characteristics. The results have been published. These measurements represents a reliable means of determining the broad band component of the model response or loading respectively, the reliability of measuring the resonance component of the response depends on the precision of modeling the dynamic characteristics of the building and on suppressing parasitic vibrations. A simple model (cube) was used to test the measuring technology and to evaluate the pressure coefficients according

to the methodology used in ENV. The possibility of determining these coefficients by the measurements that had been carried out was proved.

The first stage of the experimental research of modeling the boundary layer in the VZLÚ focused on extending the possibilities of using the BLWT. Two new arrangements for simulating the boundary layer were developed, one for the second category of terrain roughness with length scale 1:410 and the other for the third category of terrain roughness with length scale 1:560. Further, the visualizing system using a Dantec-Safex fog generator was improved. In the third year of the project, a model for measuring the boundary layer characteristics over a 2D ground wave and sinusoidal profile was produced. The measurement was carried out for four various arrangements of the model and the results are given in the final report.

In the ÚTAM, a detailed theoretical qualitative analysis of the origin of an instability of a general structure flown around by an air stream was worked out, while the general (nonlinear) description and the known types of instabilities were classified from the point of view of their mathematical expression in the phase diagram. The original result consisted in mapping each type of instability in the area determined by the natural frequencies of the aeroelastic system. The key to explaining complicated phenomena was provided by extensive experiments using a device permitting a sensitive setting of parameters and faithfully reproducing the mathematical model. The results of these experiments confirm the influence of nonlinear aeroelastic phenomena. The experimental data were evaluated using a new autoadaptive decomposition of time recordings into empirical mode functions, which decomposition was fully algorithmized and continues to be utilized in the coworkers workplace.

The mutual interaction of two conical pylons standing immediately next to each other was studied experimentally. Two series of measurements on the aeroelastic model of the two pylons in a wind tunnel of diameter 1.8 m were carried out in the VZLÚ for different distances between pylon axes and for angles of incidence. While the first series of measurements was carried out with smooth cylinders, the second one was performed with cylinders equipped with turbulizers. The response of the smooth leeward cylinder showed no signs of interference galloping. In the series of measurements that used turbulizers, interference galloping was observed when the pylon distance was 2d and the angle of incidence - 6 degrees.

The aim of the project have been reached and the results will be published. Some results have already been published.

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# Field Measurement of Soil Hydraulic Conductivity

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Application of the theories of soil physics to the description or prediction of actual processes in the field (e.g., processes involved in irrigation, drainage, water conservation, groundwater recharge and pollution, infiltration and runoff control) depends on our knowledge of the hydraulic characteristics of the soil, including the functional relation of hydraulic conductivity and of matrix suction to soil water content, as well as their spatial and temporal variation.

Soil properties such as conductivity, porosity, and pore-size distribution are scale-dependent and their magnitudes should be considered in relation to some specified or implied size of sample. All soils are inherently inhomogeneous. Their primary and secondary particles and pore spaces differ from point to point and their geometry is too complicated to characterize in microscopic detail. Hence the soil is generally characterized in "macroscopic" terms based on the gross averaging of "microscopic" heterogeneities. An implicit assumption is that the physical properties are measured on a volume of soil sufficiently large relative to the microscopic heterogeneities to permit such averaging. From these considerations, it seems unrealistic to measure the hydraulic conductivity of field soil by making laboratory determinations on discrete samples removed from their natural continuum. It is necessary to devise and test practical methods for measuring soil hydraulic conductivity on a realistic scale in situ.

In the present paper we describe the measurement of hydraulic conductivity with Decagon's handheld Mini-disk [3]. Decagon's handheld Mini-disk Infiltrometers provide quick and convenient measurement of soil hydraulic conductivity. The infiltrometer is constructed of an acrylic tube with a semi-permeable plastic disk, and a rubber stopper. A small tube is installed a short distance above the disk to regulate the suction rate.

Infiltrometers are available with three different suctions: 0.5 cm (model M1), 2.0 cm (model M2), and 6.0 cm (model M3). The standard 2 cm infiltrometer is designed to measure hydraulic conductivity of all soils. The 0.5 and 6.0 cm suction infiltrometers can provide additional information about the soil by eliminating macropores with an air entry value smaller than the bubble pressure of the infiltrometer. In our field experiments we used the standard 2 cm infiltrometer.

Measuring with Mini-disk is simple and fast. The infiltrometer is immersed in water and the rubber stopper is installed while it is still underwater. When taken out of the water, it will not infiltrate until the contact with soil is established. The disk is placed on the soil surface, and the volume change is recorded at regular intervals. A number of methods are available for measuring soil hydraulic conductivity with the disk infiltrometer. We used the method proposed by Zhang [1]. The method requires measuring cumulative infiltration vs. time and fitting the results with a second order polynomial function. The evaluation of measurement requires knowledge about the class of a given soil and its van Genuchten parameters (n and $\alpha$) [4]. The van Genuchten parameters for the 12 texture classes of soil were obtained from Carsel and Parrish [2].

The experiment with Mini-disks was done on the silty clay loam soil in the Krkonoše Mountains, location Modrý důl. The aim of the measurement was the determination of hydraulic conductivity of the soil matrix (excluding macropores). There were two horizons, for which we ran the experiment - A-horizon and B-horizon. For the A-horizon, we measured in 20 cm depth and for the B-horizon in 40 cm depth. For the soil in question, the ideal time interval for recording of the volume decrease was determined as 5 minutes.

We calculated hydraulic conductivity for the A-horizon k = 2.8E-04 cm/s and for the B-horizon k = 1.4E-04 cm/s using the method of Zhang [1].

This experiment confirms, that field measurement of the hydraulic conductivity by Decagon's Mini-disk is suitable for fast field estimate of the hydraulic conductivity of soil.

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# Equivalent Constant Amplitude of Stress Range

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This research is devoted to the modified method of a fatigue design. The paper brings a definition of equivalent constant amplitude stress range.

The research comes out from two primary principles of a fatigue design of traffic load steel constructions in Czech Republic. The paper demonstrates two methods of a fatigue design. First, it is the procedure with an application of cumulative fatigue damage. This method is described in the Czech code ČSN 73 6205. Second, it is the procedure with an application of equivalent constant amplitude stress range. The procedure is contained in the code ČSN P ENV 1993 – 2. The basis of the code is Eurocode.

Note that these two methods do not give the same results. It means that they occur cases of the fatigue design which satisfy only one condition corresponding just ones of both methods. The Czech standards allow the combined fatigue design in the area of fatigue. It is possible to compile a calculation which consists of the both procedures of a fatigue design. This combined calculation is going out of the procedure with an application of cumulative fatigue damage. The reference stress range $\Delta\sigma_p$ is calculated by " $\lambda$ method ".

From the research follows the extreme case of the reference stress range $\Delta\sigma_p$:

$$\Delta\sigma_p = \Delta\sigma_c \, (1{,}15\lambda\phi_2)^{-1}.$$

The reference stress range was determined by the damage equivalence factor $\lambda$ ,by categories of detail and by the damage equivalent impact factor $(\phi_2)$.

The calculation was compiled and demonstrated on the examples. In the research was processed the reference stress range $\Delta\sigma_p$ for 140 choice cases. They were examined bridges of five various spans and fourteen various categories of details. For the calculation was taken two different loads. They were loads: "EC Mix" with limit load 22,5 tons on the axle and "25t Mix" with limit load 25 tons. The calculation was used for one track girder steel bridge.

Those reference stress ranges $\Delta\sigma_p$ were employed to the fatigue design using procedure with an application of cumulative fatigue damage. Then we get 140 results of fatigue design.

Outcome from this part of research was taken as a base of the new method of establishing of equivalent constant amplitude stress range of railway bridges from stand point of fatigue limit. We have found out that it is possible to modify the equivalent constant amplitude stress range with calibration coefficient which will correct the original equivalent constant amplitude stress range. Moreover, the same results will be given as the calculation using procedure with an application of cumulative fatigue damage.

The values of fatigue damage were taken as a base of a next work. We have constructed the retrograde combination procedure. From these retrograde combination procedure follows, that $\Delta\sigma_p$ is not linearly dependent so as it was in combined procedure. Therefore we have replaced non-linearly dependent values by straight line. And we have used

the retrograde combination procedure ones more. The retrograde combination procedure was repeated 10 times. The procedure was demonstrated for the definite detail and a particular load. Every step was classified as a step of iteration.

Two possible calculations do not get the same results of fatigue design. The calibration coefficient change equivalent stress range $\Delta\sigma_{E,2}$.

$$\Delta\sigma_{E,2}' = s \,.\, \Delta\sigma_{E,2}$$

where $s$ is a new calibration coefficient.

The modified method of the fatigue design comes out from the stress range spectra in steel railway bridges. New coefficient will be figured out for all 140 investigated cases. The verification of new coefficient „ $s$ „ is validated on the experiments from Czech Railways.

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# The Equalization of Students´Knowledge of Building Process by Means of Internet Teaching

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**Introduction:** There are many subject at Technical University students must go through. And each school master probably considers subject he teaches to be the most important one. He is probably right.

Have a look at the subject technology of construction. Is it important for civil engineers to-be? Of course it is. Not only for intending works foreman but also for designers, investors, employees of local authorities and so on. Good designer can´t do without a good knowledge how the building can be built. Otherwise he can expect a lot of problems. It isn't easy to build a building even when the project is good and the building buildable.

Majority of civil engineers get of course some knowledge of building process during several years in their employment. However it could be better to get information enough already at university.

The department technology of construction meets one long-lasting problem within its effort to teach students in a qualified way. It is a very different stage of entrance knowledge of technology of construction between students – school-leavers of building secondary modern school and school-leavers of grammar schools.

This is why we decided ensure volume of teaching of building technology subjects at building secondary modern schools at solving grant project. We asked several secondary modern schools from the whole Czech Republic to help us with getting this information. Three of these schools (SPŠ stavební at Dušní street in Prague 1, SPŠ stavební Josefa Gočára in Prague 4 and SPŠ stavební in Liberec) answered us very willingly and sent us the required information. Some building secondary modern schools have the information about teaching of individual subjects in idividual years of study placed at Internet, so we could use them.

**Lessons in technology of construction at building seconadry modern schools:**

As we found out the extent of lessons differs a little at individual building secondary modern schools concerning the individual subjects and individual class years.

**At secondary modern schools** subjects connected with techology of construction are given during four years of study about **660 lessons** and + about **130 – 170 lessons of practise** and several weeks of skilled practise.

Constructional and technical knowledge of students of building secondary modern schools arecompleted withother skilled subjects (architecture, concrete, wooden and metallic structures, building materials, seminars).

Next tab shows a number of lessons of subjects connected with building technology a week in idividual study years (building secondary modern schools)

| Class year | 1. | 2. | 3. | 4. | 4. | 3. | 4. | 2. | 4. | 1. | 2. | 3. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subject<br>BSMS | Civil constructing | | | | ES | Building structures | | Building machinery | | Practise | | |
| Dušní, Pha 1 | 3 | 3 | 5 | 4 | | | | | | 2 | 2 | |
| Ostrava-Zábřeh | 3 | 4 | 5 | 3 | | 4 | 5 | | | 2 | 2 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liberec | 3 | 6 | 5 | 3 | 2 | 3 | | | | ? | | |
| J.Gočára, Pha 4 | 4 | 6 | 4 | 4 | | | | 2 | | | 3 | 2 |
| Valašské Meziříčí | 3 | 4 | 5 | 3 | | 3 | 5 | | | 2 | 3 | |
| Mělník | 5 | 6 | 4 | 4 | | | | | 4 | | 3 | 2 |

ES= Engineering structures

Students of civil engineering **at CTU** have maximally three terms of technology of construction subject. That means 3 x 14 weeks x 4 lessons a week = **168 lessons**.

Seeing this we must admit that the grammar school-leavers must exert a big effort to equalize this difference.

**The equalization of students´knowledge of building process by the means of Internet teaching:** To help the grammar-school leavers we decided to place some information about building process from the extent of building-secondary-modern-school teaching to Internet on pages.of department of technology of construction. It is supposed to be used for selfstudy.

This method of placing information is no new method at our department which has been overgiving information to students besides other ways also by means of saving to Internet for several years already. There are some advantages of this method : - easy access to information, - possibility of modernizing of saved information, - simple orientation at individual informatinal units.

This is why we decided to use this well-tried method as well.

Our work deals with earthwork and masonry building.

It is divided into 5 units: **Earthwork, Foundations, Load-bearing masonry walls, Ceilings, Window and door lintels .**

The worked out information has its basis in the textbook Pozemní stavitelství pro 1. a 2. ročník SPŠ stavebních (Václav Hájek) and also Zdění (Pavel Drábek), Cihlářský lexikon (Cihlářský svaz Čech a Moravy), materials from building firms,… It is a text completed with pictures (some of them are overtaken from mentioned textbooks and materials, some were drawn) and photos. The extent of the information is adapted to following classes at department of technology of construction, Faculty of civil Engineering, CTU. As some information concerning the worked out theme had been in detailed form placed to Internet in recent years, they will be only referred in this text, so that there would be minimum of doubling. On the contrary some information can exceed limit of classes at building secondary modern schools, so they can be useful also for secondary-modern-school leavers. We hope that in future this information could become one of the foundations for equalizing on-line courses.

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# Applicability of Evaporative Cooling Techniques in the Czech Republic

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The research deals with applicability of evaporative cooling techniques in Czech Republic.
In the first part analyses of possible cooling energy savings for direct and non-direct evaporative cooling are elaborated. Evaporative cooling is based on the dry-bulb temperature depression within an air volume when water is evaporated in the air stream. This process is almost adiabatic (in Czech title "adiabatic cooling" is very often used), the wet-bulb temperature of the humidified air stream remains the same and the humidity ratio increases. The air-handling process can be utilised to reduce the supply air temperature either directly or indirectly or both directly and indirectly.

Direct evaporative coolers evaporate water directly into the supply air reducing the dry-bulb temperature while the wet-bulb temperature and the enthalpy are not changed. Direct evaporative cooling can be perfectly used as a single-stage cooling method for residential buildings in dry climates. The effectiveness of a direct evaporative cooler, is determined by the difference of the dry-bulb and wet-bulb temperature of the entering air and the performance of the evaporative cooler.
An indirect evaporative cooler is a combination of a direct evaporative cooler and an air-to-air heat exchanger. First, the dry-bulb temperature of a secondary air stream is reduced by direct evaporation. Second, the humidified secondary air extracts sensible heat from the primary air in the heat exchanger. Indirect evaporative cooling reduces both the dry-bulb and the wet-bulb temperature of the primary air while the humidity ratio remains constant. The effectiveness of an indirect evaporative cooler ranges commonly between 0.6 and 0.8 and depends on both the saturation effectiveness of the direct evaporative cooler in the secondary air stream and the heat transfer.

A Microsoft Excel application (programmed within this project) process a hourly based energy balancing for a system which is using both indirect evaporative cooling and conventional cooling. The analyses of applicability for evaporative cooling are based on typical hourly climatic data for Prague, Czech Republic (Test Reference Year). Possible energy savings are presented.

In the second part, real energy savings achieved by the application of direct evaporative cooling, heat recovery, heat pump and system optimization on an extensive HVAC system of Czech Television in Prague are presented. The maintenance problems of evaporating cooling plant are discussed. The HVAC system of Czech television in Prague consists more that 100 central air-conditioning unit with central heat recovery , heat pump and energy loops. In each of supply/exhaust air channels rotary heat exchanger with bypass is utilised. Heat pump

allows to heat water for swimming pool Podolí by exhaust heat from TV studios and by easy water loop pre heating of supply air is applied as source of cold water for office fan-coil units.

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# Optimization of Reinforced Concrete Structures

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The past time in Civil Engineering was characterized by an attempt to build safe structures. In recent years a number of economical aspects as well as the reliability methods were included in the design and the construction process. While the first problem is solved by Ultimate limit state and financial assessment is included as a minimization of the weight of a structure, the last condition is usually handled by Serviceability limit state. Our particular interest is in the design of steel-reinforced concrete beams. To cover the above mentioned ideas we used EUROCODE 2 standard for both limit states. In previous work [1] the economical point of view was implemented as the total price of the requested structure in terms of amounts of the used materials, steel and concrete, respectively. To be more accurate, the price for a formwork, as a cost of a surface area, is involved in the code now. Additionally, a crack width is examined and minimized to handle the reliability of a structure under long-term loading.

From the construction point of view as well as optimization itself it appears to be advantageous to decompose the whole structure into several design elements. These user-defined elements are the parts of the structure, which poses identical optimized parameters like dimensions of the cross-section, the area and the diameter of the bending reinforcement etc. Moreover, we assume that the structure is discretized into finite elements, used for the determination of internal forces distribution. Note that the analysis of a structure is performed by the C++ FEM code SIFEL, which is under development at the Department of Structural Mechanics of the Faculty of Civil Engineering, Prague.

In the original approach [1], the optimization of cross-section reinforcement was carried out simultaneously with the determination of geometrical parameters of the structure. However, this approach is no longer possible because it would result in a huge amount of optimized variables, making the whole problem unmanageable. Therefore, we employ conceptually simple but a very efficient procedure for the design of cross-section reinforcement subjected to a bi-axial loading based on fast evaluation of internal forces. The task of designing the cross-section reinforcement for a given reinforcing bar diameter thus is reduced to a mere checking of admissible combinations of reinforcements. Although the proposed procedure is extremely simple, it appears to perform quite satisfactorily thanks to the efficient procedure of internal forces evaluation and the possibility of excluding many reinforcement combinations when at least one valid combination is found. Furthermore, it always finds the global optimum because all possible solutions are checked.

As previously indicated, the optimization is used to choose the best solution that is characterized by a low price, small cracks and passes all presented conditions. We have tried a number of optimization algorithms and recognized that a combination of a genetic algorithm (GA) and a simulated annealing approach produces not only the best results but also reduces the computing time. The applied optimization strategy is called the augmented simulated annealing method (AUSA). This algorithm effectively exploits the essentials of GAs (a population of solutions is used, rather than a single point in space) along with the basic concept of simulated annealing method guiding the search towards minimal energy states. The stepping stone in a GA-based procedure is the process of recombination in which two parents selected for reproduction combine their good characteristics to produce a better offspring. In

genetic algorithms this is accomplished through various “crossbreeding” and “mutating” operators that were appropriately adjusted for our purposes.

In spite of the smaller amount of realizations the whole program is still highly time consuming and that is why the parallelization is applied. The implicit parallelism of the genetic algorithm is used: the search towards an optimum solution is governed by the population of possible solutions and by their recombination. In this phase the division for parallel computing is made so that the root computer runs the optimization algorithm while the slave processors solve individual solutions of the proposed design problem.

The actual parallel computing scheme is based on the master and slaves parallel paradigm. Since a dynamic load balancing mechanism is employed, a good distribution of the work among the processors is ensured. The performance of the network communication is given by the latency and the bandwidth. The latency is the time necessary to start an interaction between two processors and the bandwidth is the number of bytes that can be transfered via the network within one second. The former one plays an important role in the global parallel model because it usually causes considerably low efficiency. The sensitivity analysis was successfully carried out to solve this obstacle.

The leading idea of this grant research is to shift the design process to the higher level. The whole task is implemented to carry out main requests from engineering practice. The use of more computers connected by Fast Ethernet can move this approach to a real use.

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# Optimization of RC Structures

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An effort to develop an effective and easy-to-understand design procedure goes through the whole history of Civil Engineering. The research within the grant project is focused on the design of reinforced concrete structures. In present times emphasis is put on this problem due to spread of RC structures in Civil Engineering especially in Eastern Europe. Frames are the major part in this field as one of the basic building block of various construction systems. Hence, our long-time effort is to prove the reliability and efficiency of a design tool capable of automated checking and optimization of RC beams and frames. In our previous research [1] many types of design procedures together with a variety of genetic algorithm-based optimizers were tested. As a result a combination of a parallel version of the Augmented Simulated Annealing method with one representative of deterministic methods is used.

It would be highly desirable to solve the whole problem as one optimization task but the number of all possible solutions is too high. Therefore it appears to be necessary to split the process of structural design into two main parts – the detailing of a reinforced concrete cross-section and the optimization of a whole structure in terms of basic structural characteristics like types of materials, dimensions of elements or profiles of steel bars.

The main goal of the first part is to fit an interaction diagram of a RC cross-section to a given combination of load cases. An efficient procedure for fast evaluation of internal forces for a general cross-section and an arbitrary stress-strain relationship were proposed and presented in [4]. The boundary of the *interaction diagram* for a given cross-section can be simply constructed by evaluating the values of the bending moments and the normal force for a given set of extremal deformation planes. Then, one can find the minimal reinforcement area such that the *interaction diagram* covers internal forces for all loading cases. Although the proposed procedure is extremely simple, it always finds the global optimum because all admissible solutions are checked. Another topic is a computational complexity of this method. Albeit the "hard force" method is applied the overall time spent on designing of one cross-section is less than three seconds on a common PC computer.

The second part of frame design is devoted to the proportioning of building blocks. Mathematically, the goal is to find the best combination of discrete inputs but concurrently to pass certain conditions such as structural requirements, ultimate and serviceability constraints on one side or low price, workability and good appearance on the other side. Our experience shows that genetic algorithm-based strategies are capable of solving this combinatorial task. The modified version of the Augmented Simulated Annealing method along with a differential operator outperformed many traditional methods [1]. The main principles of this method are the survival of the fittest strategy together with the simulated annealing principle, an integer coding, a differential cross-over and Gaussian mutation.

The disadvantage of all structural optimization problems is the computational complexity which is the result of both structural FEM analysis and optimization part. Our solution to this obstacle comes from the implicit parallelization of genetic algorithms [2,3]. The program is divided into an optimization and an analysis part and in this way is implemented in

the cluster of PCs. The preliminary results confirm the efficiency of this approach and indicate the directions of further research.

The presented design method offers a useful tool that can cover basic analysis and design processes and help the designer design the desired structure. The proposed optimization technique proved its capability of solving the presented design-engineering task. The disadvantage of the AUSA method is the setting of inner parameters and the need of a large number of functions calls. This obstacle is resolved by the developed parallel solution, which is now prepared for more difficult objective functions. A connection with the favorite design software AutoCAD is nowadays coming into investigation.

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# Determination of Soil Erosion by Rainfall Simulator

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Soil erosion is a serious global problem. There is about one half of the agricultural land area affected by water erosion in the Czech Republic. It was estimated that about 1.4 mil. ha of agricultural land have been spoiled by erosion and among that more than 450 000 ha have been spoiled seriously. Simulation models supported by GIS and remote sensing technologies are being used for assessment of erosion hazard as well as soil conservation planning. A large number of parameters are required for modeling of erosion mechanism. Most of erosion parameters result from soil erosion research. Erosion field research methods are expensive and time demanding. Therefore methods of laboratory research that use simulated rainfall are being intensively developed worldwide.

Jet – type laboratory rainfall simulator was built up at the Department of Irrigation Drainage and Landscape Engineering, Faculty of Civil Engineering, CTU Prague. The „Norton Ladder Rainfall Simulator" was constructed on the tilting hydraulics flume in Hydraulic laboratory in 1999. The jet-type simulator developed by Dr. Darrell Norton, USDA, Agricultural Research Service, National Soil Erosion Research Laboratory, West Lafayette, USA, was constructed to obtain soil erodibility data. These are basic inputs to mathematical models for prediction of water erosion hazard prediction.

The parameters of simulated rainfall produced by Norton Ladder Rainfall Simulator are similar to the characteristics of natural rainfall. The technical parameters of this simulator are:

- Nozzles type VeeJet 80 100 Spraying Systems
- Rain drops fall height 2.43 m
- Nozzle pressure 0.41 MPa

Pavla Paříková PhD thesis "Vodní eroze jako činitel dynamiky krajiny" processed during 1999 – 2001 carried out approximately 100 experiments to test sprinkling uniformity of this equipment, to find a relation between rainfall intensity vs. nozzle´s oscillation and to find optimal parameters of erosion container. The testing area of soil sample was determined 0.9 x 4.0 m and basic methodology of deformation effects on the soil surface was created and described.

Suitable soil taking, creating real sample laying under the rainfall simulator, soil sample consolidation process establishment and surface runoff and infiltration analysis, it was objectives of grant CTU. The first sets of real experiments were run on the "Test erosion container" surface of 0.9 x 1 m. After finished testing of small soil sample was the container full-filled (0.9 x 4 m). The methodology and reliability was improved on both sample sizes.

Soil sample has been created by 5 cm of sieved sand as a simulation of soil infiltration profile, filter which prevents fine particles wash-up out of soil sample and covering layer of 15 cm sieved clay-loam soil taken close to Horoměřice. Soil consolidation was made by repeated

bottom flooding up to the terrain found density level 1120 kg/m3. Testing intensities of simulating rain 40 a 60 mm/hr has been chosen as representative for setting surface runoff and infiltration behavior. The next series of experiments was carried out on the full soil sample size 0.9 x 4 m. Until now 15 experimental rainfall simulations were performed and a great amount of data was obtained. The methodology of preparing soil samples and experiment procedure was improved. The results show correlations between rainfall intensity and the surface runoff, soil loss and infiltration rates. Other important characteristics are slope steepness and soil surface conditions. The results prove that the rainfall simulator is suitable for the soil erosion research.

In future we suppose to study fundamental erosion processes, infiltration and soil conditions that affect the soil loss. As there is similar type of rainfall simulator at the University of Agriculture in Wien, the data obtained from the measurements are compatible to each other.

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# Evaluation of Measurement Methods and Results According to Standard CSN ISO 5725

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Possibility of application of standard CSN ISO 5725 Accuracy (trueness and precision) of measurement methods and results was investigated at the department of special geodesy. This standard is divided into six parts and they was published in Czech Republic in the year 1997 (part 5 in 1999). Determination of basic principles of accuracy evaluation of measurement methods and results was the main purpose for publishing this standard. CSN ISO 5725 offers procedures for determination of trueness estimates and extreme and intermediate measures of precision. Cases for which is suitable apply these characteristics are stated too.

Definitions of terms used for the accuracy evaluation, consequences of these definitions for performed experiments, basic statistical model and problems which should be solved during preparation of an experiment are mentioned in the introductory part of the standard. Two terms are used for description of accuracy - trueness and precision. Trueness is the closeness of agreement between the average value obtained from large series of test results and an accepted reference value. The measure of trueness is usually expressed in terms of bias, i.e. the difference between the expectation of the test results and an accepted reference value. Bias is the total systematic error. Precision is the closeness of agreement between independent test results obtained under stipulated conditions. Precision depends only on the distribution of random errors and does not relate to the true value. The measure of precision is computed as a standard deviation of the test results. Less precision is reflected by a larger standard deviation. Variability of test results depends on various factors. Operator, equipment, and surroundings are the most important factors. Two extreme conditions of precision were defined for the description of methods variability. Repeatability conditions are conditions where independent test results are obtained with the same method on identical test item in the same laboratory by the same operator using the same equipment within short intervals of time. Reproducibility conditions are conditions where test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment. Repeatability is precision under repeatability conditions and reproducibility is precision under reproducibility conditions. It means that repeatability and reproducibility are an extreme measure of precision, the former describes least variability of results, the latter describes greatest variability of results. Other intermediate conditions exists between these extremes where only some factors are varied.

Some approaches stated in CSN ISO 5725 were used for calibrations experiments. Calibrations of levelling rods are carried out by two calibration laboratories in Czech Republic and there is no standard for the technological process. Calibrations of invar levelling rods were performed by means of the laser interferometry set in geodetic laboratory of Faculty of Civil Engineering too. The technological process of calibration was suggested in previous stage of the research [1] and the standard CSN ISO 5725 was used for evaluation of above mentioned factors influences in the year 2002.

There were several problems and limitations with the standard use. Results should be obtained from measurement on identical test item according standard requests. Levelling rods are

unique items, because the length of lath meter is different for different rods. Therefore it is necessary to realize all measurements on the same rods and it is not possible to measure in the same time in all laboratories during interlaboratory experiments. The length of lath meter can vary due to vibrations caused by transport or surroundings changes (especially temperature and humidity). These influences were reduced by vibration damping and by storage of the rods in the laboratory conditions. Results should be obtained by the same operator within short intervals of time during repeatability conditions. Preparation of the equipment and the rod for calibrations is time consuming, calibration of one rod takes 30 - 50 min and the measurement is difficult for operator. Therefore one operator can carry out only 2 or 3 calibrations in day in these circumstances. There are requests for number and choice of participating laboratories for interlaboratory experiments in the standard, but it was not possible to fulfil them because there are only three laboratories in our republic which are able to perform calibrations of levelling rods.

Several intralaboratory experiments were designed and performed according to CSN ISO 5725 and influences of the operators and time intervals between measurements were studied. Interlaboratory experiment was also carried out - couple of the levelling rods was calibrated in the laboratory of Faculty of Civil Engineering, in the laboratory of Research Institute of Geodesy, Topography and Cartography (VUGTK) in Zdiby and in the laboratory of Technical University in Ostrava. These calibrations were realized in consonance to suggested technological process. These fully nested and staggered nested experiments were evaluated by analysis of variance and standard deviation of repeatability and some intermediate standard deviations were calculated. Reproducibility was not taken, because all calibrations were measured by the same operators. Standard deviation of repeatability was about 1 μm for all experiments and influences of the operators, the equipment and time were not proved. It means that used technological process described in internal document of department of special geodesy is suitable for calibrations of invar levelling rods and can be used in all laboratories with required equipment.

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# Basis for Probabilistic Design of Structural Elements in Accordance with Eurocodes

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Application of the partial factor method introduced in newly developed European standards for structural design often leads to unequal reliability of structures or structural members made of different building materials and exposed to different combinations of actions. Well-balanced structural reliability can be achieved using design procedures based on probabilistic methods. However, this approach allowed in EN 1990 Basis of Structural Design, to some extent, suffer from lack of detailed guidelines and required input data.

Presented study is, therefore, focused on guidelines and data that would enable to apply probabilistic methods for verification of structural reliability in a practice. A probabilistic design may be carried out either at the level of structural members, or a whole structural system. The research is concentrated on reliability assessment at the level of structural members using first order linear-elastic analysis.

A decisive combination of actions, a design criterion (e.g. the choice among the criteria for bending and axial force, buckling, lateral-torsional buckling, etc.), and mainly the most critical cross-section should be found using structural analysis. As a rule, an initial deterministic design of a structural member is required.

Taking into account the results of a structural analysis, a reliability analysis may concentrate on the critical cross-section only. A limit state function is then derived considering the specified design criterion. In addition, the uncertainty model coefficients are used to take into account the inaccuracy of the resistance model and the inaccuracy of the action effect model. The internal forces in the critical cross-section can be usually written as a linear function of individual actions. Following this procedure, the limit state function is linearly dependent on basic variables (material and geometrical properties, actions, and uncertainty model coefficients).

All the basic variables are considered as random variables. Their probabilistic models are derived from the available models proposed by the Joint Committee for Structural Safety (JCSS). The statistical properties of the random variables are described by the different kinds of distributions (e.g. a normal, lognormal, or Gumbel distribution) indicated by the moment characteristics (mainly the mean $\mu$ and standard deviation $\sigma$). These characteristics can be derived from characteristic values of basic variables (assuming they are a certain fractile of a given distribution and the coefficient of variation $w$ of the relevant distribution is known).

Variable actions, particularly climatic actions (e.g. snow and wind), are complex time-variant quantities that significantly complicate a reliability analysis. Two simplifications are usually accepted for their description. Time-variant behaviour is approximated using:

(1) Time-invariant models in accordance with Turkstra's rule,

(2) The Ferry Borges-Castanheta (FBC) models (jump processes).

In the time-invariant analysis considering Turkstra's rule, the leading variable action is described by its lifetime extremes (assumed as 50 years for buildings), while the accompanying action is considered by its point-in-time value (approximated usually by annual extremes).

In the time-variant reliability analysis based on the FBC models, the variable actions are described by jump processes without or with intermittencies (climatic actions are sometimes completely missing). Actual time variation of actions is approximated by rectangular wave renewal functions. Each jump process with intermittencies is characterized by the jump rate $\lambda$ (the average number of magnitude changes of the square waves in the reference time $T_{ref}$) and by the interarrival-duration intensity $\rho$ (the product of the arrival rate $\lambda$ and the mean duration with respect to a reference time $T_{ref}$). The model parameters $\lambda$ and $\rho$ are, however, very difficult to estimate. Nevertheless, parametric studies indicate that the uncertainty in determining these parameters has an insignificant effect on the resulting reliability.

Probabilistic design is based on comparison of the determined reliability index $\beta$ with its target value $\beta_t$ = 3,8 given for the 50-year design working life in EN 1990. The time-invariant analysis provides a unique value of $\beta$. However, the time-variant analysis leads to an interval limited by a lower and upper bound of $\beta$. The comparison of obtained $\beta$ with the target value $\beta_t$ is then usually made for the lower bound.

The research indicates that Turkstra's rule provides results similar to the lower bound for $\beta$ obtained by the jump processes provided that the load ratio $\chi$ of variable actions over the total actions is greater then 0,2. When variable actions become insignificant (for $\chi < 0{,}2$), the time-variant analysis seems to provide rather low bounds for $\beta$.

An investigation of this problem is intended to become a main part of the following research. Theoretical principles to solve this task should be revised and new improved formulae are needed. Then, a comparison between Turkstra's rule and FBC models on a general basis (to be able to specify whether Turkstra's rule provides a "safe" estimate of $\beta$ or not) shall be made.

Obtained results clearly indicate that structural design can be based on probabilistic methods of the reliability theory. Parametric studies enable to find adequate design characteristics.

Furthermore, probabilistic methods may also be used to minimize the total cost of a structure. A simplified objective function is usually expressed as a sum of the initial, marginal and expected malfunction cost. The decisive parameter (sectional area) may be determined for the condition of the minimum total cost.

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# Bending Capacity of Thin-Walled Steel Z - Purlins

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Thin-walled cold-formed steel beams are often used as side rails or roof purlins in industrial buildings. These beams are mostly Z-, C- or Σ-profiles. Due to frequent usage, a proper investigation of their actual behaviour is needed. The subject of the research is the bending capacity of Z-purlins, whose a compression flange is restrained by thin-walled cold-formed steel sheeting. In particular, it is focused on their plastic reserve bending capacity.

The members are inherently sensitive to local and distortional buckling, effects of structural, material and geometrical imperfections, and distorsion of a cross-section. Additionally, applied loads can cause torsional moments in the beams. These effects are partly prevented by the sheeting.

Because of complicated structural behaviour, the load-bearing capacity of the purlins is generally determined by experiments. In an analysis of simply supported beams, both theoretical investigations and full-scale tests are used.

Sixteen tests of assembly of two purlins connected with trapezoidal sheeting, loaded by two symmetrical forces introduced into webs of each purlin, were executed. The specimens were taken with regard to a slenderness ratio of a purlin $h/t$, stiffeners $c/t$, and flanges $b/t$. In addition, two different cross-section shapes were considered: a section with a skew edge stiffener to flange (denoted as A in Table 1) and with stiffener perpendicular to flange (denoted as B). Therefore, eight different cross-sections types and two different numbers of screwed connection of the sheeting and purlin were used. Vertical deflections were measured at three points along the length of each purlin and the strains were measured in the midspan cross-sections. Application of the load was regulated by deflection. The yield strength $f_y$ was determined by tension tests of undamaged parts of specimens after the experiments.

The specimens were tested to the total collapse. The maximum reached force $F_{max}$ and total deflection $\delta_{max}$ were measured during the experiments. The maximum bending moment $M_{max}$ was derived from the maximum experimental force $F_{max}$.

The bending capacity $M_R$ of the specimens was assessed in accordance with EN 1993-1-3 using the following expression $M_R = W_{eff,y,up} \times f_y$. In calculating the effective modulus of section $W_{eff,y,up}$ at the upper, compressed fibres, the critical stress of the compressed flange with an edge stiffener $\sigma_{cr}$ was determined using the comprehensive procedure considering the distortional buckling of the edge stiffener [2], [4].

Plastic capacity reserve is defined as the ratio of the actual bending capacity $M_{max}$ and the bending capacity $M_R$ determined assuming elastic behaviour of a cross-section and taking into account effective sectional parameters.

The brief summary of results is given in Table 1.

The obtained results clearly indicate that the plastic capacity reserve may be taken into account in calculations with defined restriction even for thin-walled cold-formed steel purlins stabilised by sheeting. The specimens with small slenderness of particular compressed parts of a cross-section have a significant plastic reserve that varies between 20 – 35%.

Table 1 – Results of Experiments

| Z-purlins ($h$ – $t$ - stiff.) | $W_{eff,y,up}$ | $f_y$* | $h/t$ | $b_1/t$ | $b_2/t$ | $c/t$ | $F_{max}$ | $\delta_{max}$ | $M_{max}$ | $M_R$ | $M_{max}$ / $M_R$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [mm$^3$] | [MPa] | [ - ] | [ - ] | [ - ] | [ - ] | [kN] | [mm] | [kN/m] | [kN/m] | [ - ] |
| 150 - 1,2 - B | 9 585 | 404 | 125 | 34,2 | 39,2 | 14,0 | 31,8 | 11,2 | 4,8 | 3,87 | 1,23 |
| 150 - 2,0 - A | 20 512 | 381 | 75 | 22,5 | 25,5 | 8,0 | 70,0 | 23,1 | 10,5 | 7,81 | 1,35 |
| 200 - 1,2 - B | 12 610 | 498 | 167 | 55,0 | 61,7 | 16,9 | 43,0 | 6,5 | 6,5 | 6,28 | 1,05 |
| 200 - 1,5 - A | 19 144 | 439 | 133 | 44,0 | 49,3 | 10,7 | 55,6 | 10,4 | 8,4 | 8,40 | 1,05 |
| 200 - 2,5 - B | 46 325 | 433 | 80 | 26,4 | 29,6 | 9,8 | 160,9 | 16,5 | 23,1 | 20,08 | 1,17 |
| 250 - 1,5 - B | 23 929 | 472 | 167 | 44,0 | 49,3 | 15,8 | 80,2 | 7,7 | 12,0 | 11,30 | 1,04 |
| 250 - 2,5 - B | 59 901 | 418 | 100 | 26,4 | 29,6 | 10,8 | 204,7 | 13,0 | 30,7 | 25,04 | 1,23 |
| 300 - 2,0 - B | 46 315 | 505 | 150 | 41,0 | 45,0 | 14,9 | 162,3 | 11,5 | 24,4 | 23,40 | 1,04 |

* declared steel – FeE350G (according to EN 10147)

Theoretical part of the research was focused on the investigation of the plastic behaviour of Z-purlins. The program ANSYS based on the finite element method was used in the analysis of purlins. A numerical model that includes imperfections, plasticity and effects of large deformations was developed. A bilinear material model is used in the calculations.

The following research is concentrated on comparison of the results of the tests, numerical model and existing calculation procedures allowing for the distortional buckling mode of the edge stiffener. The value of the plate imperfections in the numerical model will be calibrated using the test results. The calibrated model will be used for parametric studies. The complete results of the research are intended to offer recommendations for allowable compression strain in flange with respect to the slenderness of the compression elements of the cross-section.

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# Hydraulic Model of Drinking Water Distribution System

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Hydraulic modelling of drinking water distribution systems can help in operation of the system and also in assessment of drinking water quality. A creation of hydraulic model of water distribution system is presented in this paper. This project covers mathematical modelling of water distribution system of water treatment plant Plav – water tank Včelná – Hlavatce – Sudoměřice – water tank Hodušín. Software applications used for hydraulic modelling were ODULA and EPANET 2. Data were conversed and analysed (hydraulic and pressure applications) by this software.

A computer program ODULA enables hydraulic modelling and residence time modelling. ODULA performs extended period simulations of hydraulic and water quality behaviour within pressurised pipe networks. A network consists of pipes, nodes, pumps, valves and storage tanks or reservoirs. ODULA tracks the flow of water in each pipe, the pressure at each node, the height of water at each tank and a concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

Hydraulic model can be used for design of a new drinking water supply system or for different analyses of an existing water supply system. Modelling of hydraulic conditions in the network can be used for determination of pressures, flows, velocities, residence time and water quality changes. It is possible to design and evaluate different variants and solutions and to optimise the operation of the network.

Water quality modelling can be used for modelling of age of water throughout the network. Zero order growth is used in Epanet to model water age, where with each unit of time the "concentration" (i.e. age) increases by one unit. It enables also to model the movement and fate of reactive material as it grows (e.g., a disinfection by-product) or decreases (e.g., chlorine residual) with time. It is possible to model reactions both in the bulk flow and at the pipe wall with the use of n-th order kinetics for reactions in the bulk flow and zero or first orders kinetics for reactions at the pipe wall.

A hydraulic model and model of residence time have been created for a part of Southern Bohemia water distribution system of water treatment plant Plav – water tank Včelná – Hlavatce – Sudoměřice – water tank Hodušín. The source of water is Římov reservoir (intake 1480 l/s), river Malše (maximum intake 1000 l/s) a bore Vidov (intake 40 l/s). This water is treated at Plav water treatment plant and from here it is pumped to Včelná, Tábor and Český Krumlov. Water treatment plant Plav has capacity 1400 –1600 l/s.

The total length of this water distribution network is 89 km and hydraulic model contains 693 nodes, 7 distribution reservoirs, 661 pipes and 21 pumps. Hydraulic model is composed of gravity water conduits –Včelná – Hlavatce, Zdoba - Malá Varta and Malá Varta – Sudoměřice. Hydraulic model is composed also of parts of distribution system with pumping

Plav – Včelná, Hlavatce - Zdoba and Sudoměřice – Hodušín. Water conduit diameters are 1000 mm and 500 mm.

In the first phase of the project necessary data were measured and collected. These data were evaluated and used for creation of the model. Operation of water tanks and pumping stations was regularly consulted with JVS. Input topology data and measured values of flows, demands and hydraulic pressures during the period from 1.3.2002 to 31.3.2002 in one hour interval were obtained from JVS company.

Large amount of data was processed. At present time the model is calibrated with the use of flow data and other necessary data from March 2002. After hydraulic calibration of the model in the extended period simulation the model will be used for water quality modelling and residence time modelling. The main parameters for quality modelling will be chlorine decay and iron. For this purpose water quality measurements for calibration and verification of water quality models were performed.

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# Environmentally Optimised Design of the South Façade of a Low Energy Building

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There is an important potential of the environmental load reduction to be exploited in the case of new constructed buildings. The design team decisions could significantly improve the environmental quality of a new building in the initial phases of its design. The designers are required to propose technical solutions leading to a minimal material and energy demand during the construction and operation phases of the building's service life. The new optimisation methods including environmental impact assessment have to be integrated into the current design methods for this purpose.

The aim of this study is to demonstrate the design principles mentioned above. Four alternatives of the south façade design of the low energy building are proposed for a case study. The optimal solution is considered to provide the minimal energy use for heating as well as minimal environmental load caused by fabrication of construction materials. Architectural quality is taken account selecting the optimal alternative, too.

For this case study, a project designed for the architectural competition "Low Energy and Low Cost Building in the Czech Republic" has been chosen. The building is designed as a terraced house consisting of five identical two-floor sections. There are two flats of 73 m2 area in each section (one flat on each floor). However, only the central section of the building is analysed in this study. The largest façade of the building is oriented to the south. The northern façade is connected to a closed and unheated staircase. The attic containing some technical services is unheated as well. The building does not have any cellar. The foundations are made of reinforced concrete. The supporting structures (walls and floors) are made of earth and wooden frames. The building envelope is made of wood-based materials. Mineral wool is used for thermal insulation. The structures of the unheated spaces are made of wooden beams. Aluminium sheets are chosen for the roof covering. The building is heated by a natural gas boiler and it is ventilated mechanically by the system with heat recovery.

The four alternatives considered in this study differ from each other in the glazed area and in the passive solar concept. All the alternatives use the identical glazing unit for windows (double glazing with low emissivity coating, crypton filled, U = 1.0 W/(m2.K)).

- Alternative 1 – curtain wall: The south façade is designed as a completely glazed curtain wall. A grid of wooden columns supports the aluminium profiles of the envelope. The glazing is fixed to these profiles. A special wood-based thermal insulating attic panel completes the façade structure.
- Alternative 2 – small windows: The façade is assembled of several types of panels and of wooden frame windows. All the windows are of the same size and identical parapet height (0.9 m). The structure of panels is built of wooden I-beam frame overlaid by OSB. The cavities in the panel are filled with mineral wool thermal insulation. The vapour barrier and gypsum board coating are applied on the internal face of the panel. The external wooden cladding is fixed on vertical wooden laths.

- Alternative 3 – large windows: This alternative differs from alternative 2 in the glazed area. In this alternative, the windows height corresponds to the floor height (there is no parapet). The same type of panels is used in this alternative as well as in the previous alternative.
- Alternative 4 – sun-space: The sunspace covers one third of the façade area. The rest of façade structure is identical with alternative 3. The glazed wall ($U = 1.0$ W/($m^2$.K)) separates the sunspace from the heated space (living room). The wooden frame structure of the sunspace is glazed with current double glazing ($U = 2.8$ W/($m^2$.K)).

The following properties (assessment criteria) were calculated for each alternative in order to compare them and to select the optimal one:

- Equivalent $CO_2$ emissions and embodied energy caused by the façade construction
- Equivalent $CO_2$ emissions and embodied energy caused by the façade refurbishment
- Total equivalent $CO_2$ emissions and embodied energy
- Energy use for heating and corresponding equivalent $CO_2$ emissions
- Energy use for ventilation system operation and corresponding equivalent $CO_2$ emissions
- Architectural quality of the façade

A simple comparison among environmental properties and architectural quality of alternatives does not allow selecting the optimal solution. To provide the maximal objectivity, a multicriterion assessment method is used to evaluate the results. A single value (Vchar), which aggregates all the assessment criteria regarding their relative importance (weight), is assigned to each alternative. Comparing the Vchar-values of alternatives, the alternative 3 can be declared as the optimal one. However, the choice of the assessment criteria weights has a radical impact on the assessment results. The dependence of the assessment results on weights is tested by means of sensitivity analysis.

The presented multicriterion assessment method and the sensitivity analysis have been found very efficient during the design process. In the future it should be required to perform a similar assessment of the concept of the whole building and its structure. In this respect, a more significant environmental load reduction could be achieved. It is suitable to develop this method in order to enlarge the context of environmental assessment (more factors than only material fabrication and heating should be included).

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# Geotechnical Engineering II

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Recent efforts to create a unified body to provide a technical, professional focus for geotechnical matters have contributed a definition of geotechnical engineering that is comprehensive: Geotechnical engineering is the application of the sciences of soil mechanics and rock mechanics, engineering geology and other related disciplines to civil engineering construction, the extractive industries and the preservation and enhancement of the environment. Geotechnical engineering plays a key role in all civil engineering projects, since all construction is built on or in the ground. In addition it forms an important part of extractive industries, such as open cast and underground mining and hydrocarbon extraction and is essential in evaluating natural hazards such as earthquakes and landslides. The use of natural soil or rock makes geotechnical engineering different from many branches of egineering: whereas most engineers specify the materials they use, the geotechnical engineer must use the material existing in the ground and in general cannot control its properties. [1]

Department of Geotechnics provides since 2000 special geotechnical course with main topics: Eurocodes, Engineering Geology, Monitoring, Civil Engineering and Environmental Aspects, Foundations, Underground Structures, Embankments and Landfills. Total volume of lectures is 80 hours incl. consultations. Total number of participants for three times program repeat is actually 95. Course Gootechnical Engineering I has an accreditation by the Czech Chamber of the Authorised Engineers and Technicians. Course is closed by the exhibition of the final geotechnical works of participants in the poster form with a discussion. The participants obtain also a special certificate.

The research within the grant project is focused on advance working of the new course – a continuation as Geotechnical Enginering II. The course will be also assigned for professional community – engineers, technicians, geologists, ecologists etc.

Geotechnical Engineering II will include some parts of the:

- Public Policy (codes, standards, laws + compliance),
- Risk Management (observational method, risk assessment, instrumentation),
- Site Exploration (reconnaisance, drilling, in-situ testing, geophysics),
- Geology & Hydrogeology (composition, genesis, processes, surface fluid flow),
- Soil & Rock Mechanics (deformation, failure, seepage, applications),
- Structural Mechanics (deformation, failure, member design),
- Continuum Mechanics (elasticity, plasticity, idealisation),
- Numerical Analysis (FEM, BEM,..., geotechnical software),
- Materials (type, properties, geosynthetics),
- Structure Support Systems (e.g. foundations),
- Fluid Control Systems (e.g. dams),
- Underground Geo-structures (e.g. tunnels),
- Surface Geo-structures (e.g. embankments, landfills),
- Ground Improvement (e.g. densification, remediation ...).

Total range of the lectures is about 80 hours (divided in 2 parts incl. consultations with lecturers). First part will start in March, every months to June, total hours 4 x 10. Second part will start in October, every months to December, total hours 3 x 10. For consultations we count 10 hours. Technical support for education is complete (overhead projector MEDIUM Traveller ECO, data projector, projector screens, notebook DELL etc.), conference room of the Dept. of Geotechnics will be used as a lecture room. Course will be started in the academic year 2004/05 and we expect 40 participants approx. for three times. Participants will obtain lecture papers and other educational materials. Course will be closed by the exhibition of the works of participants in the poster form and proceedings will be isued. The participants obtain a special certificate.

The course is designed to provide participants with a theoretical and practical recent advanced knowledge of geotechnical and geoenvironmental engineering. This one year course is to provide a special foundation for careers in geotechnical (geoenvironmental) engineering, monitoring, management. It is intended for graduates in specialist areas of civil engineering, environmental engineering, earth sciences or biosciences, or in a cognate numerate scientific discipline, or appropriate professional experience.

Domain of the further adult education is a very important part in the system of academical education. Course Geotechnical Engineering II will make a contribution to the development in this area.

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# Aplication of Tensor Computation in Geodetic Networks

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The local geodetic networks are used to study, analyze and survey the relative crustal movements in earthquake prone areas. In these networks the fault attitude of the points can be detected by repeated geodetic measurements.

The strain tensor is often used to compute strain patterns for investigation crustal movements. The strain tensor is possible to use to describe local stress and twist. Two sets of observations taken in two different time epochs are required. Then two sets of adjusted coordinates are performed. It means there is pair of coordinates for each point in the network. The displacement are computed from these pairs of coordinates and farther used to compute the components of strain tensor at each point of the network.

This paper is focused to usage of strain tensor as an alternative method to vectors used in previous processing of GPS data from the western part of the Bohemia Massif. This massif is characterized by the occurrence of juvenile carbon dioxide waters, mineral springs, mofettes, young Quaternary volcanism, steep gravity gradients, increased heat flow and namely by periodical occurrences of intraplate earthquake swarms. The 1985/1986 swarm – one of the strongest ever – initiated systematic seismological investigation of the region.

The region is situated at the intersection of the principal deep fault systems of the Ohře Graben (Litoměřice and Krušné hory faults) and the Tachov-Domažlice Graben (Tachov and Marianské Lázně faults).

The GPS (Global Position System) technology was used as geodetic method to determine the attitudes of network's points. According to published materials and experience the advance GPS data processing gives horizontal precision of measured points within 0.5 cm and vertical precision within 2.0 cm. That is why the GPS measurements were supplemented by precise leveling in the most active epicentral zone of the region.

The precise leveling polygon was set up to monitor vertical movements in the most desired area of Nový Kostel among the GPS monuments. The boundary of the negative and positive block was detected just parallel to the Nový Kostel epicentral zone. Despite this conclusion the repeated measurements would have to be performed.

The points of network were situated with respect to the main geological units, traces of deep tectonic faults, local geomorphology, distribution of earthquake epicenters, and fault plane solutions. The network is divided into two parts the inner and the outer part.

The inner part consists of 17 points distributed in the active epicentral zones of region. The Nový Kostel zone and the Kraslice zone. Five of these points are used as benchmarks for precise leveling. These two zones cover more then 250 square kilometers. This inner part of network is formed by 17 points.

The outer part consists of 8 points distributed in whole active zone spreading on the Czech Republic territory. This zone covers about 2000 square kilometers and is intended to monitor possible displacements along the main faults. This part of the network is formed by 8 points.

The two GPS campaigns were performed every year (fall and spring) from 1993 to 1996. The GPS antennas were mounted to special monuments built for this purpose to achieve the compulsory centering. The sets of five Trimble 4000 SSE Geodetic Surveyor antennas and

Geodetic System Surveyor dual – frequency receivers were used. All sessions last at least 6 hours and only in fall 1993 3 hours were performed.

The data from all campaigns were processed by GPS software (version 3.4 and later). The double difference approach is used by software for processing. In principle, precise ephemerides were used for the data processing.

The network was connected to the IGS (International GPS Service) observatories and the final coordinates were transformed to ITRF (International Terrestrial Reference Frame).

Only GPS data where used to compute horizontal displacements. The adjusted three-dimensional coordinates in ITRF were transform to the plane coordinates using the transverse cylinder projection. The scale and angle deformations of this projection are for this area small enough to be ignored. The coordinates from the fall 1993 were taken as the zero epoch. The coordinates obtain from every next epoch were compared with this zero epoch.

The strain tensor as is mentioned above is computed from the pairs of displacement vectors with component $v_x$ and $v_y$ for every point as a base and all other points in the network. It was necessary to set any rule to determine which pairs and in what way should be used to compute the tensor for specific point. The method of least squares was used to solve the system of equations giving the strain tensor for computed point with respect to distances between the points in every pair.

The strain tensor can be decomposed into symmetrical and antisymmetrical parts. The symmetrical part represents the non-rotational part of the deformation and the antisymmetrical part represents average differential rotation showing the local twist.

Unfortunately the method of strain tensors did not give any new information about movement in monitored area. The horizontal shifts rarely exceeded 10 mm and computed strain tensors did not help to find any clear tendency of displacement or edges of fault blocks.

It is probably necessary to process the data from longer period that is 1993-1996 to let the displacement get larger. In addition the new type of GPS antennas Zephyr Geodetic and new receivers (Trimble 5700) were used for the newer campaign. These antennas and receivers should provide more precise and stable parameters of phase center that is considered as one of the critical factor determining the final accuracy of GPS data. There is also a chance to get some new information in case of computing strain tensors separately for expected fault blocks.

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# River Basin Management Plan

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The EU Water Framework Directive (WFD) represents one of the most significant and fundamental reforms in the field of water quality management and legislation, in both environmental and administrative terms. River Basin Management Plan (RBMP), is an instrument demonstrating how the requirements of the Water Framework Directive (WFD) might be implemented in a proposed environmental agency or authority, based on existing information. Plan Preparation Report (PPR) detailing the problems encountered with preparing the RBMP in terms of shortfalls of data, lack of necessary power and duties and other issue which will need to be addressed before RBMPs are produced in earnest.

The main objectives of RBMP is to provide a tool by which the water bodies in each River Basin District (RBD) can be managed within an all encompassing regime, the RBMP therefore, establishes the basic characteristic of water bodies, compares the current approach to classifying the baseline status of water bodies with the requirement of the WFD, and identifies the geographical distribution and extent of pressures from human activity affecting the current quality of water bodies. The first stage in developing a RBMP is to describe the River Basin District by mapping the location and boundaries of both surface and ground water bodies and describing their characteristics under methodologies.

In its simplest form the WFD requires the characterization of surface waters and ground waters within each RBD. Characterisation occurs at three levels, firstly at a board level which defines the type of water body as either lake, river, transitional or coastal. Further categories are defined for artificial and/or heavily modified water bodies. Each category is then further defined on the basis of limnological/biological characteristics. For each category of water body, ecological reference conditions based on its original, natural condition without human impact are to be defined, followed by classification of status which is simply a measure of the degree of deviation of a given water body from its original, natural condition. This process would eventuate with the division of all waters up into water body management units, which will form a basis for any decisions or regulatory controls under the WFD.

In order to understand the reason behind any deterioration or improvement of status and to assist the direction of management objectives and measures, the WFD then requires a review of the environmental impacts arising from human activities (pressures and impacts) which will allow the detection of the main problems that should be considered. These must be indirectly linked to the definition of reference conditions.

This focus towards a dynamic context of driving forces, pressures, status, impacts and responses, which is required to be reported in the final RBMP, requires a new approach to data and information collection. Monitoring networks will therefore need to be revised such that indicators of improved performance, including rates of change can only be set in the context of environmental objectives, which must be established for surface waters, ground waters and protected areas. A programme of measures for each RBD composed of both basic and, where necessary, supplementary measures for achieving or maintaining good status is then required to be developed. Basic measures are defined within the WFD that are compulsory and represent the minimum steps required to achieve good status. They include the measures required by 11 existing EU water related Directives (the bathing water directive, drinking

water directive, urban waste water directive, nitrates directives, bird directive and habitat directive) supplementary measures are those that may be needed in addition to basic measures if good status is to be achieved.

A key issue in the development of the RBMP is data and information collection and presentation. The use of GIS is a fundamental tool for both the management of information, but also the dissemination of information once it has been collected. A further important component of a RBMP is the need for consultation, both in its development and its implementation. Accordingly public consultation programmes are required as mandatory components of the WFD.

The preparation of RBMP should need to provide a general description and characteristics of the RBD, identify and map areas within RBD protected by EC legislation and national designations, summary the key significant pressures and impacts of human activity on the status of surface water and groundwater, present mapping of the current monitoring networks, provide an economic analysis of water use, outline the key environmental objectives for surface waters, ground waters and protected area, summary a programme of measures required under EC legislation to protect surface and groundwater, provide a register of existing, detailed programmes and management plans dealing with sub-basin management, summary public information and consultation measures undertaken as part of RBMP, provide a list of competent authorities that will be responsible for implementing the requirement the RBMP in accordance with the WFD, outline the arrangements for the public availability of information, provide a summary of the overall RBMP, and how the different components will interact to achieve integrated river basin management in RBD.

Characterisation of water bodies under within RBMP effectively follows three tiers of classification.

Water bodies are to be initially characterized as either ground waters or as falling within either one of the following surface water categories – rivers, lakes, transitional waters or coastal waters – or as artificial/heavily modified surface water bodies.

For each surface water category, the relevant surface water bodies within the river basin district are to be further differentiated on the basis of limnological/hydrological and biological characteristics.

Each water body type then requires the establishment of reference biological conditions or criteria on the basis of a natural or undisturbed condition, with very little anthropomorphic impact. This reference criteria sets the standard for high ecological status.

Waterbody types are then categorized on the basis of status i.e.: the degree of deviation from the category of high status. Mapping of the final classification of waterbodies on the basis of status is to be presented as part of the mapping of monitoring networks.

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# Water Management in Reservoirs with Increased Safety-Ecological Requirements of Reservoirs Relese

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Individual purposes of reservoirs are often at mutually conflicts. Depends of how we will solve all those differences from the technical-ecomomical-ecological points of view to social optimum[3]. To be able to confront, to examine and to evaluate management with water in reservoir with increased safety – ecological requirements of reservoirs, we must have available and actual hydrologic basic data. Acquirement of the meteorological datas goes before them. Among other things are characteristics hydrological dry atmosphere behoove minimum average annual discharge, m-daily flow (e.g.$Q_{355d}$), minimum flow election probability - flow behind m-daily. More apposite is thought the access, where is dry atmosphere define like period, during that is flow below threshold value. It is possible to use also next characteristics, like indicator basic flow or characteristics leaving line average daily flow [1], voluminous deficit waters in little-aqueous period etc .
Hydrologic dry atmosphere is usually examined by statistical avenues of approach. Aim next is pass judgment on probability how it can be possible expect repetition case different funds and continuation, that have set in and judge characteristics even extreme eventuality. To it like statistical quantity is used presentation descriptive characteristics of small flow. It is sought available theoretical disposition probability locality mine. flow and estimate with his parameters.

With minimum flow in the rivers, inclusive their section below reservoirs, bear ecological interest. All the time we try with pain these terms inquire into, mathematically is describe and find so optimum conditions for life fish in our rivers. At optimalizition these conditions anything be sufficient real series flow $Q_m$ [$m^3s^{-1}$] behind longer time period. Pursuant to real series flow with then they can in synthetic series foreground. model situation, that have us from aspect investigation problem interest.
For determination changes of fish habitat in choice situation (e.g. . in period dry atmosphere, behind flood, but also in normal situation) is necessary carry out at first hydrological analyses. Fish we can account as ideal bio-indicator for classification water stage biotope and hydrological regime. In past mostly lower reach river with by establishing and functional alluvium excelled immense fish wealth, namely how from aspect generic motley, so and from aspect high abundance.
There is in the rivers in Czech republic fish living with continual post (carp, pike, barbel, etc ..), with move only on limitation section flow. There are living further in the rivers fish ductile (salmon, conger), that have pass through its development in partly in the sea and in part in the rivers. From the aspect build-up weir and barrier is necessity distinguish fish ductile on two insider. To the first belongs to salmon, which with hatching place in upper rivers and descend without board, where grow up. Adults individuals pull upstream to the river, where with rub and laying spawn. On the other hand conger, representative second insider, with hatching place in the sea and minute fry there is a draught upstream to the river, where grow

up. Adults eels with again replacement without board lay spawn. Upstream river then pull adults salmons and eels spawn.

Conditions for life, that fish needs for living in the river below reservoir Římov, was examined by the help of method PHABSIM. River Malše was fission on exemplary sections. Those sections was reconnaissance from aspect hydrological and hydrobiology. For resulting solving and plasticity were used waveforms single types fishes weighted useful area WUA commensurate on flow Q. It was used series real moon flow from years 1944-1990. From these real series was modeling 500-year flow series in the profile Malše-Římov and transaction with statistical analysis. It everything was basis of determination optimum through-flow conditions, that have singles types fishes to life they need. For water management, conversant steerage reservoirs, be of the essence, that for example for fishes population isn't substantial straight throat, which traverse trough in profile, but possibility retrieval post s depths, at speeds of, fit hiding place in gout and with young, that have wait on fish like protection from major rate and in face of predators [2]. Weighted useful area shape of cross section, that include all these factors, is then at the same time quantitation so-called microhabitat in this shape of cross section [3].

It is necessary take for granted, that title to optimum habitat of fishes population and other animal kind and if need be even by people and title to water quality may be interference next e.g. stochastic factor, that have would had implicate in steerage drainage ecological flow from reservoir and namely in the real time [2]. Most notably ecological situation in the rivers below reservoirs rise in the period dry atmosphere that is necessary to have at disposal next possibilities that concept safety effects was not untimely reducted.

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# Distributed Parameters Usage in Network Simulation Models

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The research was focused on the comparison of thermal network models with lumped and distributed parameters. Calculated results were compared to measured values - internal air temperatures in two rooms with different weight of a building envelope.

*Introduction*. The important goal for building designers during building design process is to ensure an acceptable internal thermal environment in the buildings. Designers can use different simulation tools. Simulation programs for a prediction of the temperature changes in the interior of dwellings or the surface temperature of constructions are often used These methods allow us to calculate the temperatures during certain time period (day, week, year) in summer or winter season. The analysis of the thermal dynamic behaviour of rooms or buildings can be used for solving many problem situations in the building structure or HVAC system design.

A method based on a network technique is used in this research. The network is built as the analogy with RC circuits. Basic elements of the model are thermal resistivities and thermal capacities. These elements are often used as lumped parameters, this means that basic thermal properties e.g. the building envelope are split to two elements – the thermal resistivity and the thermal capacity. Better description of a real situation can be reached by means of the distributed parameter when one element includes both properties.

*Methodology*. Resultant values of predicted temperatures are calculated from an equation

$$T_k(j\omega_i) = H(j\omega_i) \cdot T_1(j\omega_i)$$

where $T_k$ is the temperature in $k$ node and $T_1$ is the temperature in the input node. $H$ values can be assessed from the system matrix describing the network [3]. . In case of distributed parameters the equation

$$\begin{bmatrix} T_1(p) \\ Q_1(p) \end{bmatrix} = \begin{bmatrix} \cos \tau_1 & \rho_0 \\ \frac{1}{\rho_0} \cdot \sinh \tau_1 & \cosh \tau_1 \end{bmatrix} \cdot \begin{bmatrix} T_2(p) \\ Q_2(p) \end{bmatrix}$$

is added to the system matrix.

By means of these expressions we can predict air temperature changes according to changes of external or internal load changes. This load can be time dependent changes of the external temperature, the solar radiation or the internal heat flow. The simulation program has been developed that uses these elements: the thermal resistivity, the thermal capacity, the distributed parameter and heat sources or loads.

*Description of models*. The zone model makes use of a five-node circuit. The first model calculates internal air temperature evoked by external air temperature changes and employs distributed parameters that are used for the description of heavyweight wall. Other parameters in the model are: the window resistivity, the ventilation resistivity, the thermal transfer resistivities from the external environment to the wall and from the wall to the interior, the thermal transfer resistivity between the interior and surrounding walls and floor, the thermal capacity of the interior, surrounding walls and the floor thermal capacity. The second model uses only lumped parameters that are used also for the description of the envelope.

*Comparison of results*. Models were verified by comparing predicted and measured internal air temperature in winter in an unoccupied building without heating during two weeks. The measurement was performed in two rooms, a ground floor room and under roof room without thermal insulation, it means heavy and light wall structures.

Resultant values of internal air temperature were drawn in graphs where a difference between peak values, a time lagging and a shape of the temperature curve can be observed. The difference between the simulated and measured air temperature for the model with distributed parameters in the ground floor room was for 90% time within 1°C, for upper room it is 85%. This figure for lumped parameter model is 72% and 82% [3,4].

The explanation of differences for simulated and measured temperatures is the estimated air infiltration rate and the thermal resisitivity of windows.

*Conclusions*. Results demonstrate good agreement between calculated and measured air temperatures.

- Distributed parameters substantially increase the accuracy of the simulation. These elements ensure quality output in buildings with heavy weight envelope.
- Lumped parameters can be used for light weight structures when results from the simulation are acceptable.
- For better results it is necessary to use accurate input values of the most sensitive elements.

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# Verification of Principles of Sustainable Construction in two Housing Designs

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Two conceptual designs of sustainable buildings for housing have been performed within a framework of the long-term project "Building Construction and Sustainable Development" supported by Ministry of Industry and Trade of the Czech Republic. The main goal was to verify possibilities and efficiency of principles of sustainable construction in the specific Czech conditions. This had to be presented on buildings having timber-framed structure. Two architectural and structural designs of two selected types of buildings for housing have been elaborated, optimised and evaluated from the point of view of wide range of sustainability criterions.

The first case design was two-storey single family house (URD - Sustainable Family House) and the second case design was 4-storey apartment building (UBD – Sustainable Apartment Building). The accommodation standard of designed sustainable houses (floor area of flats, basic indoor facilities etc.) was set on the same level as usual standard mostly used in the contemporary Czech construction of buildings for housing. Environmental parameters such as consumption of non-renewable material sources, consumption of energy sources, consumption of drinking water, waste production etc. were during the design process optimised. Consequently the investment cost level was considered with the target to keep it on common level. The process of optimisation was based on comparison of designed solution with reference buildings (existing buildings in CZ conditions) having identical use, approximately the same size and similar technical standard.

The material concept of the both case designs is based on the principle of effective use of renewable materials (wood, wood-based materials etc.), recycled materials and other materials with very good environmental parameters. Consequently, the investment cost associated with the construction of sustainable buildings for housing has to be on the same level as in the case of common housing construction with the same standard. The conceptual principles of design of sustainable buildings for housing are:

- decrease consumption of non-renewable raw materials
- increase use of renewable material sources (wood etc.)
- increase use of recycled materials
- short construction time
- prefabrication – reducing construction time and supporting technological quality

- architectural variability – enabling future changes of layout and technical facilities
- demountability, recyclability
- easy maintenance

The selection and assemblance of structural elements has to respect requirement of high performance quality within the whole life cycle of the building. It is necessary to consider expected maintenance, repair and replacement phases of particular structural elements in the design process. This requires harmonisation of life expectancy (durability) of structural elements. It also requires to enable ease replacement of elements with shorter performance life.

The leading idea of the energy concept was to reduce the heat use for space heating below to 50 kWh/($m^2$a), which is a common criterion for so called low-energy houses. The principles of energy design as an integral part of overall sustainability approach are the following:

- suitable position and orientation of building on the construction lot
- suitable architectural form (compact form)
- conceptual and detailed design avoiding thermal bridges in building envelope
- interior layout respecting thermal zones, room orientation and sizes of rooms
- suitable size of glazed facades, effective use of passive solar gains
- use of high efficient heating system mainly using renewable energy sources
- use of mechanical ventilation system with heat recovery .

The comparison of sustainable designs and reference buildings showed the potential for improvement of design and construction approaches. (Note: A Life-Cycle Assessment has been made using methodology that is presented in the contribution "A Case Study of Environmental Assessment of Housing Buildings"). I the both cases (URD - Sustainable Family House and UBD – Sustainable Apartment Building) the use of renewable materials is eight times higher and use of recycled materials is 100 times higher than in the case of reference buildings. In the same time the amount of non-recyclable waste is reduced (8x in the case of family house and 2 x in the case of apartment house). The embodied emissions of $CO_2$ are also decreased (URD by 25 %, UBD by 29 %).

The specific heat use for space heating has reached the basic goal with 39.8 kWh/($m^2$a) (reduction by 55 % compared to reference building) for single family house and 24 kWh/($m^2$a) (reduction by 79 % compared to reference building), respectively.

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# A Case Study of Environmental Assessment of Housing Buildings

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A case study of environmental performance of four housing buildings and their comparison have been performed within a framework of the long-term project "Building Construction and Sustainable Development" supported by the Ministry of Industry and Trade of the Czech Republic. The main goal was to verify possibilities of reduction of environmental impact of housing construction when implementing principles of sustainable construction in the specific Czech conditions. Two conceptual designs of sustainable buildings for housing were analysed and compared with two reference buildings having identical use, approximately the same size and similar technical standard. These two conceptual designs of sustainable housing (URD – Sustainable Family House and UBD – Sustainable Apartment Building) were elaborated within the frame of the same research project, and are presented in the contribution "Verification of Principles of Sustainable Construction in two Housing Designs". The reference buildings (RD REF – Reference Family House and BD REF – Reference Apartment Building) are existing buildings designed and constructed within the last 3 years in the Czech region.

The problem of sustainability of buildings is very complex and includes a large number of parameters and criterions from different areas of technical as well as non-technical sciences. Sustainable construction should be based on the effort to (i) decrease exhausting of primary raw materials and energy, (ii) regulate consumption of renewable resources, (iii) decrease the amount of harmful emissions and wastes, while (iv) increasing the structure's serviceability, durability and reliability throughout its entire life. These goals should be achieved while keeping the total cost on a reasonable (minimum) level and social and cultural aspects at a feasible (maximum) quality.

The evaluation methodologies have to be complex, considering all relevant flows (material, energy and other) and covering the corresponding most important essential environmental criteria. However, the admissible simplifications of the model are usually needed. Taking into account the relatively high variance of available environmental data used in environmental impact evaluation, the implementation of the stochastic approach, including sensitivity and reliability analysis is usually necessary.

The evaluation methods and models should be preferably based on the following characteristics and essential qualities:

- complexity – the method should cover the most important environmental criterions,
- time dependency – the method should consider the whole life cycle (ISO 14040)
- probability - the evaluation method should respect the probability feature of the time dependent problem.

The environmental assessment model used in the case study was based on the above-specified principles considering common principles of ISO 14040 international standard. The following specific features of developed LCA model are:

- The total expected life of all analysed buildings was considered 80 years.
- Three predefined strategies (A, B, C) of repair and renovation phases within the life cycle of each analysed building were considered.
- Assessment criteria used:
  - Environmental criteria (associated with material use): weight of materials, embodied energy, embodied $CO_2$ and $SO_2$, material input (amount of renewable sources, use of recycled materials etc.), material output (amount of recyclable materials, waste etc.)
  - Environmental criteria (use of energy within utilisation phase: heating, DHW, cooling)
  - Other parameters (floor area, heated area, building size, number of occupants etc.).

The resulting outputs from environmental impact analysis cover absolute as well as relative comparisons of specific environmental parameters of designed sustainable houses (URD and UBD) and reference houses (RD REF and BD REF) form the point of view of several aspects:

- A comparison of total consumption of energy and total amount of $CO_2$ emissions considering different renovation strategies within the whole life cycle of the building.
- A comparison of total primary energy use for different heating systems within the whole life cycle of the building.
- A comparison of environmental impacts associated with the use of different structural materials in the construction phase (embodied values).

Comparative graphs (see poster or [1]) present achieved results and show potential of possible improvements of design, construction as well as utilisation of buildings for housing. Reference buildings were analysed in the same way as new sustainable designs. The values of particular criterions achieved from analysis of reference buildings have been set in this relative comparison to be 100 %. The percentage differences of environmental parameters associated with designed sustainable buildings represent a level of improvement of quality of assessed environmental parameters. The results show the high improvement potential of environmental parameters. However, this could be achieved only in the case of correct implementation of principles of sustainable construction and use of correct assessment methodology .

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# Concept of Guidelines for Sustainable Construction of Buildings

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During last years, the Czech Republic has adopted all basic international documents concerning global problems of sustainable development. According to the World Summit on Sustainable Development Declaration (Johannesburg 2002), the Czech Republic within the State Environmental Policy reflects the interest to (i) implement the principles of sustainable development, (ii) improve the effectiveness of codes and component legislation in different areas and (iii) adopt new measures to strengthen institutional arrangements for sustainable development at national and regional level. The importance of legal instruments is increased as a result of the intention of the Czech Republic to accede to the EU.

The preparation of Guidelines for Sustainable Constructions has been motivated by the effort to reflect and incorporate specific aspects of sustainable development in the field of building industry: to incorporate them into basic principles of building's design, construction and operation.

Guidelines should create finally an well-arranged assessment methodology of building's sustainable performance. It should serve not only as a matter of the assessment and comparison of final results (buildings), but particularly as a helping aid applicable during different stages of construction projects, especially in optimisation measures (the selection of optimum variants - e.g. different technical or technological solutions). It should introduce integrated principles of sustainable construction into decision-making processes and to apply them in overall extend of the building's live-cycle.

Actually several European countries are working on their national Guidelines for Sustainable Construction. The methodology of the assessment of environmental impacts and potential consequences connected with building's existence is generally based on their live-cycle assessment (LCA) according to the set of European codes EN ISO 14000 in accordance with recommendations of OECD and IEA Policy Instruments for environmentally sustainable buildings.

The main principles leading to sustainable construction are based particularly on:

- fulfilment of functional requirements,
- minimisation of environmental impacts,
- minimisation of material's consumption, particularly non-renewable,
- minimisation of energy consumption, particularly non-renewable,
- indoor quality ensurance,
- social and cultural aspects consideration,
- economic efficiency,

All these aspects have to be respected during the entire live cycle of the building.

The Guidelines will serve to investors, owners, developers, designers, users, real estate organisations, facility managers, state and local administration dealing with building's design,

construction, operation, use, maintenance and finally demolition. In the initial phase of their implementation, the application of Guidelines on public projects is expected. Furthermore, the incorporation into General Technical Requirements as a part of Building Code is possible. The document will contain:

- definition of objectives and assessment extend,
- appropriate analysis and assessment,
- result's interpretation.

The formulation of sustainability requirements in the form of the specific set of aspects and parameters, their classification, as well as the determination of their weight factors belong among first-rate tasks.

The basic structure of expected categories of parameters has been proposed in the concept as follows:

1. Functionality (space organisation; flexibility; adaptability; suitability of standard; simple use, maintenance, control and manageability of subsystems).
2. Consumption of resources (land utilisation; consumption of non-renewable, renewable and recycled materials, demountability and recyclability; durability, serviceability of materials and elements; consumption of non-renewable and renewable energy; consumption of drinking water; use of surface and foul water).
3. Environmental impacts (harmful emissions; waste production; embodied $CO_2$ and $SO_2$ ; transport impacts; local impacts).
4. Indoor comfort (air quality, thermal comfort; moisture control; daylighting, sunlight accessibility, acoustic comfort).
5. Social and cultural aspects (safety; protection against vandalism; social integration; crime prevention).
6. Economic effectiveness (reduction of operational and utilisation costs; economic efficiency of all steps; economic adequacy).

The methodology has to be completed by specific databases of technical and economic properties and indicators.

The implementation of fundamental principles of sustainable construction to all activities connected with the realisation of building projects (with regard to the planning, design, construction and operation of all types of buildings) has to respect particular rules and regulations. Their objectivity enables to compare similar solutions with the aim to select the optimum-ones, which can guarantee the minimum possible damages to the natural environment.

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# Technologies of Roof Extensions on Prefabs

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According to the last published results of census of the people, houses and flats, which was executed in March 1991, there were permanently inhabited 3 706 000 flats in the Czech Republic. From this number were 2 150 000 flats in dwelling houses. From the total number of flats there are 1 165 000 in prefabs (i.e. 31,4 % from the total housing fund). During the years 1953 – 1990 there was constructed totally 62 456 prefabricated houses in the Czech Republic, the most in 1966 – 1975. After the year 1975 the scope of the new construction decreased and new buildings showed better quality. No dout that it was related with higher level of knowledge, actualisation, stricting of norms and regulations in response to discovered faults. Gradually there was approved, declared and used 14 fundamental construction systems, followed by material and district options. Prefab´s construction is just loosing its moral service life and it is unescapably approaching time, when physical service life will be exhausted. For keeping of this housing fund and prolongation of its service life systemal and complex approach to design and executing of regeneration is essential. Actual social requirement is a prefab´s regeneration and extension and prolongation of theirs service life for about 30 – 50 years.

The choice of a topic is qualified by growing need to systematic and deep study the issue of existing construction fund, which was performed in prefab technology. But not only from the constructional point of view but also technological, economic and architectural. Specific possibility of prefab object´s regeneration is a decision about establishing of a roof extension. This solution infuences the regeneration´s result from the utility and architectonic point of view. Performance of this kind of construction should be according to a unification and financial possibilities subjected to a qualified selection of suitable technologies. These technologies finally decide about quality and exerted charges of performance. Condition of quality execution of object´s regeneration together with the extension is so just the selection of optimal technics and their jointing into a production process and flexibal possibility of frution´s managing according to specific build´s conditions. Bringing the collection off these processes in harmony with actual requirements to the buildings of this kind means to take a lot of disparate information and influences , which complicate and also different from classical construction process. Construction intention of this kind is just following with many conditons and defects of extending building. It is also a problem of the infuence of construction action to the condition of all object. Selected technological processes and their jointing decide about keeping or improvement of technical values of extending object. It also affects surrounding, enviroment and wider social relationships which are connected with the extending building. In case of neglecting or postponing the regeneration of this fund there is a possibility of growing number breakdowns and also significant change of social structure of inhabitants. Aggravation of dwelling enviroment often means leaving of midle layers of inhabitants consecutive aggravating of social relationships. Housing estates so can be places of concentration of possesional lawest inhabitants, unemployeds and otherwise social handicaped people. We must

admit, that this process is just slowing because of a lack of the new dwelling construction. In case of such dilapidated approach to the problematic of the prefabs, there comes up to strip down such object.

The main idea is cost-effectiveness of intention of extension´s executing, when the price for unit of floor area according to falling costs off for making house connections, groundworks and foundations is cheaply and moving lower that at new construction. Another significant element of savings and rational step of many investors is supposed connection and also reducing of execution potencial of building´s supplier.According to exceed life cycle we expect rekonstruction of the most exposed constructional parts such prefab´s object, or its modification to fulfill actuall norm and society requirements. The most suitable is to do statical secure, thermal insulation of cladding, change of fittings, filling of openings etc. If we are talking about suitability of executing of roof extensions and regeneration, we mean mainly using of complex of construction site and mechanization at the same time. It should not be forget aspect of loading of the surrounding by construction. The performance of regeneration of such object namely must be performed in time of full using the object and its surrounding.

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# Cleaning of Facades with a View to Graffity Removing

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**A list of the most widespread materials of signs in our market-place**

The graffity durability (especially the removal resistance) is influenced by the used type of the material of the colour and the basis material as well. Among types of materials used for graffity making there are common chalk, fat chalk, pencils, pens, different types of markers and some kinds of colours (oil, nitro-cellulose, acrylic, alkyd) aplicated with brushes or in aerosol sprays. There is also a special group of scraped and carved signs.

Presently **sprays** are the most widespread agents for making sings on walls, columns, pavings etc. They can be used on any surfaces and even on very indented reliefs. The colour intensity and the line width depends on the distance of the spray from the surface. A wide scale of colours which is these days in the form of sprays in the market provides „sprayers" with a big option ( as far as the shade, hiding power, shine, fluorescence etc. are concerned ).

Colours in sprays generally contain a solid pigment as a chromatic component or inert carrier coloured with a suitable colour. This usually prevents the colour component from leakage into the material structure and thus makes sign removing easier. Sign liquidation usually consists of colour vehicle dissolving and its consequential wipe or washing-off. But it is important to realize that some colour vehicles dry out. It means that they react with air oxygen and their solubility decreases with time. The speed of drying also depends on the temperature. The higher the faster. That is why it is important to remove signs as soon as possible.

**Hit Colour Decospray**

Contains acetone, propane, butane and irritates eyes. It does not contain freons or heavy metals. Used for objects made of wood, metal, stone, glass and plastic.

Dry for powdering after c. 20 min, completely dry after c. 12 hours.

**Special RAL – Lackspray**

Contains acetone, propane, butane and irritates eyes. It does not contain freons or heavy metals. Used for objects made of wood, metal, stone, glass and plastic.

Dry for powdering after c. 20 min, completely dry after c. 12 hours.

**Prima RAL**

Universal use on metal, wood, ceramics, stone, concrete, glass, plastics. Wind, petrol, oil resistant. Can be used for interiors as well as exteriors. Dry for powdering after c. 20 min, completely dry after c. 12 hours. Contains butane, extremely flammable, irritates eyes.

**Aerosol art colours**

**Montana cans**

Special quick-drying colour, for use both in interiors and exteriors. Extremely flammable.

**Markers** ( felt tip marker ) are favourite especially for writing on smooth surfaces of different materials. Due to their construction they are difficult to use on rough surfaces. Markers fillings usually contain organic paint dissolved in a suitable organic dissolvent. Paints of markers have generally small covering ability so the original structure under signs remains rather distinct.But the paint lotion can leak into the material before the dissolvent evaporates. Colour dissolvability is used for their removing. Use of organic dissolvents for cleaning often causes leaking of the colour into the cleaned material and that of course makes cleaning harder.

**Hardcore L-marker**
**Aerosol art bombing marker**
**Edding 390 permanent marker**

**Chalk** belongs among the oldest writing materials. It is easily removable from most surfaces. It does not affect the basis, it is easy to wipe and can be easily washed-off with cold water. Fat chalks ( cryon wax ), contain certain amount of wax ( or vaseline or oil ) which is water-repellent, but generally dissolves in organic non-polar dissolvents ( petrol, toluene ).

**Paintings:** Before sprays were discovered paintings made with brushes were used more often than they are today. Today brushes are used just exceptionally in remote places where a sprayer has enough time. The character of paints is similar to those used in sprays.

**Surface character**

A significant influence on signs durability has even the surface character.To a certain extent it designates the choice of an instrument which the painting will be made with and markedly influences possibilities of cleaning. Rough or incoherent surface limits e.g. the use of instruments ( chalk, pencils, markers ), which must be in contact with it. If they are used, however, hollows in the surface are not usually painted at all or just little. Unfortunately cleaning of such surfaces is more difficult as well. They are uneasy to wipe, the material of tampons gets caught in juts etc. On the contrary smooth surface are easier to wipe or wash but more instruments can be used for creation of paintings (especially markers and fat chalk )

**The methods of graffity removal**

There are mechanical and chemical methods.

**Antigraffity paints requirements in conservationists' point of view:**

- preservation of the original appearence of the surface, preservation of steam permeability easy application, long-term durability and function, easy graffity removability, removability of antigraffity paint

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# Control of the Water Treatment Process with Neural Networks

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Water treatment process represents a very complex non-linear system with plenty of input and output parameters which are mutually interconnected by links. It was shown that numerical modelling of the coagulation, flocculation, and sedimentation processes based on the solving governing partial differential equations can be ineffective and it has slow control response. Recently, neural networks were successfully applied to approximate complex non-linear processes. The study is aimed to design the neural control system of the water treatment process based on the modern control theory [2]. Neural networks have the ability to fix basic rules covered in the data during the training period and this knowledge is consequently used to control the system during a real operation [3].

The neural modelling approach does not require a description of how the processes occur in either the micro or macro environments, only knowledge of important factors that govern the process. Our research is aimed not only to develop the reliable simulation model of the coagulation, flocculation, and sedimentation process, but we are interested in a mathematical model of the control system. The simulation model of the treatment process is then integrated into a process control architecture. In our study we are dealt with the concept of a neural network as a simulation model in the internal model control (IMC) strategy [1]. Our project is focused to study the ability of neural networks to control the water treatment plant.

Internal model based control system (IMC) consists of three main parts. Firstly, it is a process (simulation) model which produces the forecast of the behaviour of the system in the future. Secondly, it is the control system which is the inverted process model and it is used to produce the control action. Finally, there is included a filter to control the feedback link into the control model and to pre-process data. The first major consideration is the length of the overall process time. As mentioned previously, the coagulation-flocculation-sedimentation process is a continuous and lengthy process (4 h on average), and the intermediate state of the process is difficult to assess. This consideration leads to the conclusion that the feedback link to the control system is at the current time out-of date, and it is thus optional.

IMC strategy is modify to control the water treatment process [4], and it can be explained as follows. The first part of the system is represented by the neural network which is used as a simulation (process) model. The simulation model uses these inputs: raw water colour, turbidity, raw water pH, $KNK_{4,5}$ (compared with the immediate preceding sample), alum dosage, PAC dosage, and the clarifier overflow rate. The only output is the effluent turbidity of the clarifier. With the use of a set of input quality parameters, intended alum and PAC dosages, the process model is able to predict the effluent turbidity under the given scenario of control.

The control model works in a reverse way and it is based on neural network too. The input and output parameters for the control model are the same group as that of the simulation model, except that the effluent turbidity becomes an input parameter and the alum dosage becomes output parameter. The control model uses as inputs also the PAC dosage, required

effluent turbidity (limit value), and it generates the needed alum dosage to satisfy the required turbidity in the clarifier.

There are a significant difference between the simulation and the control neural network model. While the simulation model is trained to be able to predict the effluent turbidity in any operation situation, the control model should be trained on the right operation situations only. The reason is that the control model should in the real operation provide right regulation actions only. To settle a proper performance of the ICM a noise filter is added between the simulation and control model. This filter has two basic functions:

- it should evaluate if the predicted effluent turbidity computed by simulation model fits the limit value (operation standard),
- it should be able to evaluate if the feedback information will be proceed to the control model or not.

The ICM system is based on the iterative process when the proper alum dosage is determined as follows. Firstly, the initial guess of the alum dosage $Al_1$ should be done. This dosage can be initialized by the previous value. Then the initial alum dosage with other inputs (temperature, raw pH, PAC dosage, $KNK_{4,5}$ ) are proceeded to the simulation model and the predicted effluent turbidity $ET_1$ is evaluated. If $ET_1$ is higher than the limit value the new initial guess of the alum dosage should be done. Then the predicted effluent turbidity $ET_1$ with other inputs are proceeded to the control model which generates predicted alum dosage $Al_2$. Ideally, if the inverse model is perfect, then $Al_1 = Al_2$. However, the simulation model and the control model are built with differences. Thus, numerically there could be a difference between $Al_1$ and $Al_2$. The next step is to adjust the alum dosage $Al_1$ to optimize this difference to a minimum. This problem can be solved by standard optimization procedures based on mathematical programming.

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# Data Mining Methods in the Field of Waste Water Treatment

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During last decennary the research in the field of waste water treatment is preferentially aimed on the control of the treatment plants and on the optimization of their operation. The reason is that the waste water treatment control significantly impacts the efficiency of the treatment process and its economics. A complex character of particular processes performed in a treatment plant, absence of suitable process models, large variance of inflows and a limited flexibility of the design of treatment plants prove that current technologies are not used efficiently enough. Generally spoken, it can be emphasised that to reach a higher efficiency of the treatment processes there are another approaches needed except a direct application of the control theory.

This study deals with the use of Data Mining methods, which are also known as Knowledge Discovery in Databases. Data mining methods is a group of computational approaches which allows to the user to discover mutual relations among data. Data mining methods are divided into classical statistical approaches as regressive analysis, factor analysis, analysis of principal components, spectral analysis and cluster analysis. Second group of data mining methods is represented by approaches from the area of machine learning and artificial intelligence. The study uses neural networks to control the Nebušice water treatment plant, which was chosen as a case study, and it provides a methodological approach of an application of the expert system, genetic algorithms and fuzzy control. This paper continues on the grant research NAZV No. QC0244 "Comprehensive approach to designing reconstructions and modernizing of wastewater treatment plants".

Measured data from the wastewater treatment plant of Nebušice contains following factors: raw water pH, suspended solids, raw water COD and output COD, dissolved oxygen and temperature. Most of these factors were measured with the constant time period, which is a good assumption to consider the process dynamics.

In the process of data mining there exist several methodologies which are able to consequently prepare data, analyse data and to use data in the decision making process (control). One of them is the CRISP-DM methodology [1,2] (Cross-Industry Standard Process for Data Mining). This methodology consists of follows phases:

- First phase is oriented on *comprehension of the studied problem*. During this phase it is necessary to clearly formulate problem from system point of view and to define goals which should be reached.
- Second phase represents *comprehension of data and their collection*. During this phase only the relevant and reliable data are collected. It means such a data which have direct relation to the goals defined previously.
- During the phase of *data preparation* it is necessary to rearrange the data to their direct use by data mining methods. Preprocessing of the data is represented typically by data sampling on calibration and validation data sets, data standardization and normalization.

- In the phase of modelling the data mining methods are implemented on the prepared data sets. It is obviously recommended to perform more of these methods and finally use this one which fits the data best.

With the use of data mining methods there were identified significant relations among the data from the Nebušice wastewater treatment plant. These relations can be consequently used to control treatment process more efficiently.

Expert systems are special algorithms which are performed on computers and which are capable to solve complex problems from a special area. They differ from traditional programs in plenty of aspects. Expert systems deal with the use of experience of real experts in the form of heuristics [3], instead of mathematical modelling of antecedents and consequents. A basic assumption is that experts are able to effectively control in conditions of data absence.

Sanchez et al. [4] studied architecture of the integrated expert system to control a wastewater treatment plant. His approach includes design of knowledge base and data base. This expert system consists of several integrated sub-systems which are classified into three levels: data base, knowledge base and control level. Knowledge is obtained by asking of experts, operators and from literature. In our study we have dealt with application of expert system to control the wastewater treatment plant of Nebušice.

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# Hydrodynamics and Water Quality Modelling in a Reservoir

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Recently, questions of water quality modelling have arisen. These problems have become very important in the field of water management. Reliable knowledge of the water quality distribution in a reservoir is significant especially in the case of water-supply reservoirs, but it plays important role to perform other environment functions of reservoirs. This contribution deals with mathematical modelling of hydrodynamics and water quality parameters in reservoirs. Mathematical concept of the used approach is based on a laterally averaged two-dimensional water quality and hydrodynamic model. To accomplish an application the CE-QUAL-W2 model [1] was used.

To perform water-supply reservoir efficiently it is very important to choose a proper water withdrawal elevation, where the water quality is best. The water treatment process is consequently economical. Mentioned problems were mostly accomplished empirically without the use of water quality mathematical models. According to Pitter [3] there is not suitable to perform water-supply intake from the bottom layer of the reservoir, because the water quality is often radically worse than in the top layer. However, there is not suitable to intake water from the top layer during the growing season as the algal bloom increases. Questions of water-supply withdrawal and water quality forecasting in reservoirs studied Zelinka [4], who formulated several recommendations. However, these results are entirely based on empirical experiences and he did not use methodology of mathematical water quality modelling.

Modelling of hydrodynamics and water quality is based on numerical solving of governing equations [2], which are obtained by performing a mass and a momentum balance. Continuity equation:

$$\frac{\partial u_x}{\partial x}+\frac{\partial u_y}{\partial y}+\frac{\partial u_z}{\partial z}=0$$

where $u_x$, $u_y$, $u_z$ are the velocities in the x, y, and z axes, respectively. Momentum Navier-Stokes equations get after time averaging of the velocities the shape:

$$\frac{\partial u_x}{\partial t}+u_x\frac{\partial u_x}{\partial x}+u_y\frac{\partial u_x}{\partial y}+u_z\frac{\partial u_x}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{\mu}{\rho}\left(\frac{\partial^2 u_x}{\partial x^2}+\frac{\partial^2 u_x}{\partial y^2}+\frac{\partial^2 u_x}{\partial z^2}\right)+\frac{1}{\rho}\left(\frac{\partial \tau_{xx}}{\partial x}+\frac{\partial \tau_{xy}}{\partial y}+\frac{\partial \tau_{xz}}{\partial z}\right)$$

$$\frac{\partial u_y}{\partial t}+u_x\frac{\partial u_y}{\partial x}+u_y\frac{\partial u_y}{\partial y}+u_z\frac{\partial u_y}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\frac{\mu}{\rho}\left(\frac{\partial^2 u_y}{\partial x^2}+\frac{\partial^2 u_y}{\partial y^2}+\frac{\partial^2 u_y}{\partial z^2}\right)+\frac{1}{\rho}\left(\frac{\partial \tau_{yx}}{\partial x}+\frac{\partial \tau_{yy}}{\partial y}+\frac{\partial \tau_{yz}}{\partial z}\right)$$

$$\frac{\partial u_z}{\partial t} + u_x \frac{\partial u_z}{\partial x} + u_y \frac{\partial u_z}{\partial y} + u_z \frac{\partial u_z}{\partial z} = -g - \frac{1}{\rho}\frac{\partial p}{\partial z} + \frac{\mu}{\rho}\left(\frac{\partial^2 u_z}{\partial x^2} + \frac{\partial^2 u_z}{\partial y^2} + \frac{\partial^2 u_z}{\partial z^2}\right) + \frac{1}{\rho}\left(\frac{\partial \tau_{zx}}{\partial x} + \frac{\partial \tau_{zy}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right)$$

where $\mu$ is dynamic viscosity, and $\tau_{ij}$ are turbulent shear stresses. It was shown that the Coriolis effect can be eliminated with respect to the coordinate system. Governing equations can be further simplified by lateral averaging in the direction of y-axes.

Thermal regime in the reservoir is described by Furier-Kirchhoff equation:

$$\frac{\partial \tau}{\partial t} + u_x \frac{\partial \tau}{\partial x} + u_y \frac{\partial \tau}{\partial y} + u_z \frac{\partial \tau}{\partial z} = a\left(\frac{\partial^2 \tau}{\partial x^2} + \frac{\partial^2 \tau}{\partial y^2} + \frac{\partial^2 \tau}{\partial z^2}\right)$$

$$a = \frac{\lambda}{c\rho}$$

where $\tau$ is temperature, $\lambda$ is thermal conductivity, and $c$ is the specific heat of water.

As a case study to model hydrodynamics and water quality the Římov reservoir on the Malše river was chosen. We modelled all the hydrodynamic parameters (velocities, temperature, viscosity, density) and following water quality parameters: suspended solids, ortho-phosphorus, ammonia, nitrate and nitrite, organic matter, algae, and dissolved oxygen.

Results have shown that modelling of hydrodynamics and water quality in a reservoir can provide very useful information to improve water quality control, and to perform a water treatment plant more effectively. Finally, the water quality modelling has capacity to improve the environmental function of reservoirs.

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# Risk Modified Dynamic Model Creation

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The Modified Dynamic Model is model based on a matrix structure. The method which calculates the results in the future is Modified KSIM [1] [2]. General KSIM method is not able to use:

a) Managers influences
b) Interventions of interactions
c) Influences of the risks

With using the risk interactions we can inquire the stability of model structure. The results of the model calculation without the risk have most often no dramatic changes. The results with the risk interactions have the local changes of trends or changes of trends in interval with risk attack.

Economics requires a description of universal attributes on one hand and changes its involvements and objectives in time to the other. In its nature it is the technical piece of work that creates long-term sustainable values of economic live-cycle of every region, enterprise and city.

An economic tribulation needs for technical, managerial or technological reasoning a broader definition of components (elemental activities, processes, etc.), then further ability to define theses on the unified (descriptive) procedure base of a standard model. The whole range of economic problems defines its processes (elements) simultaneously with a solution method of the given task. The solution and the chosen definition of the problem create (generate) in economic applications a balanced facet

Among the first class model we will place in models changing *goal objective* value of process **P** by means of selected parameter $x_i$.

$$M_{\text{goal oriented}} = \left\{ \begin{matrix} \boldsymbol{P} & (x_1, x_2, \ldots, x_n) \\ \textbf{goal} & \left| x_i \right. \end{matrix} \right\}. \tag{1a}$$

The second model types for creation of steering intervention for management are models, based on simulations and parameterisation of calculations of changes in particular input values. Simulation is universally oriented to the behaviour pattern from out standpoints of parameter changes, describing process **P**

$$M_{\text{simultion of steering interventions}} = \left\{ \begin{matrix} \boldsymbol{P} & (x_1, x_2, \ldots, x_n) \\ \textbf{sim} & \left| (x_i \leftrightarrow (a,b), x_j \leftrightarrow (c,d), \ldots) \right. \end{matrix} \right\}. \tag{1b}$$

The third class of models description engages models with scenarios as a starting point for steering interventions calculation. Under steering scenarios we will understand in time and space developed sequence, realized on the basis of a process **P**, will be written down as

$$M_{\text{scenario of steering interventions}} = \left\{ \begin{array}{c} \boldsymbol{P} \quad (x_1, x_2, \ldots, x_n) \\ \hline \mathbf{scen_1}(a \to x_i, b \to x_j, \ldots) \\ \hline \mathbf{scen_2}(c \to x_i, d \to x_j, \ldots) \\ \hline \mathbf{scen_3}(e \to x_i, f \to x_j, \ldots) \end{array} \right\}. \tag{1c}$$

The fourth model class will be models using optimisation as supporting technique. By virtue of optimisation function $\mathbf{g}(\cdot)$ for optimal arguments $\mathbf{x}$ are searched, accomplishment of steering management intervention restricted on process $\mathbf{P}$ might be written down as

$$M_{\text{optisation of steering interventions}} = \left\{ \begin{array}{c} \mathbf{P}(\bullet) \\ \hline optim\_\mathbf{g}(\bullet) \end{array} \right\}. \tag{1d}$$

The risk parameters in interactions create feasible area between the best and the worst solution of the model element. In this area there will be a real progress of the model standard. In this time, there are random numbers in the MDM with two distributions – uniform and normal. The system is opened and it is possible to add the next missing type of a random number distribution. The risk interactions are set to the model by means of dialogs, where the modeler can determine a position for the risk attack. The position is exactly determined by the index of the row and column in interaction matrix $\boldsymbol{A}$. A very important is the information about time interval in which the risk interaction is active – in which is the model under the risk attack. After the risk attack it could be possible that the trend of the model element is different from the interval with the risk influence. After ending time of risk interval there are some trends identical with the risk attack and some trends are absolutely different.

The MDM simulation software [2] is able to satisfy even complicated and ambitious demands and sophisticated requirements. In the chapter 12 [2] are worked an aplicated examples, which show using of the MDM for practical cases. There is an example for regional development, production process etc. The calculations in MDM with the risk interactions can describe the unsuitability in the model structure and the modeler is able to design useful changes or external interventions.

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# Temperature Fields Measurement in Road Bridge Barikádníků in Prague

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The aim of the measurements was to collect data on the real fluctuation of temperature fields and maximum temperature gradients in a large bridge structure in the Czech Republic during different year seasons.

The composite steel and concrete bridge structure carries six lanes of the main Prague road over the Vltava River. The structure rests on old, reconstructed piers, and each traffic direction is carried by a separate bridge. Transversally, the bridge consists of two steel boxes connected with a reinforced concrete deck with cantilevers.

Longitudinally, the bridge makes a continuous beam with four spans of 46.40 + 51.75 + 46.40 m. The bridge is straight in spans 1 and 2, but in spans 3 and 4 it makes a direction curve .

Span 1 of the bridge is situated over accessible terrain (railway siding area), the other spans are located over the river. The inspection facility was designed in the form of footbridges. Maintenance of the remaining parts of the bridge was assumed to be performed from vessels anchored in the river.

The applied measuring methods involved temperature measurement with resistance platinum sensors. These methods were selected because resistance sensors have a long-term stability of electrical parameters and achieve a relatively high measurement accuracy. These measurement methods are, at the same time, suitable for measuring of large or far-away structures, using electronic, manual, or automatically controlled systems.

As this measurement was conducted on a composite steel and concrete structure, two types of temperature sensors had to be developed. Based on commercially available resistance sensors MT 100, the following devices were constructed:

- contact sensors for temperature measurement of steel structures
- probes for temperature measurement inside a concrete deck.

The basic demand on the construction of the contact sensor was to achieve the best possible heat transfer between the sensor and the measured structure (steel), while thermally insulating the sensor from the outside the environment. Therefore, the developed sensor had a

large contact area of 1260 $mm^2$ and heat transfer was increased even more by the use of silicon oil. The whole sensor was forced down to the steel structure mechanically with holders.

In order to achieve the highest possible measurement accuracy, all the sensors were individually calibrated in the laboratory.

For measurement of temperature gradients in the concrete deck, sensors with increased mechanical strength were developed. These could be placed in the concrete structure during the construction. During this measurement project, they were sited in holes drilled later in the concrete deck.

Such measurements of temperature fields of composite steel and concrete bridges have been performed by a number of researchers. The main benefit of the described experiment stems from the fact that it has been the first temperature measurement inside a bridge structure ever undertaken in the Czech Republic. The experiment helped researchers penetrate into the mass of the structure composed of steel and concrete. To use a precise formulation, the experiment involved measurement of temperature field gradients in the bridge structure cross section.

This project is being conducted with the participation of Ph.D. student Ing. Jan Pytel and undergraduate students Dana Borůvková and Jakub Římal.

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# Temperature Fields Measurement in Railway Bridge in Královské Poříčí

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In designing steel and concrete composite bridges (steel beam, reinforced concrete deck), engineers should consider potential non-uniform increase of temperature in the bridge cross section. The temperature increase results from different thermal conductivity and thickness of both materials, different sun exposure levels in both parts of the structure, and different conditions of temperature decrease due to the flowing air. Differences in temperature, which may vary greatly in individual bridges due to specific conditions, were assumed to be $15^0$C by the Czech Load Bridge Code. This value indicated to what extent the deck can be warmer (colder) than the steel beam. Temperature variations were very strongly idealized by being considered constant along the entire height of the beam and thickness of the deck. The situation when the steel beam is warmer than the concrete deck (which usually occurs on sunny afternoons when the beam is exposed to sunshine) is unfavourable for stresses in the reinforced concrete deck. It is due to the fact that tensile stresses from temperature add to tensions from concrete creep.

Since the demand stipulated by the Czech Load Bridge Code appeared to be too idealized, long-term measurements were conducted on one of the bridges in Královské Poříčí. The aims of the measurements included widening knowledge of real temperature distribution and, therefore, also stress in composite bridges. The measurements were also supposed to contribute to the improvement of the Czech Load Bridge Code ČSN 73 2089.

The bridge in Královské Poříčí has a continuous gravel bed. The load-bearing structure of the bridge is made by two major solid-web beams connected with a monolithic reinforced concrete deck 200-290 mm thick. The deck is coupled with the beams by means of stud connectors welded to the upper chord of the beams.

The applied measuring methods involved temperature measurement with resistance platinum sensors. These methods were selected because resistance sensors have a long-term stability of electrical parameters and achieve a relatively high measurement accuracy. These measurement methods are, at the same, time suitable for measuring of large or far-away structures, using electronic, manual, or automatically controlled systems.

Sensors inside the deck were placed in the concrete deck so that they could measure the temperature gradient of this deck.. In the layout, the holes made corners of a square with a side of 200 mm. The specially developed sensors were placed on the steel structure. In order to achieve the highest possible measurement accuracy, all the sensors were individually calibrated in the laboratory.

The applied measuring equipment facilitated objective recording of measured data in a digital format. At the same time, it helped to achieve a relatively high accuracy and reproducibility of measurement.

The temperature measurement was conducted on the bridge in Královské Poříčí in the summer and winter seasons. Although the measurement did not record the most unfavourable temperature fluctuations in the load-bearing steel-concrete section of the bridge, the measured values can be considered as values close to these extremes as the measurements were made during days with high temperature fluctuations under the direct sun exposure effects.

The measured values suggest that:

- the temperature fluctuation along the height of the section is general and does not correspond to simplified assumptions of most standards of that time for the design of steel and concrete composite bridges;
- the temperature fluctuation along the height of the concrete deck can be considered linear;
- the measured values do not correspond to theoretical calculations very much. The discrepancy can be explained by a significant impact of the gravel bed in insulating the upper surface of the concrete deck.

This project is being conducted with the participation of Ph.D. students Ing. Jan Pytel and Ing. Jana Zaoralová, and undergraduate student Jakub Římal.

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# Risk in Tunnels Assessed Using Bayesian Networks

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Tunnels and other underground structures are becoming indispensable engineering works in highly congested urban regions and other areas. Tunnel structures are however complicated engineering systems that may be exposed to rare hazard situations leading to unfavourable events with serious consequences (risks). Submitted contribution describes an attempt to assess and evaluate risks in tunnels that are presently being designed as a part of newly developing highway route in Prague area. Quantitative risk assessment is based on application of Bayesian networks supplemented by decision and utility nodes (influential diagram) as described in [1,2].

Random nodes of Bayesian networks (influential diagram) describe discrete states of main factors (design elements) of the tunnel system including transport intensity, hazards situations, fire start, fire flashover, smoke intensity and number of endangered persons. Decision nodes describe alternative arrangement of concerning tunnel length, distance of escaping exits, fire extinguish equipment, ventilation and information system. Utility nodes are used to describe social risk (injuries) and other damages caused by unfavourable events and cost of additional tunnel equipment. Causal links between nodes (including decision and utility nodes) are represented by arrays connecting appropriate causal (parents) and consequent (children) nodes.

Input data for each node consists of conditional probability distribution of chance nodes and data for the utility nodes. The pattern of the input data for children nodes depends on the states of relevant parent nodes. Required input data are based on available information from similar tunnel routes and on expert judgments. Analysis of the network indicates that the expected total risk is significantly dependent on the states of considered decisions nodes, in particular on the tunnel length in combination with fire distinguishing equipment, ventilation and information system.

An important question concerning risk assessment is a comparison of obtained results with acceptable limits. Criteria for social limits may be taken from available international standards (e.g. ISO 2394 General principles on reliability of structures) and literature [3]. It is important to note that the total risk may generally include economic as well as social and environmental consequences. To evaluate all unfavourable consequences it is necessary to express them in terms of one unit. This seems to be extremely difficult task. So called "Implied cost adverting fatality" *ICAF* is indicated in Table 1, which indicates that the cost of one life is estimated to about 1 to 3 millions of USD [4].

However data indicated in Table 1 are still a subject of ongoing investigations and should be considered as indicative values only. Moreover, a combination of economic and social risks may not be in some circumstances acceptable. Then both the social and economic risks (and possibly other risk components) should be assess and evaluated separately using independent criteria as indicated in [3] and [4].

Results obtained in this study enabled to assess tunnel safety using criteria recommended in [3,4]. In addition the results provide valuable background information used in final design of the route, particularly in design of escaping exits, ventilation and information system. However, in order to balance the total risk and relevant costs of mitigation measures,

further investigation of input data (conditional probabilities and consequences of unfavourable events) is required. It appears that Bayesian networks supplemented by decision and utility nodes provide an effective and transparent tool to analyse and assess risk of rare events in tunnels.

| Country | *g*- annual income | *e*- life time | 2 *w*- working part of e | ICAF(Δe) [$\times 10^6$] |
|---|---|---|---|---|
| US | 34000 | 77 | 0.15 | 2.6 |
| Japan | 26000 | 81 | 0.15 | 2.1 |
| Germany | 25000 | 77 | 0.125 | 1.9 |
| UK | 22000 | 77 | 0.125 | 1.7 |
| Czech Republic | 8000 | 75 | 0.15 | 0.6 |
| Mexico | 8800 | 72 | 0.15 | 0.6 |
| South Africa | 9100 | 55 | 0.15 | 0.5 |
| Colombia | 5900 | 70 | 0.15 | 0.4 |
| China | 3900 | 70 | 0.15 | 0.3 |
| India | 2400 | 63 | 0.15 | 0.1 |
| Nigeria | 800 | 47 | 0.18 | 0.04 |

*Table 1. The Implied Cost of Averting a Fatality – ICAF*(Δ*e*),financial data in PPP US$ (1999) obtained from UN-HDR 2001, Worldbank.

Available experience indicates that the Bayesian belief network provides transparent, logical and effective tool for analysing engineering systems. However, it should be underlined that any analysis of an engineering system is always dependent on input data, often of random nature. These data should be estimated with due regard to specific technological and economic conditions of a given system. In particular, economical, social and environmental consequences of adverse events should be analysed in detail. Nevertheless, obtained results proof to be very useful for improving design of newly developing tunnel in Prague area.

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# Probabilistic Modelling of Carbonation Depth

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Service life of a structure depends on many factors and uncertainties, some of them are difficult to be predicted and described. One of the adverse chemical factors endangering reliability of concrete structures is a carbonation of concrete cover. Carbonation may significant affect protection of reinforcement against corrosion.

Many models exist for the description of carbonation and its time-dependent impact to concrete structures. However, random properties of surrounding environment and material characteristic of concrete have a strong influence on resulting effects of carbonation and, consequently, it is not possible to predict fully carbonation effects on concrete structures.

The depth of carbonation may be represented by random fields varying in time and through the considered structure influenced by

– material characteristic of concrete (composition of concrete, type of cement, size and shape of coarse aggregate, pore system, cracks etc.);

– environmental properties (concentration of $CO_2$, relative humidity of surrounding atmosphere, influence of rain and of sol radiation etc.).

For the carbonation of concrete exposed to open air distinction should be made between concrete elements protected from rain and elements exposed to rain. The following model for carbonation depth is indicated in [1]

$$d(t) = A\, t^{0,5\text{-n}} \tag{1}$$

where $d(t)$ denotes carbonation depth [mm], $t$ time [years], $A$ carbonation coefficient [mm/year$^{0.5-n}$], $n$ is a parameter of climatic conditions, $n$ can be assumed to be 0 for indoor conditions and 0,3 for outdoor conditions. Relationship (1) is used as a basis for the derivation of the prior model of carbonation considering 31 cooling towers of power stations in the Czech Republic [2].

Available data indicates that the carbonation depth have a positive skewness $\alpha = 2w$. The gamma distribution Gamma $(\mu,\sigma)$ seems to be the most suitable as a prior distribution for the carbonation coefficient $A$. Both coefficient of variation $w$ and skewness $\alpha$ seem to be time dependent quantities that can be expressed as

$$w(t) = \alpha(t)/2 = 0{,}1\, t^{0,5} \tag{2}$$

The prior model of carbonation be refined taking into account evaluation of specific data obtained from tests.

Both the carbonation depth and the concrete cover seem to have a positive skewness $\alpha$. Several types of the probability distribution have been tested and the most suitable ones are indicated in [2]. If the skewness of carbonation depth or concrete cover is close to zero then the normal distribution, denoted N($\mu$, $\sigma$), or the beta distribution Beta($\mu$, $\sigma$, $a$, $b$) may be applied. An obvious disadvantage of the normal distribution is the occurrence of negative values. Then the beta distribution Beta($\mu$, $\sigma$, 0, 2 $\mu$ ) with the lower bound $a = 0$ and upper bound $b = 2\ \mu$ may be useful. The beta distribution with the lower bound $a = 0$ can be used when $\alpha < 2\ w$ (for $\alpha = 2\ w$ it becomes the gamma distribution Gamma($\mu$, $\sigma$)).

Probabilistic methods of structural reliability can be applied for analysis of a structure endangered by carbonation or other adverse environmental influences. The probability $p_f$ of the carbonation effects $E(\boldsymbol{X})$ randomly exceeding the structural resistance $R(\boldsymbol{X})$ can be assessed according to the following relationship

$$p_f = P\{(\xi_R R(\boldsymbol{X}) - \xi_E E(\boldsymbol{X})) < 0\}, \quad (3)$$

where $\boldsymbol{X}$ is a vector of basic variables, $\xi_R$ and $\xi_E$ are model uncertainties of resistance and action effects.

Thickness of concrete cover to reinforcement is an important factor controlling the carbonation progress. The greater the cover, the longer is the time interval before the reduction of pH factor achieve the critical value. Increasing quality of the concrete (mainly its low permeability) and the thickness of cover can positively influence durability of structure. Thus, current standards for structural design recommend a thickness of concrete cover for a lower strength of concrete and a lower thickness for higher strength. However, greater thickness of concrete cover increases weight of a structure and have negative impact to its overall cost and cracking of concrete. It is shown that methods of probabilistic optimisation provide a guidance for the specification of adequate requirements [3].

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# Study of Earth Heat Exchanger

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Earth heat exchanger is simple device for pre-cooling air in summer and pre-heating air in winter. Air is use for distribution energy in low energy houses. Earth heat exchanger is simple but effective. We use solar energy accumulated in earth surface.
The results are created in foreign countries but these models are connected with specific climatic region.

The measurement is important in comparison with results from mathematical models.
These results are not universal for all regions. We must consider else climate, microenvironmental and occupant request. Project targets are find out register behaviour during the year and determine his realistic energy contribution. By the help of gauging instrument we want recognize characteristics of register (first of all temperature) and surroundings and influence register on vegetation.
Construction of heat exchanger must be design from cheap and at the same time from durable materials. We usually use plastic piping or tube as a material pipeline register. The exchanger must have such a shape for facilitation of this service - primary it is easy cleaning. Supply line is facilities with by-pass. That is short way around the exchanger. We can use by-pass, when earth heat exchanger does not work or if we want mixture air from outside and from the exchanger. Plastic hermetical pipes with average 100 - 250 mm are most suitable place to the trench. The exchanger can be place below object to the trench, or near peripheral object wall. Pipeline is often stores to the depths 1.5 – 2.0 m. Optimum length of heat earth exchange is about 30 m. This dimension depends on air volume.
The exchanger is necessary construct tight because we need radon keep from air flowing in the pipeline system. It is impossible suck in incoming air below ground level by system from drainage piping. The risk of contamination of air is high here. Energy contribution of exchanger is necessary consider in accord to local conditions in places construction with using simulation tools. Entering value are characteristics of earth exchanger (dimension, situation), earth-characteristics, temperature conditions in site, relief, depth groundwater and influence over earth temperature.
Down slope must be design for secured outflow condensation water from pipe to the drainage. There is problem with bacteria and micro-organism in condensation water and thereby to devaluation input air. Near untimely relief and shallow storage drainage problem can be set in with conscription condensation water. This problem is even worse solvable, if object is not cellarage. It is also possible inform about possibility flowage of the exchanger by water if water level rise in drainage. The most suitable is solution when we utilize rooms below ground level. Good idea is create the exchanger with down slope to object and condensation removal to the common drainage in object. Low risk is with backward penetration water.

The exchanger can be formative solving like straight construction with declivity direction to source or like arrangement from some parallel pipeline. Pipeline wall must have good heat conductivity. Duration conduit must be optimal for enable warming-up air on required value and at the same time low-pressure losses.
The exchanger as device can operate only at that time, if energy losses of parts earth circumambient exchanger are constant offset by heat supply from surrounding earth. There is question where is optimal air volume, where is amount ventilation air so large that causes freeze through earth in surroundings exchanger and exchanger reaches the disturbance of his function. The exchanger is not able practically work after it. The by-pass repairs situation when the exchanger does not work for few days. That would however mean, that we will need equipment with antifreeze protection and that is reason why the system is already less favourable.

Our target is formed such conditions which eliminate failure. Practically that means that exchanger is able to work (in according with his average and depths storage) for object with air requirement to the 300 m3/h.

Earth heat exchanger makes local refrigeration earth at point storage. Straight and demonstrable influence on vegetation was not sighting, because the place of storage is usually a part of land, which is covered by grass.
The results are connected with outer climatic conditions and next findings will be formulated in next work.

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# The Application of Revised Universal Soil Loss Equation (RUSLE) for the Estimation of Erosion Risks in the Kamenice River Watershed

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Empirical prediction models serve as tools for determination of erosion risks in research area and design of erosion control there to decrease negative impacts of water erosion on soil. One of them – the Revised Universal Soil Loss Equation (RUSLE) model – was created in the USA in 60$^{th}$ of 20$^{th}$ century on the basis of early developed and till now widely used the Universal Soil Loss Equation (USLE) model. It is able to predict long-term annual average value of soil loss from runoff profile. The RUSLE model was adjusted in respect to recent research result in the field of erosion problems [3].

RUSLE is one of the most used empirical models for determining soil loss now. This program is able to determinate the values of soil transport from watershed either to the river or to the reservoir according to the factors which influence on erosion processes It is suitable for requirements of both scientific-research and engineering field. An advantage of this model is very simple, fast and purposeful computation of soil loss with possibility to use a big amount of input data that describe all factors influencing on erosion processes. The factors are: R factor of rainfall erosivity (it includes e.g. type of climate, intensity and total of precipitation), K factor of soil erodibility (it includes e.g. type of soil, texture, structure and infiltration ability of soil), LS factor of topography (it includes e.g. slope length and steepness), C factor of vegetation and management (it includes characteristics of vegetation cover, canopy cover, surface roughness, management in agricultural operations, etc.) and P factor of support practices (it includes characteristics of contouring, strip cropping, terracing, etc.). The big advantage of this program is that it contains a lot of data sets (databases) including important data about erosion and its factors for main areas in the USA. The calculation of soil loss is then very simplified. The databases are: CITY (with information about climate), CROP (with information about vegetation cover), and OPERATION (with information about cover management). For more information see [1], [3] and http://www.sedlab.olemiss.edu/RUSLE/.

Basic circumstance for model using is a presence of data files (databases) in program environment that create the basis for assessment of model inputs. A system of databases was already created for using the RUSLE program in the conditions of the USA. It is necessary to obtain corresponding databases for model applications in the area of the Czech Republic and to test them in selected locations. Up to now, the model was used by means of manually entered input data in the condition of the Czech Republic. The RUSLE model is full computed program working in DOS environment. The new RUSLE2 model version was developed in 2002 for using model in Windows environment (see http://bioengr.ag.utk.edu/rusle2/). RUSLE2, like RUSLE, predicts long-term, average-annual erosion by water for broad range of farming, conservation, mining, construction, and forestry uses. It is object-oriented, Windows interface allows dramatic scientific and graphical advances. RUSLE2 is derived from previous DOS RUSLE software based on the widely-used Revised Universal Soil Loss Equation (RUSLE) and can reuse much of the extensive data available for that model.

The RUSLE model application and verification is already processed during the working on dissertation thesis "Application of RUSLE for determination of erosion risk in the conditions of the Czech Republic". A research area was selected for this purpose in Kamenice watershed in southern Bohemia where all necessary input data were collected (in the framework of CTU grant No. 309902201 "The application of the Revised Universal Soil Loss Equation (RUSLE) for the estimation of erosion risk in the conditions of the Czech Republic") and an erosion risk was evaluated using the USLE model in the framework of GA CR project No. 103/96/1710 „Transport processes in the watershed-reservoir system "[2].

The main goal of this project was to continue applying the RUSLE model and to verify possibilities of its using for evaluation of erosion risks. During this project - working with the RUSLE program, the creating databases was finished, the computations were carried out for selected fields in Kamenice watershed, and the comparison was done between obtained results (specific soil loss values using RUSLE) and values from case study using USLE under the same conditions. The selected fields were tilled in the framework of rotational system of cropping and also as pastures. The results were obtained for three different time period corresponding to the different type of vegetation management.

Results:

- data files were created for the Kamenice watershed characteristics to fill database CITY, CROP and OPERATION, and transfer to RUSLE program environment to compute final soil loss values with respect to different conditions of climate, morphology, and crop and soil management in the USA and Czech republic,
- inserted databases were tested in research area, the computation to determinate specific soil loss in runoff profiles was done, and the results were compared,
- the methodology for creating databases is in process now,
- the problems and results of project were checked out with Prof. A. Klik from BOKU Vienna during his meting at CTU Prague in October 2002,
- results will be used in dissertation thesis, which is going to be defended in summer 2003.

The RUSLE program was found as very available tool for determining soil loss values on agricultural land. Its using is simple and purposeful. The results obtained in the framework of this project are satisfactory and do not show any fundamental deviation in comparison with erosion risk evaluation carried out by means of the USLE model.

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# Compression Tests of Masonry from Unburned Bricks, Mechanical Physical Properties of Unburned Bricks

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This part of the research project "Compression Tests of Masonry from Unburned Bricks, Mechanical Physical Properties of Unburned Bricks" is direct continuing to the research project „Dependence of Stability in Pressure of Unburned Bricks on Method of Stabilisation" which was processing in the year 2001 and is following in checking new materials and technological possibilities in building structures from the aspect of sustainable buildings.

Today's concept of low-energy buildings is connected especially with minimize of operating energy costs. From the aspect of the real environmental effect is it only a part of the evaluation. If we are talking about ecological architecture we are talking not only about low energy houses but also about **sustainable buildings** [1]. We are monitoring not only minimize of operating energy cost, but possibilities of material recycling, of using renewable materials, minimize of using unrenewable materials, energy costs by production of materials using by structural constructions and so on. The environmental problems in building construction have much wider context, not only technical but also social, cultural and economical.

Earthen structures offer in this context some solutions. In the middle of 90. moved this problem from the sphere of experimental building on lots of universities in Europe, USA, Australia and Africa. The most important centres in research of earthen constructions in Europe are in Germany at TU Kassel, TU Berlin, Bauhaus University Weimar, other places are in Austria, Switzerland, Denmark and France.

The goal of the project was answered the question about optimalization between prime energy used by pressing of the bricks and by producing of additives and between the benefit of pressure strength and to find out the impact of method of stabilization on pressure strength and other properties of unburned bricks. Last year was constructed the pressing form to produce the test samples of unburned bricks. The elements ware producing in Experimental Centre of CTU at The Faculty of Civil Engineering. There ware produced following test sets: 3 levels of pressing (2,0; 4,0; 8,0 MPa) for each of three ways of stabilization - without stabilising admixture (only by pressure), with lime 5% and with cement 5%. Together it was made **9 test sets**; each of the set had 6 samples. From each set were tested 5 samples for pressure strength and the last sample was tested for heat conductivity factor $\lambda$.

The basic mixture (the convenient basic materials and the ingredients and theirs relation) was defined by the approachable literature [3] and by the own experiments. The basic mixture is made from 80% of argillaceous gravel sand with maximal fraction 32 mm and 20% of clay. For activation connecting abilities of the clay is using 7% water for mixture without admixture and 11% water for mixture with lime or cement. The multitude of lime and cement is 5%. After the production ware the test samples ripened and drying up for 6 weeks. The experiments of pressure stabilisation ware made by using the ČSN 72 2605 „Experiments of ceramic products – mechanical dispositions". For the experiment the pressing sides ware covered by 3 mm gypsum milk.

The highest strength was by bricks stabilized by cement (7,92 MPa by the pressure 2,0 MPa, 8,12 MPa by the pressure 4,0 MPa and 10,17 MPa by 8,0 MPa). The strength of unburned bricks stabilized only by pressure was 5,52; 7,62; 9,22 MPa for each value of pressure and by bricks stabilized by lime ware the pressures the lowest (4,04; 4,48; 5,75 MPa). The reason of these low values by lime was short time for carbonisation and preclusion of air approach by pressure, which is necessary for carbonisation. From this values and theirs analysis result that from the point of view of pressure strength it seems to be more effective to use higher compacting pressure than to use the admixture like lime or cement. But it is necessary to appreciate, that the pressure strength is just only one of assessed properties of building structures. For the earthen constructions it more important their moisture and water resistance and from this point of view could these admixtures by very important. These experiments of moisture and water resistance are in progress now.

For each sample set ware setting values of heat conductivity factor. On each sample ware making 18 measures. The measures ware making by RNDr. Vítěslav Vydra, CSc., CTU, FCE, Department of physics. They are following values of heat conductivity factor of each sample set: for unburned bricks stabilized only by pressure 1,594 W/mK by the pressure 2,0 MPa, 1,677 W/mK by the pressure 4,0 MPa and 1,824 W/mK, for the bricks stabilised by lime 5% ware the values 1,147; 1,174; 1,238 W/mK and for the bricks stabilised by cement 5% ware the values 1,080; 1,151; 1,180 W/mK. These experiments should show approximative values of heat conductivity factor. The degradation of the values depends not on value of pressure but on way of stabilization. The sample stabilized by cement or lime with lower volume weight had better values of heat conductivity factor.

Finally we can say that it is possible safety use unburned bricks on load-bearing structures if we strictly preclude impact of humidity. Thermal resistance of earthen structures is more effective to provide by sandwich constructions with using thermal insulation. This is one of the first sets of experiments making with earthen structures. For wider application is necessary to make larger research.

In terms of this research project was in the beginning of October made short search in two floating villages round the town Mělník, which ware flowed in the September 2002. The goal of the research was to provide the range of earthen structures in historical parts of these villages. In the village Brozánky by Mělník was about 40% houses in the historical part of village broken. By all of this broken houses ware parts or whole constructions made by using earth. We expect that this technologies ware used by all houses build in the same time it means that the number of earthen structures in historical buildings in the country is much more wider.

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# Ecological Study in Water Reservoir Flaje Catchment

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The climatic conditions in the catchment of Flájský brook and Fláje reservoir were evaluated as a part of the work in the international project Huminstoffeinträge in Oberflächengewässer in co-operation with TU Dresden.

Catchment of water reservoir Flaje is situated in northern part of Czech republic near boundary with Germany. Main purpose of water reservoir Fláje is accumulation of water for drinking water supply, provision of minimum flow in profile Český Jiřetín, reduction of flood flows and particularly also protection of the territory under dam against floods. Other purpose is production of water energy. During the last decades there were changes in water quality and the negative impact of man activity on water quality increased. Humic substances increased in raw water and it had negative impact on drinking water quality.

Water quality parameters were evaluated in main tributaries to Flaje reservoir. Evaluation of the amount and quality of rainwater in this area is also presented in this paper. They were compared with water quality parameters of water taken from Flaje reservoir and raw water at Meziboří Water Treatment Plant.

**Climate**

In catchment of Flaje reservoir are precipitation stations Český Jiřetín-Fláje and Klíny and climatic station Nová Ves v Horách. We obtained data form period 1.1.1991 – 31.12.2001. Station Český Jiřetín-Fláje is situated 740 m above the sea level. Total precipitation amount for monitored period was 12 152 mm, which respond to mean annual precipitation amount 1105 mm. Station Klíny is situated 820 m above the sea level. Total precipitation amount for monitored period was 11 825 mm, which respond to mean annual precipitation amount 1075 mm. Climatic station Nová Ves v Horách is situated 725 m above sea level. Total precipitation amount for monitored period was 9477 mm, which respond to mean annual precipitation amount 861,5 mm. In climatic station Nová Ves v Horách there are measured air temperature, relative air humidity, and direction of wind, velocity of wind, daily sunshine duration and daily precipitation amounts.

If we compared measured data, we detect, than data from stations Český Jiřetín –Fláje and station Klíny are corresponding. Years 1992, 1995 and 1998 were richer in precipitation amounts. On the contrary, years 1991 and 1997 had small precipitation amounts. Highest monthly precipitation amount is in March and then during the summer (mainly in June and July). Smallest monthly precipitation amount is in April, October and January. As regards the maximum daily precipitation amounts in particular years, they occurred during the summer months in most cases and they were caused by storm rainfalls mainly during July and August. Maximum daily precipitations were measured at station Český Jiřetín in 2.8.1995 – 63,1 mm,

at station Klíny in 2.8.1995 – 64,8 mm and at station Nová Ves v Horách in 23.6.1992 – 64,8 61,4 mm.

**Precipitation and water quality**

We obtained measured data of depositions from stations Rudolice v Horách and Všechlapy from Czech hydro meteorological institute. The nearest climate station with measurement of depositions is station Rudolice v Horách, which is 8,5 km far from precipitation station Klíny and 18,6 km from precipitation station Český Jiřetín. We obtained month weighted average values from period 1996 – 2001. Measured parameters were: Amount of precipitation [mm], conductivity [µS/cm], pH, Na [mg/l], K [mg/l], $NH_4$ [mg/l], Mg [mg/l], Ca [mg/l], Mn [µg/l], Zn [µg/l], Pb [µg/l], Cd [µg/l], Ni [µg/l], Fe [mg/l], F [mg/l], Cl [mg/l], $NO_3$ [mg/l], $SO_4$ [mg/l].

Station Rudolice v Horách is located 840 m above the sea level. Parameters $SO_4$, F, Fe, Cd, Zn and conductivity have decreasing trend. Increasing trend is in parameters $NO_3$. Parameter $NH_4$ is without changes. Parameters Ni, Cl, Pb, Mn, Ca, K, and Na random fluctuate. There is low pH of precipitation – 4,5, which slowly increase.

Station Všechlapy is located 216 m above the sea level. Decreasing trend is in parameters $SO_4$, F, Fe, Zn and Mn. Increasing trend is in parameters pH, Na, Ca and Mg.

When we compare the stations, higher amount and concentration of pollution in precipitation at Všechlapy is evident. We assume that amount and concentration of pollution in precipitation decline with elevation above sea level. For catchment of reservoir Flaje values measured in station Rudolice v Horách are more representative.

Chemistry of surface waters is determined by interaction of rainfalls and geologic and biologic conditions in the area. It is influenced by pollution of air and environment. When we compare water quality in tributaries to Flaje reservoir, the highest mean values of UV absorbance, dissolved and total organic carbon and chemical oxygen demand has tributary Rašeliník. . It has also higher concentrations of Al and the lowest pH value. Low pH value and higher Al concentrations has also Flájský brook. Water quality in Flaje Reservoir deteriorates in chemical oxygen demand and humic substances.

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# Automated Measurements of Hydraulic Parameters of the Soils in Presence of the Preferential Flow Close to Saturation

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While variably saturated water flow is adequately described for homogenous soils, the prediction of water flow in highly heterogeneous soils, where preferential flow appears, could be questionable. When moisture increase to level of the saturation in these soils, large pores begin to fill with water and starts to conduct major portion of the flow. High velocities in fractures, or in local low-density regions causes that prerequisites of Richard's equation are not satisfied. These soils typically occur in areas of mountain's watersheds, which are the subject of particular interest due to their important role in water retention. Fast preferential flow also affects significantly the contaminant transport.

Powerful tool for preferential flow modeling seems to be dual-permeability models. The difficulty is still in lack of the experimental data suitable for the model validation for specific studied soil.

Laboratory infiltration-outflow experiment was proposed, to ensure the control of the boundary conditions. Large undisturbed soil samples, were used for experiments. Downward flow was introduced in soil core and inflow and outflow rates were measured. Disc infiltrometer was used to adjust boundary condition to different small suctions at the top of the sample. Seepage face was used as the bottom boundary condition. Tensiometers were installed to measure the suction pressure head in several heights. The design of the automated experimental apparatus and the test experiments results are described in [1].

To study the infiltration in detail, visualization of the water flow was suggested. Recent progress in using of magnetic resonance imaging (MRI) of soils [2], demonstrates the potential of this method in detection of the preferential flow. Because the source of the visible signal is the hydrogen protons in MRI, it is possible to detect the soil water directly without any tracer. On the other hand in soil only the signal in large pores is detectable, due to inconvenient magnetic resonance properties of soils.

To be able to perform imaging of running infiltration-outflow experiment, the second experimental set-up was designed to meet the specific requirements of MRI. As in case of original laboratory experiment, data acquisition system was installed to measure inflow, outflow and important pressures. The experiment was performed in the whole-body MRIS unit, which is based on a 2 Tesla, 100cm bore magnet and controlled by an upgraded Bruker MSL console. Custom knee gradient coil (G240) and the radio frequency probe (sine space) were used. The console style holder fixed the sample position without touching the probe inner surface, in order to minimize influence of probe vibrations to the sample. The infiltration disc allows both tension and pressure infiltrations using NYBOLT membrane. For ponding infiltration the membrane was removed and the disc was tightly fitted to the sample. To avoid interferences between electronics of the set-up and MRI unit, all pressure transducers had to be moved outside the Faraday cage, which is built around the magnet. Two types of pressure measurement were made; pressure transducer (15psi range), was used to record the capillary

pressure, and one pressure transducer (14" $H_2O$ range) was used to monitor pressure changes in infiltration disc. Ceramic tensiometer cup and the disc were connected to the pressure transducer with long thin non-compressible tubing. The spin-echo (SE) pulse sequence MR protocol was used for all types of imaging. Four different MR scanning techniques were performed, all of them based on the (SE) pulse sequence MR protocol. Fast vertical 2D imaging of transient infiltration and the drainage was done during the transient parts. When repeated, a sequence of images showed the propagating wetting front. During the steady parts of the experiments the multiple horizontal 2D imaging was done several times, across the whole volume of the sample. The measurement of longitudinal relaxation rate T1 contains even more information. This is mainly dependent on the size of pores. The T1 mapping was done both in horizontal and vertical direction, with the same resolution as was used for imaging.

The presented experiment is unique in a sense that it allows to trace the flowpathes during the classical infiltration-outflow process. Presented data is the result obtained during the apparatus testing, to prove the functionality of the system. At the moment the infiltration outflow experiment of the same set-up is repeated in the lab to check the possible bias of results due to influences related to the exposition to magnetic field changes.

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# Influence of Factors on Function of Excavator Working Tool

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The optimum utilisation of energy supplied to the excavator wheel rests upon the optimisation of mode parameters of breaking aimed at diminishing the energy demand of the mining process at keeping theoretical efficiency. With bucket wheel excavators, the mining process is subject, similarly to any process in the course of which rock breaking takes place, to general regularities influencing the final effect. Then, theoretical conclusions and practical results can be applied that have been verified in the operation of drilling units and tunnelling machines, in the course of which a considerable energy and thus also economic saving was made by the regulation of mode parameters of breaking. The solution proposed is based on the determination of basic dimensions of the cut mined, especially the width-depth ratio according to the criterion of minimum specific energy by volume.

The final effect of any mining process is achieving the maximum efficiency, which represents, in the case of exploitation by wheel excavators that are part of the equipment complex, efficiency by volume corresponding to the maximum utilisation of all machines included into the equipment complex. The theoretical efficiency of the excavator determining the theoretical volume amount of broken (loose) rock per unit time is a technical parameter of the machine and is directly proportional to the geometrical volume of the bucket and the number of bucket tips. The excavator is able to achieve this theoretical efficiency under optimal conditions of mining, but not in the whole bench under breaking, so that in these cases this efficiency can be regarded as a momentary value. The achievement of the maximum efficiency in the course of working one bench is a primary precondition for the effective mining process, and if digging resistances do not exceed the breaking ability of the wheel, the wheel excavator is able to achieve this maximum efficiency. In the opposite case, the volume of material broken is reduced, the machine is overloaded, the failure rate increases and operational reliability is worsened. The final effect of excavator efficiency is affected by many parameters that are not only technical, as can be seen in:

Wheel power input → Breaking ability of the wheel (wheel geometry, tooth and bucket geometry, blade and knife material) → Machine-rock interaction (digging resistances, mode parameters of breaking – effects of human factor) → Theoretical efficiency.

The efficiency of wheel excavators and energy demand of the mining process are directly proportional to *digging resistances*. This technological quantity expressing *machine – rock* interaction depends on the set of input quantities:

a) constants

- geological factors (rock) – they are expressed by a set of technical and petrographic properties.
- the other influences - they are a set of prevailingly non-influenceable factors, to which the stress state of solid mass, the moisture content, chemism and temperature of rocks belong.

b) variables
- technical factors – they are given by properties of the breaking tool that is determined by a breaking technology.
- technological factors – are determined by mode parameters (wheel rpm and the rate of turning the superstructure) that condition the shape and the size of the cut of rock under breaking. If the machine is not equipped with full automation, a human factor enters to the breaking process.

It follows from the analysis of the mentioned factors that merely the technological factors can offer possibilities of solving energy conditions in mining. The measure of efficiency of any breaking process is energy consumption related usually to the unit of volume of rock under breaking. This common viewpoint will be essential when evaluating, from the standpoint of energy, the mining process of bucket wheel excavators.

Thus, what is a decisive factor for economical mining is a human factor that at present influences the dimensions of the cut mined without objective information on the breaking process, and thus influences the efficiency and energy demand of mining. To eliminate a negative effect of the driver of the excavator, the installation of an information system is necessary. In virtue of the minimisation of specific energy by volume, the system will make it possible to determine needful dimensions of the cut, and thus will enable the optimum regulation of excavator efficiency; naturally, all above mentioned being in accordance with other control and protective elements of the excavator.

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# Opimalization of Maintenance Management of Housing Found

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There is a one third of value domestic possession in housing found. It is more than government has put to privatisation during the beginning of 90´s. According by results of the last census (1.3.2001) there are 4369 thousand apartments. 4.015.653 apartments have been permanently used and 2.303.697 have been located in blocks of flats. It means 57 per cent of permanently used apartments. So there were near two million buildings (1.970.774) involves three parts of it. 199.798 blocks of flats represent 9.9 per cent; share of 1.729.163 houses represents main part of government housing found, 87.9 expressed in per cent points. The rest of total figure is small 2.2 per cent and means weekend houses or something like that. There are 41.813 objects in this part.

Growth of housing found between 1970 and 1980 represented 565 thousand apartments. 797 thousands flats were built up during this time. A view of the last twenty years has shown increasing for 300 thousand apartments per decade.

A state is the result involved of many effects like an environment were the object is situated or purpose of using or quality of maintenance management.

We can divide age of the government housing found to three parts. One third of flats was built up before 1945 (27.2 per cent), a half was built up between 1946 and 1990 (65.6 per cent) and rest of it involves 7.2 % only and this part has been building up after 1990. More than half of it needs extensive repairs. On the top of many of them are near useless state.

What is purpose of this grant is to achieve haw to maintenance housing found better, to find up the way haw to build systematic manual for application repairs witch would be more efficient. We are founding for new tools for maintenance companies.

Systematic methodology would cover real state of the buildings and helps to start global monitoring all of parts objects as structures, technical equipment during whole life cycle assessment.

This tool only can guarantee that following repair or maintenance would keep use standards. If we do not get all information about state of all parts of buildings, we can not start using available procedures.

Useful access to information makes more efficient monitoring technical and moral state of objects. It help to manage repairs monitor costs make revisions look for suppliers, change structural components which are over.

The aim of mainenance system is processing of data about repairs and maintanence from 3 main area:

- Standard repairs – those, which need the start of remedies in short time and we can plan them in short time
- Preventive repairs – those, which we plan it for long time and they help to keep the building in good condition and help to protract life cycle assessment of buildings. They save investment for buing new components.
- Accidental repairs – those, which need immediate start of remedies, so that the next damages will not come or it could not treat health of occupants.

The basement for the best purpose of investment in maintenance of housing found is surgical knowledge about his construction-technical state. If we want to create tabular informatics' system that it will be possible to use for maintenance management of housing found we have to integrate the database.

1. For new buildings
   - Construction documents comprise building plans, construction permission for approval of building
   - Construction details of adjustment of finished building

2. For older building where the construction documents are not survive or the building documents are in insufficient state, there have to be do
   - Town-planning and architectural survey which sums up the building from view of wide relationships in the given agglomeration
   - Survey of environmental conditions following felicitous changes e.g. hydrological and geological
   - In-depth survey of structural and technological state of building

3. During all life cycle assessment of buildings
   - Overview of didn't finish repairs in building
   - Inspection report of technical equipment in building
   - Documents about realized repairs and building modifications
   - Documents about structural-technical state of individual structure components

Maintenance and next also regeneration and modernization of buildings is difficult. And from time view it is long-term matter. So there is necessary perfect structural-technological arrangement that assures the right utilization of financial recourses invested to all maintenance and it extends life cycle assessment of buildings. Global methodology of maintenance helps owners and maintenance companies of housing found with economical monitoring, it helps them to make plan of investment and better to determine basic charge of rent.

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# Technical solution of draining shaft manufacturing using special concrete and concreting design including a new mould

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The problems connected with the bottom of draining shafts include basically two serious technical problems to be fulfilled by the usage requirement, i.e. the aggressiveness of sewage to concrete and its erosive action. In principle, there are troughs and gutters shaped on the bottom of draining shafts that receive the main part of drained sewage. If the shafts get overfilled above guiding troughs, this is an exceptional case caused mostly by higher amounts of precipitation drained in the sewerage network, and in this case, contamination of common waste is diluted and therefore reduced.

This makes it clear that the technological problem of manufacturing draining shafts must be focused on the appropriate quality of namely troughs and gutters shaped on the bottom of shafts. In this sense, the highest possible production quality must be ensured. Unless special drainage wells for chemical products (acids, alkalis etc.) are concerned, draining shafts may be made of high-quality cement concrete, resistant to the aggressiveness of common sewage water.

The basic precondition for the production of this type of concrete is the quality of applied aggregates, where the decisive question is the quantity of unsuitable soft and absorptive grains found in quarried sands, namely feldspars, chalk, mica, arenaceous marl grains, various conglomerates, the quantity of particles to be washed away, humus content etc. A certain type of sewage aggressiveness also affects the used silicate binder, which should be cement with certain resistance, e.g. of CEM V. 42.5 R class. The amount of mix water must be minimized by using suitable liquefying admixtures or stabilizing agents.

The requirement for the parameters of cement concrete consists in ensuring its resistance to wear, achievable high volume density and related low absorptivity. By ensuring these parameters, the natural accompanying feature will be a relatively high strength.

With regard to the location of the plant manufacturing these shafts, run by the SKANSKA Prefa company, and the sites of aggregate quarries, the formula for cement concrete mix was designed.

Justification:

- the use of crushed basalt aggregates from Dobkovičky locality (grading: 4-8 and 8-16) is of high significance for lowering wear and increasing total durability
- the use of silica fume fly ash will contribute to improved workability of green concrete and will enhance the surface structure of finished concrete
- the liquefying agent Woerment FM 375 based on polycarboxylatether has high liquefying efficiency lowering significantly the W/C ratio w
- the stabilizing agent Woermann Visquard SCC 916 prevents potential segregation of green concrete or its segregation during processing allowing minimum possible water loss or potential bleeding of concrete

This type of concrete serves for standard sewers of domestic drainage outlets, namely for lower shaft units or only for the bottom of lower units. For drainage wells of aggressive

substances, such as acids and other types of caustic agents, namely those chemically aggressive to hardened cement stone, troughs or inserts to be used for bottom parts of lower shaft units of melted basalt, or other similar materials resistant to the given type of drained substances must be used. Within the grant project works, the concreting procedure of shaft bottom was re-designed so that it is implemented in an reverted position to that which will be subsequently used. Due to the change in the concreting procedure, a new mould was designed too. The moulding part consists of a two-part external steel mould with installations for fitting an additional centering (tongue and semi-groove). The mould has a flange fitting to be connected with the internal mould part with vertical square fittings (flange) for interconnecting (by screws) both mould halves into one whole.

The mould interior consists of a two-part centering casing with vertical inserts to ensure a uniform internal diameter (1000 mm). Both sections are fitted with flanges on both sides. The flange in the lower part secures interconnection of internal and external casings. The upper flange allows mounting of the negative bottom shape mould onto the internal section. Vertically the mould is divided into 2 parts with square fittings (flanges) serving for inserting releasing steel inserts on both sides, which after removal allow for subsequent demoulding of the internal part. The assembled internal part of the centering is fitted with a negative moulding section of troughs and gutters manufactured in keeping with the customer's requirements. The moulding unit is shaped as a replaceable item of plate or hardened PVC for various alternatives of drains and sewer connection bottoms.

Justification:

- the design of troughs and gutters as a releasable mould of plate or rather hardened PVC, forming the shaft bottom is a standard item for various alternatives of drains or sewer connections
- by flanges in the two-part internal mould section are meant the fittings which, in the lower part, enclose the external mould with the internal section at the point of a future tongue and groove joint with another centering
- internal mould is of two-part type, vertically divided, with inserts for demoulding which will take place after overturning the mould into its final mounting position

In its complex character, the submitted technical design is partially demanding for moulding devices and preparation of the whole manufacturing process, namely for obtaining the moulding units for moulding the shaft bottom, but after mastering several commonly used drain connections production may become continuous. Apart from production time shortened to one unit, the advantage of this solution consists in reduced product handling during the manufacturing process. Implementation of the designed technology requires, in the first place, development of technical documents for manufacturing the moulding device, and its production. Apart from this, it is necessary to manufacture the basic negative shapes of the shaft bottom.

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# Accuracy Evaluation of LVDTs and Strain Gages for Dynamic Measurement of Engineering Structures

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**Introduction**

Aim of the present study was to assess an accuracy of dynamic measurement by LVDTs in medium frequency range (20-120 Hz) and strain gages in low frequency range (0-10 Hz). The assessment of the LVDTs and strain gages accuracy is of great importance for measurements on most structures in civil and transport engineering (e.g.buildings and bridges).

**Method of evaluation**

The accuracy of LVDT sensors E300 (Lucas-Schaevitz) has been evaluated. The sensors have been tested in special setup for calibration which has been constructed at Centre of Composites, CTU, Klokner Institute. The setup consists of flat-membrane loud-speaker and DC Hi-Fi amplifier. The loud-speaker has a low-pass characteristic and relatively high linearity. The displacement of load-speaker membrane has been measured by LVDT sensor. Dynamic signal in range 20 - 120 Hz has been measured by high speed voltmeter HP 44704A (16 bits, 100 kSa/sec) and digitized data have been transfered to PC Pentium. Two ranges of input voltage have been considered: 1V and 2V. Signal from LVDT has been analyzed by software LabWindows CVI 5.01.

At the second stage the accuracy of strain gauges has been analyzed. The sensors have been tested in equipment for calibration (CE) which has been constructed at CTU, Klokner Institute. The parameters of calibration equipment are following: amplitude 0-10 mm, frequency 0-50 Hz, distortion max 0.1 %. A composite cantilever beam with two strain gages has been fixed to base of CE and a top of the beam to the moving plate of CE. Signal from strain gages has been measured by board HP 44732A (dynamic strain gage multiplexer) and analyzed by software LabWindows CVI.

**Results**

The dependence of noise on mechanical frequency has been calculated and the coresponding Effective Numbers of Bits (ENOB) were evaluated. The dynamic signal has been processed by Chebyshev low pass digital filter with max. frequency 500 Hz .

The Effective Numbers of Bits (ENOB) have been found: for the input 1V 4.08- 6.44 and for input 2V has been evaluated in dependence on input frequency (20-120 Hz). The results are included in Tables 1 and 2. The low accuracy in the range 20-50 Hz has been caused probably by uncertainties in transfer of dynamical forces between membrane and sensor. Further the relation of ENOB on sampling frequency has been analyzed. The accuracy of results can be substantialy influenced by filtering, eg. for input 1V the difference was more than 2 bits (see Table 3).

The preliminary results of dynamic measurements by strain gages show, that the effective number of bits can achieve l2 bit limit.

Table 1 Measurement with LVDT,evaluation of ENOB, input 2V,sampling frequency 100 kHz

| Input Frequency | Effective Number of Bits | Effective Number of Bits |
|---|---|---|
| Hz | Without Filter | Filter DP 500 Hz |
| 20 | 4,07 | 4,08 |
| 40 | 4,70 | 4,73 |
| 50 | 5,41 | 5,46 |
| 60 | 6,03 | 6,17 |
| 80 | 6,26 | 6,50 |
| 100 | 6,09 | 6,77 |
| 120 | 6,07 | 6,44 |

Table 2 Measurement with LVDT,evaluation of ENOB, input 1V,sampling frequency 100 kHz

| Input Frequency | ENOB | ENOB |
|---|---|---|
| Hz | Without Filter | Filter DP 500 Hz |
| 20 | 5,88 | 6,57 |
| 40 | 6,04 | 6,77 |
| 50 | 6,17 | 7,87 |
| 60 | 6,14 | 8,61 |
| 80 | 6,10 | 8,28 |
| 100 | 5,95 | 7,76 |
| 120 | 5,9 | 6,82 |

Table 3 Measurement with LVDT, ENOB on sampling, input 2 and 1V, frequency 60Hz

| Sampling Frequency | ENOB | ENOB | ENOB | ENOB |
|---|---|---|---|---|
| kHz | 2V, Without Filter | 2V, Filter DP 500 Hz | 1V, Without Filter | 1V, Filter DP 500 Hz |
| 100 | 6,12 | 6,29 | 6,14 | 8,61 |
| 50 | 6,12 | 6,29 | 6,08 | 8,56 |
| 20 | 6,12 | 6,29 | 6,23 | 8,29 |
| 10 | 6,12 | 6,21 | 6,22 | 8,12 |
| 5 | 6,13 | 6,21 | 6,21 | 7,97 |
| 2 | 6,12 | 6,14 | 6,21 | 6,80 |
| 1 | 6,11 | 6,11 | 6,21 | 6,21 |

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# Floods Analysis and Mitigation on the Orlice River (FLAMOR)

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The Czech Republic has undergone important casualties caused by the catastrophic floods of July 1997 and again of August 2002. The catchments of the Tichá Orlice River and Divoká Orlice River, in the north-eastern part of the Czech Republic, were affected by three catastrophic flood events over a period of four years, leading to loss of life, injuries, and major material damage (in July 1997, July 1998 and March 2000). Therefore, the local authorities wish to take sustainable actions to avoid or mitigate, with time, any harmful consequences of floods in these watersheds. With the support of Swiss Agency for Development and Cooperation (SDC) – Humanitarian Aid & Swiss Disaster Relief (HA/SDR) the international project Floods Analysis and Mitigation on the Orlice River (FLAMOR) was started.

The main bearers of the project - the Swiss Federal Institute of Technology in Lausanne and the Czech Technical University in Prague – Faculty of Civil Engineering, together with other institutions in the Czech Republic, especially the Labe River Basin Board State Authority, the Research Institute for Land Reclamation and Soil Conservation (VUMOP), Prague, and the Institute for Hydrodynamics of the Academy of Sciences of the Czech Republic (IH), Prague, with co-operation with Orlice Hydro-Geologic Co., the Orlice Cities Association and the Orlicko-Třebovsko Cities Association, have taken on flood risk assessment and mitigation for selected parts of the Tichá Orlice and Divoká Orlice watersheds. The three main objectives of the project are as follows:

- Elaboration of a method for establishing flood maps in the given areas by mathematical modeling techniques.
- Identification of vulnerability and estimation of risks. The identified risk areas and impacts are assessed with the help of Geographical Information System (GIS), linking land occupation with the anticipated types of damage.
- Determination of adequate prevention and preparedness measures. These measures may be structural or nonstructural, realized in the framework of existing improvements, taking into account legislative constraints on land use and territory improvement.

The first phase of the FLAMOR project finished in 2002 concerned the numerical flood hazard modelling and flood hazard mapping using different numerical models and evaluation methods. The Žamberk, Ústí nad Orlicí and Choceň cities were selected as the localities for the pilot studies. All these cities were heavily affected during the 1997 and 1998 floods.

The numerical modeling of flood situations required a lot of topographic data. The amount and required quality of topographic data used depended on the type of hydraulic model used. For 1D simulation tools topographic information was used in the form of measured cross sections obtained with classical land surveying methods. Two dimensional modeling required a greater amount of input data, because detailed topographic information was necessary to create a sufficiently accurate digital terrain model (DTM) of the flooded area. The DTM was based on the evaluation of aerial snaps taken after the flood in 1997. The raw DTM data

included elevations of terrain breaklines as well as elevation data in a fine raster of points. Besides the topography data also a large amount of other necessary information and data (hydraulic, hydrological, calibration data etc.) had to be collected and evaluated.

Three different simulation tools were used to simulate the N-years floods as well as the 1997 flood events and to produce the flood hazard maps All the models were calibrated with the July 1997 flood information. For the classical 1D hydraulic modeling in non urban areas the HEC-RAS hydraulic model was used while the very detailed 2D modelling of flood flow in the urbanised areas was done with two different 2D models - the FAST 2D model and the quasi 2D model FldPln. The results of different models were compared and advantages and disadvantages of different modelling approaches were clearly identified.

Selected calibrated models were finally used to simulate a set of flood events with different return periods and to produce detailed maps of flood characteristics (water elevations, depths, flow velocities) and the flood hazard maps (evaluation of flood danger) for the whole pilot study area using CAD/GIS software. These simulation results are currently used in the second phase of the project as input for the risk analysis and efficiency evaluation of various mitigation measures.

The local authorities of Žamberk, Choceň and Ústí nad Orlicí cities can immediately use these preliminary results of the FLAMOR project's first phase to regulate land use, to prepare flood control plans and to make other conclusions based on this detailed information. The methodologies and results provided by this investigation will also serve as a case study for other applications in other watersheds on the territory of the Czech Republic, and in other countries with similar problems and a similar natural environment.

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# Computer Support of Practices of Engineering Surveying Objects

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Rapid developments in engineering and the computer sciences have greatly changed both the instrumentation and methodology in engineering geodesy. All topics are shared in one way with the accent of the research pointing towards the systematic mathematical treatment of geodetic problems. The main objectives are to encourage and promote research on the foundations of geodesy in any way possible in a form suitable for use in teaching as well as research work. The experience from the last period supports our opinion that the topic should be treated within educational process in geodetic objects. The intention is to embody problems related to teaching methods, modelling, to the analysis of general educational processes, but also to qualitative aspects in the temporal evolution of sciences.

In Europe the modern education now frequently have high course requirements. Even if textbooks are available, the development in geodesy is so fast, that new materials always need to be included in the teaching. There is necessary to investigate and test the use of modern computer supported cooperative work systems to give lectures or classroom type training with possibility for student feedback. Geodesy is taught in many relations (surveying, geophysics, remote sensing, satellite systems), and computer supported methods should assist these fields in having access to geodetic teaching material.

The technical solution of the problem is bound on the computer equipment of the network and primarily of the end users where no special configurations and computer facilities must be required. A possibility of an Internet connection and a web explorer installed are, of course, the key conditions for the end users. The choice of a program language is determined by more points of view. The copyrights protection and eventual initial costs are of the first priority. The lucidity and a simple end-users-controlling are the principal aims of the resulting product. Second thoughts on all of the therein before aspects, the PHP (Personal Home Page) script-language, with an additional connection to the database MySQL (Structured Query Language), has shown up to be the most convenient from the choice available, for example ASP, Perl, Java. The PHP runs inside a HTML document and gives it a possibility to generate the contents required. The PHP-language was intended for the web-work and it has become the top in such a field. The program runs interactively. The students are prompted for a user id and password. Simplicity of the mean and quickness of connecting to a database belong to its greatest preferences. One of the most significant merits is its independence of a computer platform. Syntax of the language was improved in the course of its development by the constructions, which were familiar to the users who used to program in object-oriented and procedural languages. The PHP consists of the usual control structures, operators, types of variables, declarations of classes and objects, which are expected from compiled or interpreted languages. A text editor is required to save “clear“ text. A series of freeware or commercial

programs, which emphasize syntax or contain a fundamental syntax in the form prescribed, can be advantageously employed. In case of photographs or other scanned settings another suitable software must be used to their arrangements.

The front page of the product is parted into individual subjects. An attention is devoted preferably to exercises. Result checks need not be implemented for some objects, in particular, in cases where the elaboration is up to a certain measure subjective and there is not possible to make a unique decision; for example, the drawing documentation of a conservation care of historical monuments. Confining of a number of allowed accesses stops from misusing tests by judging the correct results. Implementation of a password choice prevents from an unauthorized access.

Manipulation is drawn in such a way to correspond to the currently used standards. Orientation is simplified by distinctions of text levels, colors and font magnification. An aesthetical performance, in particular, the graphical appearance of the screen, the choice of characters, colors of text and backgrounds, plays a role.

The principals of the grant solving and a guide of technical performance are introduced in [1]. Contribution [2] modification, concerning the opening of the university lectures on mining-measurements in Habsbourgh Monarchy in 1762, will be introduced on pages of basic information of the object coded GP10, which is its direct continuation. Mining-measurement specialized public was made acquainted in the original paper form so with the history of its development as with the temporary stage containing the grant output. Similarly for [3] and the object coded SPGD. Report [4] in the journal of the faculties of civil engineering of technical universities in Czech Republic announces establishing a photo-catalogue of the Czech instrumentation of 16-20th centuries on web both in English and Czech versions in the framework of DEJZ pages.

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# The Analysis of the Unsteady Thermal Behaviour of the Building

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Building simulation programs based of two calculation methods published in the preliminary European standard prEN ISO 13792 are under development now. In the future, it should be possible to analyse the response to the load from internal and external heat sources (solar radiation, air temperature, heating system and so on) much more precisely.
Existing sophisticated computer programs for analysis of the thermal performance of buildings are very costly and not users friendly. Therefore these well-known and respectable programs are most used in academic environment but also in some progressive design offices.
More simple programs are not able to calculate the behaviour of more than one room during the calculation period of one day but they are easy to use and could be quite cheap.
Such program is being developed also by one of the authors of this paper.
One of the main problems in the field of building simulation programs is the verification of their results. It is commonly known fact that various building simulation programs could have different results for the same problem and it is necessary to have quite a long practice with the program to be able to use it properly. Well-known and longer time used programs are of course usually verified but the results of new simulation programs must be compared either with results of respected programs or with the experimental data measured in-situ.
The second mentioned possibility of verification of a simulation program must be of course based on a long-term measurement performed on preferably simple building because such simple building could be afterwards easily modeled in any of the building simulation programs being verified. The measurement must be also carried out in the way that results of measurement are not affected by interaction with other buildings or behavior of users.
The final result of such measurements should be the year course of the external air temperature, total solar radiation and air humidity and the year course of the internal air temperature and humidity together with the surface temperatures, air change rate and internal heat gains.
There is so far only a few such reference models based on measured data and no such model exists in Czech Republic but one – ours.
The first long-term measurement of necessary data for its creation was started in the end of the year 2001. The measurements continued during the year 2002 and will result in collection of yearly data for simple building located in Prague.
The simple building used for measurement is a little observation building located on the roof of building of the Faculty of Civil Engineering in Prague. This building has only one room with tin roof without insulation and tin walls insulated with glass wool.
There were realize changes on building: The floor of this building was insulated by polystyrene boards covered by wooden based boards. A door with a single glass replaced the former opaque tin door.
In the end of the year 2002 we were succeed with attaching of second observation building for purpose of measurement located on the roof of same building.

The floor of second test building was insulated by polystyrene boards covered by wooden based boards. The walls and roof was insulated by mineral wool insulation. A door with a single glass replaced original door.
The measurement in this simple buildings is carried out by means of Ahlborn measuring devices and sensors which collect data describing the internal and external air temperature and humidity, global solar radiation, $CO_2$ concentration (initial data for air change rate calculation) and internal surface temperatures.
This measurement is supposed to be carried out without interruption until the end of the year 2003. Results will be finally used for creation of reference model for verification of building simulation programs.

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# Corrosion Control in a Distribution Network of Drinking Water

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The quality of drinking water can be affected by the nature of the material used in a water distribution system and this can be especially so in a large water distribution network where a variety of materials are used to transport and deliver water to the user.

Corrosion of system pipes has economic, hydraulic and aesthetic impact, including water leaks, corrosion product build up, increased pumping costs and water quality deterioration. Corrosion products detected at the consumers´ taps cause colour (red water), taste and odour and eventually health problems depending on the pipe materials. Corrosion of iron is also the primary factor controlling bio film growth in pipes.

Distinguishing between water quality problems and corrosion rate is important. Although the total mass of corrosion products inside the pipes is a function of the corrosion rate integrated over time, water quality deterioration primary depends on the precipitation and dissolution properties of the corrosion products. Corrosivity of particular water depends on its chemical properties (e.g. pH, alkalinity, dissolved oxygen etc.) and physical characteristics (temperature, flow rate).

Several theories has been proposed since the beginning of the century to explain why certain water qualities appear to be less corrosive than others (1):

Tillmans et al. in 1927 observed protective layers of crystalline calcium carbonate if the water was saturated with respect to this compound.

Langelier in 1936 further developed this theory and introduced the Langelier Saturation Index (LSI) as a tool to achieve equilibrium for calcium carbonate.

Kuch in 1985 discussed the red water problems and emphasised the importance of stagnation versus high flow velocities in iron pipes.

The buffer capacity is referred to as the most important factor for the formation of good protective layers. When the buffer capacity is high, the iron (III) ions form siderite instead of forming the less protective goethite, FeOOH, iron hydroxide $Fe(OH)_2$, or other iron products. Siderite than oxidizes to magnetite, $Fe_2O_3$, or goethite while retaining a crystal line structure and therefore a more protective scale (2).

A traditional and widely used method of corrosion monitoring is based on weight loss, involving the exposure of coupons of pipeline material to the same operating conditions of the

pipeline. A relative simple and rapid method for field monitoring of corrosion is the analysis of iron in the distributed water. Instantaneous corrosion rate measurements are often obtained through the use of electrochemical measurements (3).

This research was focused on the pipelines travelling from the WT Plav to the city of Tábor. The first part of these pipelines was constructed and put into service in 1987 from the WT Plav to the Hosín water reservoir. This part of the pipelines serves the city of České Budějovice and its surrounding region with the population of about 110.000 inhabitants. The second part from the Hosín to the city of Veselí nad Lužnicí was put into service in 1993. The construction of the main pipelines continued in the direction of Tábor – Čekanice and connected also to the cities of Soběslav, Planá, Sezimovo Ústí and the village Roudná. The total number of consumers have been served by the pipelines under study is about 75 km from Plav to the city of Tábor. The material of these pipelines is steel without using any type of inside coating. These pipelines were suffering from some trouble in the quality of the drinking water. There were high levels of dissolved iron concentration and turbidity that are accompanied with microorganisms' activity. Seven places were chosen as locations for corrosion monitoring and taking samples for the analysis of the main characteristics of the drinking water. The tested coupons were prepared from three types of materials: steel, cast iron and concrete. For steel the material was chosen to agree with TNV 757121, while for cast iron coupons, the material was chosen to agree with CSN 422410. The concrete coupons were made from a mixture of cement, sand and water by the same way used for cementing pipelines. Holder frames from plastic material were used to insert the coupons into the pipe loops. The dimensions of the cast iron and concrete coupons were 50x50x5 mm with a total surface area of 60 $cm^2$, while the surface area of steel coupons was 34 $cm^2$. From pre-tests carried out, it was decided to use two exposure periods: 63 days and 126 days. After this period the coupons were analysed for dry weight. Corrosion rates were also calculated.

The highest values of the corrosion rates were observed at the Hosín pipe loop. This high corrosion rate of 84 μm/year in the first part of the main pipelines may have played a major role in the decay of the free chlorine residuals.

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# Effect of Chlorination and Sonication on Removal of Humic Compounds from Water

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Humic compounds are amorphous organic macromolecules that are responsible for the colour of natural water. They play an important role in the water treatment and in the formation of disinfection by-products (DBPs) in the treated water. Humic compounds are responsible for 40 – 80% of the dissolved organic carbon (DOC) in many surface waters. Yeh et al. (1) have proposed that the organic matter in natural water (NOM) is fractionated into humic acid, fulvic acid, hydrophylic acid and a neutral fraction. However, the structure of these compounds is still not well known. Humic compounds can be characterized by non-specific parameters. Important examples include dissolved organic carbon content (DOC) and UV absorbance in the range of 254 to 280 nm. There are many other techniques to characterize the structure of these compounds, for example ultra filtration, membrane filtration, bio filtration, measurement of the degree of aromaticity and different chromatographic and mass-spectrometric techniques.

The following reasons explain why humic compounds must be removed from water:

1. the yellow colour of humic compounds is incompatible with the requirements that drinking water is colourless,
2. humic compounds have a potential for bacterial regrowth,
3. humic compounds leads to the formation of disinfection by-products,
4. humic compounds can form complexes with heavy metals present in water as a consequence; they reach the consumer since they cannot be precipitated in the water treatment plant.

Humid compounds are a primary source of organic carbon found in drinking water (2) and will readily adsorb to iron oxides formed during ferrous pipe corrosion. It has been hypothesized that adsorption of humid substances to iron oxides may create a nutrient-rich environment that promotes biofilm growth, resulting in an increase in heterotrophic and coliform bacteria in drinking water (3).

Humic compounds are considered to be the primary precursor to DBPs formation and it is present in nearly all-natural waters. Different techniques are used to remove it from water. A very common method is coagulation/flocculation, followed by sedimentation or flotation. After the treatment the water still contains humic compounds, hence, needs further purification. This rest of humic compounds should be removed by other methods, such as oxidation by strong oxidation agents, adsorption on activated carbon or synthetic adsorption resins, biofiltration after pre-treatment with oxidation agents etc. Changes in aquatic humic compounds have been shown to cause changes in reactivity, the formation potential of disinfection by-products DBPs and in microbial available carbon.

The research was focused on the removal of humic compounds from the water of Rašeliník Brook that is one of the water reservoir Fláje tributaries situated in Ore Mountains.

Laboratory studies of the chlorination of the sample from this stream under different conditions were done. The effect of various pH values on UV absorbance $A_{254}$ and $A_{204}$ and chlorine consumption during the chlorination of the water sample were study. It was shown, that pH value plays an important role during chlorination of water with humic compounds.

Sonification at different frequencies and at different time was carried out also on water from Raselinik Brook. The effect of this treatment was followed using UV absorbance measurement method ($A_{254}$ ). The experimental results indicated, that the sonication was not sufficient to decompose the humic compounds in water. It is clear, that without an oxidant the ultrasound is not the appropriate pre-treatment method for humic compounds elimination from water.

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# Characteristics of Organic Precursors and their Relationship with Disinfection By-products

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The formation of disinfection by-products (DBPs) due to reactional oxidants with natural organic matter (NOM) has been under investigation since the discovery of their presence in chlorinated drinking water by Rook (1). Since then, research has led to a better understanding of the kinetics and yield of the DBPs forming reactions. NOM contains precursors for DBPs formation during water treatment disinfection operation. In addition, it contains nonhumic substances, which may be a target for control in source water.

The mayor-halogenated DBPs that are commonly identified from chlorine treatment are trihalomethanes (THMs), haloacetic acids (HAAs), haloacetonitrile (HANs), cyanogens halides and halopicrins (2,3).

The rate and yield of the DBPs formation reactions are affected by several parameters, including the identity and concentration of the halogenating agent and the reactive sites in the organic precursor molecules, solution pH and temperature, and the concentration of bromide and ammonia in water (4). For instance, the yield of THMs is widely reported to increase with increasing pH (5) while that of HAAs decreases. The later trends are less universal than the trends for THMs.

THMs and HAAs in drinking water constitute a potential health risk. Animals that ingested THMs and HAAs have shown detrimental effects. Similar negative health effect are being recognised in humans. The US EPA has set a Stage 1 maximum contaminant level (MCL) of 0,060 $mg.l^{-1}$ for the sum of five HAAs and lowered the MCL for THMs from 0,100 to 0,080 $mg.l^{-1}$ because of their greater perceived health risk. Under the Stage 2 MCL HAAs is expected to be reducing to 0,030 $mg.l^{-1}$ and THMs to 0,040 $mg.l^{-1}$.

Considerable effort has been devoted to finding surrogates that identify THM and HAA precursors in raw water and allow monitoring of their elimination during treatment. Commonly used surrogates include UV Absorbance $A_{254}$, DOC and the ratio of DOC to $A_{254}$. A number of studies have used linear regression techniques to correlate THMs and HAAs formation potential (THMFP and HAAFP) with DOC and $A_{254}$ (6). THMFP is the difference between the final THM concentration and the initial concentration in a sample at standard reaction conditions.

The objective of this research was to investigate the ways in which disinfection by-products formation potential of THMs and HAAs due to the presence of humic compounds could be used as a tool to predict the quality of raw water. Water samples were collected since 2001 at

different sites of Fláje catchments (Rašeliník Brook, Radní Brook, Flájský Brook, Mackovský Brook and Fláje reservoir). THMFP and HAAFP were determined in each sample. THMs were determined by headspace solid phase micro extraction, using a Carboxen coated fibre (Supelco), HAAs were analysed by liquid – liquid extraction from an acidified sample into MTBE after esterification by boron trifluoride. Gas chromatography – mass spectrometry (GC 8000/MD 800 Fisons) was used as a final analytical technique. Other parameters such as DOC and $A_{254}$ were tested in all samples. It was observed, that the maximum THMFP presented water from Rašelinik Brook (∅ 0,140 $mg.mg^{-1}$ DOC) whereas the minimum was in water from Radní Brook (∅ 0,088 $mg.mg^{-1}$ DOC). The maximum HAAFP was stated in water from Flájský Brook (∅ 0,101 $mg.mg^{-1}$ DOC), the minimum in water from Radní Brook (∅ 0,083 $mg.mg^{-1}$ DOC). The seasonal evolution of THMFP in the water under study was also observed. The results of tests measured in December were the highest, and the overall trend advanced from September to December 2001 (7). The findings of this research suggest, that the parameters THMFP and HAAFP represents a good tool for row water quality evaluation.

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# Research of Co-operation of Soil and Geotextile Like Basis for Static Proposition of Bank

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Under the IG CTU interval initiation grant was made several sets of experiments - interaction between soil and geotextile, because banks of roadwork and railway track was impasted using geotextile more often in this days. Research of co-operation of soil and geotextile was concetrated to complete and correct understanding of this problematic. The results were used for statical desinging of road and railway bank. The tests was executed at the Klokner Institute testing room with soils from the real bulding site, where was used geotextile. The first soil was taken near Libcice nad Vltavou area from railway corridor Praha-Bubenec - Kralupy nad Vltavou. The second specimen was taken from Lovosice area. The tests was destructive. It means that the tests was stoped at the moment of geotextile destruction.

During the whole test was made digital videogram, which was subserved for presentation on the scientifical symposiums and like support for teaching.

The tests was performed as followed:

About 150 mm of soil was placed at the bottom of the testing device, the size of which was 500 x 500 mm. The soil was loaded with force 80kPa for half an hour. On top of the soil was placed a piece of geotextile, the size of which was 200 x 600 mm, 100 mm was used for its fixation in the testing device, and the geotextile was covered by another 100 mm of soil. The assembly was loaded with force of 20 kN (corresponded to 80 kPa) and allowed to consolidate for one hour. The geotextile was pulled out under the 60 kN load, which was constant during whole test, at the speed 1mm per 10 s or the geotextile was pulled out under the 20 kN load at the same speed while the resisting force was measured. When the resistance reached its maximum and started decreasing, moment in which the assembly soil-geotextile reached maximum strength, the pulling out was broken, the vertical load was increased about 20 kN (maximum force was 100 kN) and test continued.

All the experiments were conducted by series of measurements for geotextile GEOLON PP 40 and geotextile GEOLON PP 60 and were loaded with a force 20 kN and 60 kN. For each specimen of soil was made 4 sets of measurements

Throughout this testing were recorded these quantities:

- vertical force
- vertical displacment
- horizontal force (the force at which the geotextile was being pulled out)
- horizontal displament of the geotextile
- time

After the tests was prepared mathematical model of assembly soil – geotextile. This model was created using the special designing software Particle Flow Code ($PFC^{2D}$) by ITASCA, which was determinated for soils modeling. Model treats the situation as a time dependent problem and models the soil and geotextile as an assembly of balls connected by axial and shear stiffness. The balls may have arbitrary size and can be sliding and axial fixed. Once this is exceeded, the balls disconnect and a crack apperars. Using this software and model we can study all actions which are happened during the simulation of breaking process. The mathematical model was used for comparation with concrete results.
All resuts were presented on the poster for Workshop 2003.

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# Measuring Methods and Equipments Applied at the Model Plant of Roll-Belt-Conveyer

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On the model plant of roll-belt-conveyer, which consists on the whole of 3 separate sections (a straight horizontal conveyer, an oblique conveyer and an oblique threedimensional-curved conveyer), are implementid measurations. Their result is a determination of some transport process incident parameters, these are: the cross-section form of convolute belt of roll-belt-conveyer, the determination of degree of slippage between a belt wall and a transported material, the determination of size of resistance to motion,of belt speed and of stretching forces.

The determination of the cross-section form of convolute belt is possible to implement at a convolute zone by measuration a diameter of convolution and a size of overlap, as well as at a roll-up and roll-out zone by a position finding of to select referential points outspread distinguished points of belt (e.g. a belt border, a belt middle) using common length-measuring instruments.

For the determination of true cross-section form of convolute belt, particularly then for a measuration of convolute belt form in a threedimensional curvature was developed measuring equipment [1]. Its main segments are: a pivoted measuring wheel and an at circular path guided stylus. The stylus is sliding guided in the direction of his longitudinal axis and on his belt-opposite end carries a recorder. The measuring wheel revolves on the circular path of convolute belt and the stylus is nevertheless sustained in contact with a belt surface. The recorder at the same time draws a scheme of convolute belt cross-section.

The slippage between the belt and the transported material is defined by the relation: $s = 100 \cdot (v_B - v_M) / v_B$ [%], $v_B$-velocity of belt [m.s$^{-1}$],$v_M$-velocity of transported material [m.s$^{-1}$]. The actual velocity of transported material was measured but for a reaction at the transport process. This measuration is based on the principle, that to the transported material were adding small characteristic elements (transmitters of signal) in a loading place. Their movement is watched along a transport line contactiess. As suitable transmitters of signal are used small permanent magnets (diameter 5mm, high 3mm). The following their movement senzors are deployed to steady distances along the convolute zone of conveyer. With this are used sensors with resistiv magnets, that contains a bridge circuit of four megnet-resistive elements, that cause an output bridge-circuit voltage. The in transported material drifted magnet evokes in way trough the senzor an output analogous signal. Hi is next transformed by the help of a photographic line recorder (UV-recorder) to a graph. The velocity of belt is registered so that on the belt are deployed reflective marks, that are taked by photosensors. The signals of photosensors are transfered to a graph. On the model plants of roll-belt-conveyer are measured next: a total resistance to motion – represented by circumferendial force of drive drum - $F_D$ -, and stretching forces – $F_S$.

The drive units are pivoted for this purpose in the centre of rotation of drive drum (the oblique conveyer) eventually in the centre of rotation of countershaft (the straight horizontal conveyer,

the oblique threedimensional-curved conveyer). The drive units are supported by sensor of forces, so that supporting forces are proportional the circumferential forces of drive drum. The stretching forces - $F_S$ are determined independently for every side on stretching bolts.

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# Mechanical Properties of Composites and Adhesives for Strengthening of RC Structures

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## Introduction

Polymer composites are increasingly used for strengthening of reinforced concrete, steel and wood. The reasons are following: resistance to corrosion, low weight, reduction of labor costs. Basic forms of composites for strengthening are unidirectional strips or bidirectional sheets or fabrics. Composites (particularly unidirectional) have very high strength and stiffness in tension along the fibres, but not across the fibres or in shear. Moreover composites along the fibres behave linear elastic to failure without plastic deformation. Recently, CFRP (Carbon Fibre Reinforced Plastics) are in use: eg. UD strips have excellent mechanical properties in tension (E-modulus 170- 300 GPa, tensile strength 1300- 2800 MPa).

The strengthening of RC structures by bonding continuous fiber sheets to concrete or jacketing with the sheets (continuous fiber sheet method) or with continuous fiber strands (continuous fiber strand method) are those in which upgrading is carried out after impregnation resin applied to the continuous fibers hardens and bonds to concrete surface. In addition to continuous fiber sheets, continuous fiber strands, and impregnation resin, the materials used include smoothing agents (used to smooth the surface irregularities and level differences in the concrete), surface preparation material, grout for filling cracks on the surface, primer to improve bonding and adhesives for bonding.

Besides of test methods for bond properties of continuous fibre sheets to concrete and pull-off strength of continuous fibre sheets with concrete, there are numerous methods for testing of constituent materials i.e. composites for strenghtening and adhesives. Continuous fibre sheets (strips) have to be tested among others: in tension, overlap splice strength, fatigue strength, freeze-thaw resistance, water, acid and alkali resistance. Test methods for bond properties of continuous fibre sheets to concrete are necessary for evaluation of the characteristic values for the bond strength, interfacial fracture energy and the relationship between bond stress and relative displacement.

## Adhesives

The purpose of the adhesive is to provide a shear load between the concrete surface and the composite material. Commonly used adhesive is based on epoxy resin, containing fillers, softening and toughening additives and others.

Typical mechanical properties of epoxy adhesives used in civil engineering applications are shown in Table 1. Further, two adhesives have been tested at CTU Klokner Institute: MBT-Mbrace Epoxikleber 220 (producer MBT, Austria Bauchemie, Krieglach, A) and Sikadur 30 (producer Sika AG Zurich, CH) which are used for the bonding of CFRP strips to concrete. The properties in tension have been tested according to ISO 527 Plastics- Determination of tensile properties in electronic testing machine Instron 1273 (100 kN). Properties of specimen in shear have been tested according to ASTM D 5379D Test method for shear properties of composite materials by the V-notched beam method (Iosipescu). Strain rate was for both tests

1 mm.min$^{-1}$, size of specimen for tensile test 10x20x170 mm, effective length 105 mm between clamps. Size of specimen for Iosipescu shear test has been 10x20x80 mm. Analog signal from testing machine has been measured by data acquisition system HP 3852, digitized data transferred through GPIB to PC Pentium and analyzed by software LabWindows CVI 5.01 (National Instruments).

The results are given in Table 1 where is shown, that the mechanical properties eg. tensile strength and strain at break and fracture energy can vary significantly.

Table 1 Properties of adhesives, tested at CTU KI

| Property (at 20°C) | Epoxy adhesive [4] | MBT Epoxy 220 | Sika 30 |
|---|---|---|---|
| Density (kg.m$^{-3}$) | 1100 – 1700 | 1645 | 1735 |
| Young´s modulus (GPa) | 0.5 – 20 | 8.067 | 7.712 |
| Shear modulus (GPa) | 0.2 – 8 | 0.419 | 0.456 |
| Poisson´s ratio | 0.3 – 0.4 | | |
| Tensile strength (MPa) | 9 – 30 | 70.01 | 26.05 |
| Shear strength (MPa) | 10 – 30 | 10.80 | 15.62 |
| Compressive strength (MPa) | 55 – 110 | | |
| Tensile strain at break (%) | 0.5 – 5 | 1.23 | 0.347 |
| Approx. fracture energy in tension (kJm$^{-2}$) | 0.200 – 1.00 | 75.713 | 5.492 |
| Coefficient of thermal expansion (10$^{-6}$.K$^{-1}$) | 25 – 100 | | |
| Water absorption: 7 days at 25 °C (%w/w) | 0.1 – 3 | | |
| Glass transition temperature (°C) | 45 - 80 | | |

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# Investigation into Strength of Thin – Walled Girders

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Steel plated girders with slender webs exhibit a very high bearing capacity in relation to their self weight. This allows lightweight and economical structures. However, the utilization of the high bearing capacity is combined with considerable out-of-plane deformations of the web. When a girder is subjected to cyclic loading, repeated web buckling deflections, so called "web breathing ", may lead to fatigue cracks. Such cracks generally commence at the fillet welds connecting the web to its boundary elements and can finally lead to the failure of the structure.

In the present treatise, an account of scale fatigue tests on steel plated girders under repeated shear and bending loading is given. The aim of this examination was to analyze the initiation and propagation of fatigue cracks occuring in the breathing webs and their effect on the failure mechanism of the whole girder.

„Loading function" implies the maximal amplitude of the secondary maximal bending alteration $\Delta\sigma_b$ . In this regard, a whole number of basic questions arise:

a) When determining the said alteration amplitude, which external impulses should be considered?
b) In which location along the perimeter of the testing web panel will occur the highest value of this amplitude?
c) Which way to evaluate both the secondary bending stress mentioned and adequate alteration amplitude if it is known that these values are globally dependent on many parameters?
d) How, once initiated, does a fatigue crack grow till the failure of the whole test specimen?
e) According to which collapse mechanism does the test specimen actually fail?
f) How many cycles of web breathing are necessary before the fatigue limit state is reached?

Incidentally, „Resistance function" is urgently connected with a robustness of structural elements to fatigue, what gives rise to further problems, as follows:

g) By which number of cycles of the alteration $\Delta\sigma_b$ should be the required monitoring grounded on?
h) Which meaning is necessary to classify as belonging to the word „failure", if the lexical unit is tied in closely with a concept of the life?

The failure of the test girders occurred is one of the following two modes:
(a) Most girders exhibited a typical shear failure mode, large buckles developing along the tension diagonal and plastic zones becoming manifest in the girder flanges. In the end, when the main fatigue crack cut most of the tension band, the girders behaved, and failed, like ones having a large opening in the web. The cutting off of the tension band was usually materialized by one long fatigue crack, but in several cases (when the cutting crack followed the flange and the transverse stiffener)by a set of short separate cracks.

When one of the transverse stiffeners bounding the breathing web panel was subject to a large point load, as was the case with the central vertical stiffeners of the girders, additional fatigue cracks sometimes occurred in the web sheet in the close vicinity of the stiffener, then influencing the failure mechanism described above.

(b) Some girders collapsed as a result of the compression flange buckling vertically when the flange was separated from the web sheet (supporting the flange) by a long enough fatigue crack. This flange buckling occurs under the action of the compression force existing in the flange, and generated by the effect of a bending moment; therefore, it tends to happen in those web panels (if the test girder has four panels or more) and in those portions of the flange where the effect of the bending moment is largest.

For a design check of web breathing, it would be useful to introduce a double check for the effects of web breathing, i.e. to work with two degrees of the fatigue limit state, viz.
(a) a fatigue-failure limit state;
(b) an initiation of the first through-crack fatigue limit state.

The fatigue assessment of breathing webs should then proceed as follows:

- The first limit state, connected with fatigue failure, shall not be reached before the whole planned life of the structure has been exploited.
- The other limit state, related to the initiation of the first fatigue-through-crack, governs the maximum time before which the first inspection of the girder for potential fatigue cracks needs to be carried out.

If no fatigue fissures are found during the inspection, the useful life of the girder can be extended until another inspection is conducted after one half of the time period to the first inspection (this reflecting the fact that the degree of cumulative damage in the breathing web is then larger than during the first period). Failing to detect any fatigue cracks even then, the system of inspections can be extended in the same way. If, and when, a fatigue crack is detected, it shall be carefully measured – via frequent enough inspections – with the view to find out whether it (i) propagates or (ii) has stabilized.

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Section 14

# ARCHITECTURE
# &
# TOWN PLANNING

# Optimum Laser Systems in Industrial Metrology (part 4)

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The further observation of a selected part of the scientific and research network "Stare Mesto pod Sneznikem" was carried out. Especially, this project is focused on a possibility to determine the influence of the vertical component of refraction on a measured vertical angle. So called Sanchez's method is used, which consists in solution of a vertical triangle with precisely determined slope distances. These distances were determined by GPS fast static method and checked by electronic distance meters. In addition, the prior analysis of accuracy was applied to desired refractive angles depending on accuracy of determined distances and configuration (shape or area) of a vertical triangle. According to available information, this experiment is the first verification of Sanchez's method in the area of the Czech Republic.

It is possible to use a device based on digital camera for vertical shifts monitoring, which was designed and calibrated during prior phase of the research. To test the precision of the measurement of the vertical shifts there was designed an experiment, when laser was placed at the distance 1,2 m from the device (short distance minimises the influence of refraction). With reference to the device's weight the laser was mounted on the tool, which allows to realise shifts with accuracy superior to 0,1 mm in the range of 50 mm.
In the experiment there was always first made height adjustment of the laser, then made the measurement. Experiment was split into three parts, each of them simulating different types of the measurement. Achieved results confirmed the presupposed standard deviation 0,18 mm of vertical shift measurement.

There can be used plenty of methods and devices to monitor the influence of the atmosphere on geodetic measurement. One of them is use of device for laser spot's position detection together with laser beam coming through the desired space. Thus detected position of the laser spot allows to verify the atmosphere's influence models. Experimental measurement was realised in laboratory, ambient temperature changes were made artificially in short section of the laser beam's trajectory. There was measured the position of the laser spot together with values of the atmospheric elements (temperature, pressure, humidity) in the real time. The difference between shifts acquired from models and acquired from the camera is about 0,1 mm, the length of the sight was 28 m. The experiment proved considerable correspondence between measured and calculated shifts and thereby there was verified used procedure [1].

Proving tests of quality of electronical geodetical instruments for using in building and industrial surveying were proceeded in year 2002.

Digital levelling instrument Sokkia SDL 2 (construction Zeiss) was one of tested instruments. Influence of surroundings was studied (for example influence of induced vibration, lighting, covering of rod scale, gust wind). Study of temperature changes impact on position of exposure axis was the most extensive part of this research. Tests proved speed of alignment 40 s/1 °C and continued changes of position caused error under 0,1 mm/30 m. Accuracy of instrument settlement in direction of sight line (longitudinal) is significant for these tests. Testing of this instrument confirms that using of this instrument is reliable in common conditions and characteristics of instrument correspond specifications of producer.

Proving tests of hand-feed laser short range distance meter Leica DISTO were focused on several practical areas.Accuracy of measured horizontal distances was checked using 100 m long base line. Intermediate points were traced in distances 10 m on this base line and distances between these points were measured with total station Leica TC 1800 with accuracy better than 1 mm. Performed tests ensured range even 100 m and accuracy is characterized with standard deviation 0,93 mm during favourable conditions (producers states 1,5 mm). But differences appeared in some measured sections, distances should be measured more than once because of blunders elimination. Other tests were applied to checking some trigonometrical functions - for example calculation of angle (usually right angle) using three distances (e.g. two circumferential flanks and diagonal of smaller building object) for primary control measurement for inspection of setting-out according to ČSN 73 0420-2:2002. Hand-feed distance meter can be used for routine building practice instead of more expensive geodetical systems [2].

Laser scanning systems enable contactless spatial measurement, 3D modeling and visualization compound buildings and constructions, underground spaces and arbitrary terrains with exceptional velocity, accuracy, complexity and security. Visual 3D model of scanned object is imaged in form so called cloud of points using suitable software and it is possible to transfer this form to 2D or 3D CAD systems. These systems combine the most modern pulse laser technology, which is able to detect natural surface in available distance, with optics, which permit even million measurement during several minutes [3].

New laser instruments for positioning are very interesting [4]. LaserStation 3D Pro TRIMBLE set determines the positions of individual detailed points in distance 50 m with accuracy 1,5 ± 3 mm.

Systems for automatical control of building and mining machines with utilization of GPS and total stations have increasingly applications. Profiler 4000 is exerted for constructions of tunnels.

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# Sustainable Growth and Life-Cycle Management of Buildings and Towns: Management of Development of Czech Towns in the Past

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The research aimed at analysing and evaluation of the municipal economy and development policy in a selected sample of Czech towns in the period from the 1850s to 1938. On the background of annual municipal budgets, research of relevant data on major investments, census data and analyses of contemporary maps and development plans, the long-term effects of particular decisions, development projects and investments and general strategy of municipal budgeting were studied in terms of the benefits leading to prosperity of a particular town.
The development policy of municipalities was always constrained by contemporary legal frameworks and municipalities were also strictly limited in their activities as for their financial resources. In general, the scope of services and responsibilities was steadily increasing. This resulted in an increasing inequality between decreasing incomes from property and restricted tax surcharges and fees on the one hand, and the soaring expenditures for the services provided by a municipality on the other hand. Consequently, the municipalities were becoming increasingly dependent on external resources – from central government, banks, big enterprises, etc. – which increased their dependence on the subjects who owned the resources. Their choices were often rather dilemmas between unsatisfactory quality of service to public and unsustainable policy of deficit financing. It was rather lobbying of mayors that helped the municipalities to get necessary resources for financing their projects.
The municipalities included in the research behave pragmatically and tried to use up all the potentials and possibilities available in the respective period. The following table shows certain stages that were identified in the researched period, their characteristics in social and economic settings, the challenges for and response of municipalities and the impact on their economy.

| stage | social and economic setting | challenge for cities | municipal response | impact on municipal economy |
|---|---|---|---|---|
| early industrialisation (before 1880s / 1890s) | laissez-faire: decline of traditional small artisan businesses; volatile new industrial manufacturing – factories scattered in and around urban area | opening the town: abolition of privileges, demolition of town walls; increased density and pollution: sanitation problems, social disparities | early: inertia – pre-industrial concept of town management, incomes from estate property and forests<br>later: mission of municipalities in basic social services (schools, social services) | early: balanced, very tight budget; decline of competitiveness of traditional municipal enterprises<br>later: expanding municipal budgets, debt financing of development |

| stage | social and economic setting | challenge for cities | municipal response | impact on municipal economy |
|---|---|---|---|---|
| advanced industrial (1880s / 1890s to the World War I) | concentration of capital; rapid increase of urban population; spatial concentration of factories along railways | urban expansion; need for technical infrastructures and transportation facilities (railway stations, local public transport) | development / clearance plans, planning controls and enforcement; systems of technical infrastructure: water supply, sewerage, anti-flood protection, slaughter, gas, electricity | expanding municipal services – non-profit establishments for utilities and transport; search for new resources of income – tax surcharges -> increased dependence on taxpayers |
| social state moving to welfare (the inter-war period of the "First Republic") | equal citizens rights; growth and concentration of financial capital; restructuring of industry (new industries) | scarcity of development land within own jurisdiction; responsibility for well-being of citizens | effort to annex suburban communities; devolution of some services to state and widening scope of public investment and services | growth of dependency on the state; selling-off the property; vicious circle of increased deficit budgeting necessary for keeping the machine of development running |

The timing of the particular stages may vary in different towns and regions, with regards to the general advance of development of the region and/or the town, the size of the town, etc.

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# Architecture - Environment, City planning, Construction, Space Arrangement, Technology for Sustainable Development

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Sustainable development is a very actual theme nowadays. This task is also one of the priorities in development policy of EU. In architecture we could contribute in many ways. Savings of energy is possible in production of materials, transportation, space arrangement…, as well as in ways of use of a finished work – room, house, office, city… The task is not to save as much electrical energy as possible, but to see the complexity of problem and to find the best in particular situation. Some indicators are measurable and easy countable, some not, e.g. social and esthetical values. Harmony could rise only from complexity. Architects have to know about impacts and side effects of their work.

For realization of low energy architecture it is very important to optimal land utilization. It means evaluation of existing environment conditions in specific locality. Warm losses of buildings depend on city planning solution. To achieve energy saving is possible when the city planning is based on concentric construction, compact residential unit, suitable position or location of the building. Topography is also very important- configuration of the land and its orientation, atmospherical conditions, windiness of the locality, location water areas and flows, density of surrounding constructions or density and sorts of surroundings vegetation. Combination and synergism of these mentioned climatic factors enable to create suitable local climate. This suitable local climate could be than noticeable in energy intensity of specify locality. Basically is possible to say that ecological arrangements are cheaper and easier if they are applied in high level of city planning.

Space arrangement is one of the most necessary things in conception of low energy houses. Important is also the orientation and spaces layout in environments and the shape of the building. Most compact shape of the building is the bowl and as this shape is not good for internal spaces design is necessary at least to plan the house as compact as possible. That means not flat or broken to small parts. When the house is reasonably situated in environment, we can save up to 50% of heat losses comparing to situation, when the house is situated on plane and waste area. In this situation we can reduce energy losses from wind with work with terrain and nature. From the placing in terrain is derived the interior concept of the building. In our case the best orientation of buildings is with front facade to the south. Then is the best to situate small windows on the north facade area between 15-25% and open the facade on south, area is limited to 30-50%. The main base of low energy houses is situating of the warmest room in the centre of disposition and then continues fluently to coldest on the frame of the building. Then the heat losses are only difference between coldest room and the exterior. For application of solar energy conservation is good to integrate green wintergardens (solar spaces) and solar walls in south facade of building. Wintergardens are good for utilization of direct solar energy profit in interior. Through the ventilation the warm air is delivered to the

whole house and heating the colder rooms on other side of building. There can be integrated solar active system of solar collectors, which eliminates solar peaks and provides comfortable lighting of the interior. System of solar walls is used both either for heating of ventilation air and for space heating. To optimise the energy utilisation from the solar walls, the energy is stored internally in building integrated heat storages.

Another point of view we could put on particular materials, which are used in construction. The connections are also very wide spread. We have to mention a possibility of recycle use, an energy needs in producing, transportation, in construction as well as consequence effects when material is in use – durability, ability of making right inner climate in building etc. Examples of ecological materials, which nowadays celebrate revivals mainly in housing projects, are constructions made from straw, or clay. One has to count the advantages and disadvantages, and find the right way of use. But these materials sometimes could astonish us. The lower energy demands are evident. Construction made from straw parcels with clay plaster could have same, even higher fire resistance, than brick wall. Parcels are in the wall under high pressure, so the construction is self extinguish. Clay is perfect material for making man friendly inner climate. Unburned clay could transport humidity very effectively. In houses made from this material is ideal 40 – 60 % humidity in air. Clay also can release negative ions into atmosphere, which are necessary in natural way for good breathing.

Architecture is around us. It has big impact on our lives. Harmony is possible, when we know about all aspects and when we are able to find up the best solution.

# Effective Disconnexion of Thin-Walled Structures Using the Blasting Technique

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The needs for fast, safe and economic demolition technologies conduce to next progress in blasting technique. These needs, so de-facto, inspire the new technologies research and theirs use in building practise.

These trends are explicit e.g. in shaped charges range. The accrual of labour effectiveness is uncompromising at thin-walled structural elements destruction. Naturally, the construction and use of shaped charges underlie to the progress too. Only lately we used to construct the charges for steel elements destruction as two-piece for "shear cut". These charges were designed practically by military formulas. But the non-military blasting technique rises from "maximal work – minimal energy" principle. Only on this condition we are able to limit outside effects and use the blasting technique in wide range of building industry.

Within the framework of the long-time program for the panel-housing fault clearing is necessary to allow to the physical lifetime of the panel houses. It is impossible repeatedly protract only the moral lifetime of these houses. Especially the oldest houses must be reviewed whether it is not preferable to let them see out and then to pull them down. In principle it concerns firstly those houses built in period 1955 – 1970. Of course, also some houses built in the period 1970 – 1990 could be so failed that it will be more effective to pull them down.

There are three general methods for the demolition of the prefabricated panel houses: sequential dismantling with manual joints-disconnection, machine-demolition with hydraulic tools and blasting.

During both manual and machine demolition the construction system is found in special conditions. The danger lies in the fact that the system was not designed and viewed for these conditions. Prefabricated panel housing with well-proposed and performed joints is statically more stable than the classical brick-housing generally. The panel construction is rigid and interlaced and therefore is able to transfer relatively high surcharge. At present there are not visible marks of the possible danger. But then the small impulse can invoke the progressive collapse of whole house with tragic results. The situation responds to the gas-explosion or the heavy vehicle stroke. And the foreign experiences say that such case can turn up. With respect to the diagnosed faults of Czech prefabricated-housing we must view every house distributively especially in static aspect.

Although in the Czech Republic there is not the blasting technique thought as suitable for the demolition of panel-houses in general, the reality is the other. All the preparative works are made on the non-failed construction using of this technology. That way practically negates the hazard of the progressive collapse and guarantees the maximum volume of the workers-safety. The blast is finished when the safety circuit is closed and cleared. The fast work-rate and relatively short environmental-stress (noise, dust, vibration) rank among other advantages of this technology. So the blasting technology appears as the optimal for the demolition of the prefabricated panel-house.

Of course the design of the charge can not think the concrete-crushing and the armature-cutting together. Such charge would be too strong and would be conducted by the

excessive shock wave and fragments-flight. Practically the charge is designed only for the concrete-crushing and the armature is subsequently disconnected otherwise. Now the destruction of the reinforced-concrete construction is designed with a view to the change of the statical scheme. The blast breaks down the specific concrete section and the left armature can not transfer the concentrated loading and the construction must collapse. All kinds of the many-storied buildings demolition so draws on the primary blasting and the secondary machine disconnection of the fallen construction.

The destruction of the reinforced-concrete constructions using explosives is consequently the branch with good chance of the next grow. The workers-safety, work-speed, minimum environment-stress and the high degree of the qualification are undisputed advantages of the blasting technology. But there exists the need of the modern technologies application to the definite surpassing of these advantages. This relates to the switch-over to the non-blastingholed charges and non-electrical ignition. Although the blasting technique is more effective than the machine disconnecting the blast-preparation requires firstly the considerable number of the blastholes. Selected prefabricated panels must be perforated in all the surface. This technique requires among other the assembling and the disassembling of the horse scaffold. Although the blastholes are relatively short the need of the work and the time is high.

One of the possible ways to the rationalisation of the work is using the non-blastingholes charges. Currently the argumentation is exercised that it is impossible to construct such shaped charge of the acceptable size which will be able to crush the concrete and to cut the armature together. But such charge is not necessary. Using the shaped charge we can evoke the building-collapse by the change of the statical scheme and not by the direct destruction of the support. Similar-type explosive shaped charges begin to be of use for the destruction of the steel constructions.

The time and work savings and the next environment-stress decrease (the redrawing of the drilling-scheme, the drilling with noise, dust and vibrations, the inspection of blastholes, charges loading and caulking, detonators interconnecting fall away) are so great that this technology stepwise would pass dominant for thin-walled reinforced-concrete constructional elements destruction after the development ending.

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# Research of Historical and Contemporary Architecture - 4th Phase (year 2002)

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The comprehensive subject of the research project comprises 9 parts focusing on either historiography or the study of historical, functional, spatial and building structure of buildings. Twelve staff members of the Institute of the History of Architecture participate in its solution. The topics chosen are in harmony with the specializations of individual research workers and aim at important research trends in the history of architecture and the possibilities of the applications of the results in undergraduate and postgraduate studies.

During all the time of its existence the Institute of History of Architecture has been contributing to the formation of integral and plastic view on historical architecture, especially in Czech lands. It has, above all, contributed to the growing trend to study the whole social spectrum of historical building production in the context of the history of material culture. That is why research workers are becoming increasingly interested not only in the dominant role of progressive trends but also in the medium stream production of the period as well as peripheral and regressive tendencies. These phenomena are studied both in that part of architectural production which directly and visibly reflects artistic and ideological trends and in architectural works in which utility, dependence on structural design and other formative principles prevail in structure and expression. Historical city design and rural architecture are also studied.

The subject **Czech architectural drawing between historism and modernism** (E. Fantová, B. Fanta) has already reached the stage permitting to logically arrange and evaluate the collected material. The results are supposed to be publicly presented in the form of exhibition.

Related methodological approaches made it possible to connect the research of **spatial and functional pattern of medieval town house** (M. Hauserová) and that of **feudal residences** (M. Rykl). Both researchers attended scientific conferences in the country as well as abroad and presented there their jointly prepared contributions dealing with selected aspects of medieval dwelling culture. Results of both research lines were published in the country and abroad.

The current phase of research of **cathedral and mendicant monastic architecture** (P. Kalina) was closed by finishing the manuscript of a book devoted to Prague's architecture in the 14$^{th}$ and the early 15$^{th}$ century. One part of the results will be published in the form of invited lecture at TU Aachen.

Research of **renaissance and baroque school houses** (K. Kibic) continued with collection of materials.

Systematically organized collection of documentation related to **historical structures and building plans** (M. Ebel, J. Škabrada) made it possible to publish the results first in the form of CTU lecture notes and later also in the form of book.

The research group dealing with **the 1960s in Czech architecture** (headed by P. Urlich, B. Filsaková, J. Florián, O. Ševčík, P. Vorlík) continued the wide-range research work that is apparently approaching its main goal, a well-founded evaluating synthesis.

For the scheme **rondocubism** (P. Škranc) the theoretical background of this decorative trend in Czech architecture in the 1920s was studied as an additional contribution to the synthetic study that is being prepared.
The topic of **historical landscape parks in the time of classicism in the work of a bohemian architect J. J. Joendl** became a subject of the research of P. Vlček.

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# Central Archives of Historical Building Surveys

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Historical building surveys (further referred to as HBS) are essential professional documentation of immovable cultural monuments. These surveys are unpublished preliminary reports analyzing the history, evolution, importance and principles of future use of historical buildings. They consist of a written part, drawings and pictures. For protected historical buildings, these reports are fundamental materials documenting in detail the state of the building at the time of the survey and, in addition, formulating the principles of further use of the building in accordance with the principles of monument preservation. Their methodics was published by SÚPP (Standard non-destructive historical buildings research, Prague 1998, 2001).

The grant is a direct continuation of the previous grant from the years 1997-1999 (GA ČR 103/97/0593), which in cooperation with specialized institutions and with individuals laid the foundations of a system for the central archives of historical building surveys. There had been no central files before.

The grant funds are used to finance the direct costs of production and filing of extra copies of the historical survey reports. The Faculty of Architecture (Institute of History of Architecture and Arts) is the chief coordinator of the grant because the teaching program contains lectures on the theory and practice of historical building survey, both in daily regular study courses and specialized study for the doctor's degree. Research of historical architecture is closely related to historical building survey. Thus, in addition, the current results of historical building survey may be used to enrich the courses at all types of study, particularly for doctor's degree.

The grant funds made it possible to produce one extra archival copy of the substantial part of results of historical building surveys conducted both in Bohemia and Moravia. In six years, 700 surveys (some of them included more that one part) have been collected. The archival copies are filed in the National Central Archives in Prague where they are available in the local library and can be studied there under standard conditions. The list of conducted surveys is available on the Internet (http://www.shp.cvut.cz; http://www.sweb.cz/s-h-p/archshp/archshp.xls) and, in addition, it is regularly published in professional periodicals. These periodicals (primarily the journal Zprávy památkové péče) also regularly report on new acquisitions and stress the fundamental role of the archives.

Among the new filed historical building surveys are great numbers of very important historical buildings in Czech Republic. These are for example historical building surveys of monasterial and order buildings (Jihlava, Klatovy, Telč, Mělník, Znojmo, Veselí nad Moravou), castles (Bečov, Bouzov, Červené Poříčí, Česká Lípa, Chudenice, Jemniště, Kamýk nad Vltavou, Komorní Hrádek, Kostomlaty pod Milešovkou, Krupka, Lednice, Mirošov, Náměšť na Hané, Nový Rychnov, Pernštejn, Prostějov, Rabí, Stekník, Šluknov, Štěkeň, Šternberk, Třebíč, Varvažov, Vítkův Hrádek), many churches (St. Barbora´s cathedral in Kutná Hora, cathedral in Olomouc and a lot of other town and country churches), a number of palaces in Prague, Brno and Olomouc, several tens middle-class or country houses.

In 2002, the responsible grant researcher has submitted a proposal for the extension of the grant to the years 2003-2005.

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# The Central Europe Metadatabase of Geographical Data

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The project aimed at establishing first phase to a wider research leading to information service for the needs of spatial planning. Special stress is put on the cross-border co-operation and planning. The programme of the research as developed during the project is following:

- preliminary research of existing resources that are relevant to the spatial planning.
- building up the infrastructure of the project:
  - establishing of web-page with interactive database interface of institutions that are related to the data relevant to spatial planning.
  - creating the metadatabase interface together with interactive input form, that enable communication with the involved institutions.
  - transformation of the Czech National Metadatabase into the metadatabase.
- building up the personal network, consisting of one expert in each country or state (lander) in the case of Austria and German. These experts as mediators will guarantee that all relevant institutions will supply the information on their data.
- evaluation of the project

The outcome of the first phase is the interactive database that offers:

- a list of the found systems and unstructured description of data-sets
- a list of matadatabases that refer to those systems or directly to the data-sets administrated by those systems.

The interactive database is accessible on the address:
http://www.utpcr.cz/sklep/projekty/EU_metadata.

At the moment the stress is placed upon the creation of the network of collaborators in the neighbouring countries. The collaboration with the foreign experts is considered as necessary for filling up the framework of metadata and for continuous up-dating the metadatabase. The importance of such network was confirmed by the fact that extremely fragmented information field is encountered, where many administrative levels (International, National, Landers/regional, local level), administrative departments and several disciplines (land surveying/geodesy, remote sensing, ecology, geography, demography…) are involved.

As land-use planning use the secondary information that is not primary produced with the land-use planning in its focus, there is the need for further description that help us to interpret the offered information. This description is the essential part of the metadatabase structure. For that reason the content of the metadatabase will be further fined to the level of data-sets attribute description. This kind of "low-level" data collection have to be done with the assistance of the identified key institutions.

Apart from the content of metadatabase the another important issue is the metadatabase structure. The stress is placed on the interoperability of the databases - shared ontology that facilitate the automatic information exchange. Out of several standards prescribing the metadata structure, there are two of them in further consideration: European standards CEN and the newly issued ISO 19115 standard. The right choice and application of those standards is necessary for active "membership" in relevant information community.

In the course of the recent project phase the communicative infrastructure is being created. This infrastructure consists of two components: (a) structured metadatabase application that is public, read only; (b) structured form that will enable data-providers/administrators to insert the data into metadatabase. Further components that will facilitate the discussion on the data ontology are in the consideration, as all terms in German, Polish, Hungarian, Slovak and Slovene have to refer to simple English equivalent. The metadatabase is build on Access platform, interactivity is based on php scripts, automatic data exchange will be facilitated through XML format.

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# Digital Methods within the Design and Presentation of Architecture

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Over the past ten years digital technologies have become an intrinsic part of the work of an architect and are gradually beginning to influence even architecture itself. The investigation of this phenomenon is possible from many aspects and this paper concentrates, in particular, on the use of digital technologies in the actual creative process, in the presentation of the architectural project and the implementation of digital models in the sphere of the history of architecture.

Within the framework of the investigation's intention, the possibilities were considered and tested of the inclusion of the digital modelling methods from the beginning of the creative process (the early stage) and the influence of these work procedures (technologies) on the esthetics of architecture. In particular, the general modelling systems like 3DStudio have proved to be a suitable instrument supporting creativity, and thus, the design procedures can correspond to the new technologies – these are non-linear dynamic processes of intersections and flows. Experiments may be initiated with radically new concepts of space, with elements of play, with awareness of being undetermined. The programs enable us to verify spatial, light and material solutions quickly. A separate chapter are the projects where the computer plays an active role in the creation of the design, known as "computer esthetics".

There is a certain parallel here to the use of physical models, whether working or conceptual, in the design process. Naturally, the path is being investigated for the mutual combination of the digital and physical models, which is basically two-way thanks to peripheral equipment such as 3D scanners and 3D printers (rapid prototyping). For this purpose a MicroScribe 3D touch scanner was purchased for our institute with the essential program equipment. The combination of the digital model with its physical counterpart allows use to be made of the best of both spheres and these methods of working are already beginning to be part of architectural practice.

The second part of our work is aimed at the actual presentation of the project. Whether this is a standard two-dimensional presentation influenced by the use of progressive computer depiction methods or new methods of presentation which, influenced by digital methods, bring new stimuli and approaches to the presentation of an architectural work. This concerns in particular the use of visualization, animation and virtual models, which may be said to have become standard over the past ten years. Of the newer presentation technologies, we should mention the use of virtual reality – the cybernetic world (cyberspace), which enables the creators and the observers of the architectural work to perceive the presented work in a new and more intensive manner.

New work procedures have been proposed and tested in the individual modelling programs, whether in the classical CAD systems or in the specialized modelling and visualization programs (AutoCad, Bentley Microstation, Arc+, 3DStudio and others). The creation of new procedures for modelling and presentation has been tested on concrete projects for residential and civic buildings. Of great importance in the creation of the

conceptual, working or final digital models is the mutual compatibility of the individual programs. Attention was also concentrated on the compatibility of the 3D programs with the "support" applications (Adobe Photoshop, Corel Draw, Corel Photopaint, Adobe Premiere, Macromedia Dreamweaver, etc.), with emphasis on the processing of the input data and the final presentation. A demonstration of the results of this work was part of the exhibition entitled "The Unreal and Constructed World of Models ", ABF Foundation, March 2002.
New methods of presentation in architecture do not only influence the actual perception of architectural projects, but also their informative value in the process of designing and decision making is far higher than in the case of classical project documentation. The possibilities of the use of the digital presentation for the participation of the client ordering the project are considerable.

A further important part of our work is the theme: Digital models – an instrument for the investigation of the history of architecture. New methods are proposed and tested for the creation of digital models of historical constructions (work processes, the structure of models, the presentation of results). A key project of this theme is the "virtual collection of Cubist houses". The aim of the project is to create digital models not only of the existing buildings, but also of the projects which were unfortunately never realized. The basic data for 6 Prague Cubist buildings has been collected and digitalised (the remainder will be processed next term). The basic data is used not only for the creation of the computer models, but also for the processing of their physical counterparts in the subject known as MZT II (Modelling and Graphic Techniques II). One of the basic problems is the correct evaluation of the input data. In the case of the buildings which were realized, these are mainly the construction drawings, the measurement of the actual execution, photographic documentation and photogrammetry. In the case of the buildings which were never realised or have not been preserved (in part or in whole), important items are sketches, historical texts and photographs, period descriptions, the study of other buildings by the same architect and so on. The data is precise to a varying degree, collected by various people in various periods of time using various methods and very often they are mutually incompatible or even contradictory.

One of the important advantages of the presentation of historical architecture with the aid of digital technology is the element of time and movement which cannot be created in the case of physical models. This means, of course, the virtual passing through of the building or complex of buildings, but also and gradual development of the building in the course of time, individual styles and so on.

The creation of a 3D digital model means a tremendous improvement in the documentation of buildings. It may become part of the databank of important buildings of the past and of the present, and also of projects which were never realized and yet influenced the development of architecture.

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# Planners´Formation for Sustainable Urban and Regional Development

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To learn complex and not only technical and technological problem – solutions is especially important for those, who participate in man-made environment´s formation by the building and construction processes. They decide about the use of non-renewable resources (as the land, for example), locate the results of their professional activity into landscape or existing settlements and thus cultivate or devastate the environment. Multidisciplinary character of management of human settlements´and regional development ask for conceptual professionals based on multidisciplinary profile.

In 1991, the Department of Urban Planning and Regional Development was founded at the C.T.U´s Faculty of Civil Engineering. Because the management of urban and regional development is influenced by political and economical prosperity of State and a number of other impacts, the comprehensive educational process, comprises apart from technical subjects also general bases of planning and town-planning, urban design, communal economy, ecology, sociology, demography, legislational and building – law. Pedagogic activity and research at the Department concentrate on concepts of urban and rural areas´development and management, i.e. strategic, long term planning and conceiving of complex communal plans of sustainable development. The main goal of the Department is to form experts educated not only professionaly, but educated generaly „at all". The conception has been very favourably accepted by Czech and foreign students of Faculty of Civil Enginneering, mostly because enlarge possibilities of their enforcement in professional practice.

**1. General knowledge and contextual sensibility.**

Do our technical colleges and secondary technical schools make their graduates think of the influences of projected technological and technical developments on the quality of the environment and of their social and cultural impacts? Is the technical education completed with a complex knowledge of part of social and natural sciences? The Department provides a complex of courses of City- and Regional-planning, Urban Design and Settlements´ Development for all students of the Faculty of Civil Engineering and guarantees a professional module of Urban and Rural Areas Planning. It offers at the same time the advanced, postgraduate studies in the subjects described above. The teaching concept is based on the fact that the interdisciplinary character of management of human settlements and regions requires conceptual specialists with interdisciplinary professional orientation, who will be able to make qualified decisions both on the basic level of state administration, that is in Local Authorities´councils, as well as on higher levels of state administration, and who will be able to set and process the planning documentation of the area.

**2. 20$^{ieth}$ century experience.**

Throughout the post-war era the aim of education and teaching has been to produce clearly and explicitly profiled specialists with a large knowledge of their field of study, but unfortunately missing knowledge of connected or synthetizing subjects.

**3. Settlement´s genetic code.**

The effort to formulate the essential elements of the "settlement´s genetic code" should always be a part of the introduction to the study of urban planning and architecture. This should form the basis and source of initial analyses to achieve a successful development or redevelopment solutions. From the point of view of a system the planning and architectural designs in principle would reflect the changes in the organisation of the development and building processes in relation to the surrounding world as well as in relation to the inner functions and structures.

**4. Genetic code of a construction.**

The genetic code of a construction, a building is characterised by two groups of elements:

- by its typical structure and applied architectural elements and reciprocal bonds, i.e. by the morphology of applied architectural elements
- by its typical functions, phenomena.

**5. How the philosophy of sustainable development influences the planning of regions, settlements and buildings?**

Ecological transformation of settlements has the key importance when solving the crisis of environment. Urban growth together with starting shortage of natural resources and affected environment represent the global threat to our living conditions. Deterioration of natural environment was firstly manifested by the air, water and soil pollutions, disappearing greenery, increasing noise-pollution and nuclear deposits. Then losses and general functional unsutability to satisfy the real needs of inhabitants were specified. Urbanization and consequently process of concentration of population in large-scale cities, housing problems, disappearance of cultural identity of settlements, result in uniformity, utilitarity of technical products and buildings, as well. Diversified and healthy environment represent a basic value for healthy development of society.Therefore, the new forms of ecologically balanced urban development on a highest scientific and technical level are needed – „development" does not always mean „growth".

**7. Strategic thinking**

Implementation of the principles of sustainable development is impossible without the strategic thinking. It means the systematic creation of long-term concepts with the time-horizon exceeding usually the time-horizon of master- and development plans. It should comprise the identification, formulation and precision of the long term goals of development, i.e. visions of the ideal development results. It means under the specific conditions of our settlements´network the orientation on non-growth scenarios of development mostly, connected with increase of operational efficiency, limitation of resources depletion, structural transformation of resources for settlements function and existence.

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# Transformation of Urbanisme

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Sustainable development principles and a new political context require changes in methods and instruments of spatial management.

The main goal of the research is to analyze existing principles and methods of urban design and to search for new ones, as well as to define their linkage to the Building and Planning Act. In the previous years several key topics of urban and planning practice were identified and studied. The outputs were internally discussed, submitted to external experts and published. A dictionary of terminology in urban and country planning was forwarded to the Ministry of Regional Development for a wider discussion with professional public.
The research reports of below listed topics were published and presented during several conferences and seminars in the Czech Republic and abroad in 2002. The reports are available at the Department of Urban Design and Planning of CTU Prague.

- Sub-urbanization and transformation of rural settlements, urban design of villages. The discussion of conceptual changes in rural settlement under the presure of suburbanisation and urban sprawe.
- Tradition of deliberate design of urban space creation, methods and techniques of urban composition analyses
- Transformation of public spaces and for its functional consequences
- Cultural landscape and instruments its treatment, protection of landscape identity
- Regulatory instruments, content of regulatory plans, terminology and examples of methodology of regulatory instruments – comparative research of contemporary local detailed plans in Germany, Austria, Switzerland, Italy, etc.
- Regulatory instruments in history – analysis of zoning and building regulations in development plans of Czech towns in the 19th and 20$^{th}$ centuries.
- GIS management methodology in urban and regional planning – analysis of existing and emerging standards for metadata and draft of the GIS data and metadata management.

Additional topics were elaborated in 2002:

- Changes in the land use and development of urban regions in the Czech Republic aiming at development of database of land – use from the 1960s onwards.
- Recreation potential of the Czech Republic, analysis of potentials for summer recreation. The research was made of numbers of visitors to two summer resorts, the available facilities and their usage. Another survey was held at hiking and biking paths as for numbers of users and their destinations.

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# Spatial Models of Historical Buildings - Possible Areas of Utilization

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The main aim of this paper is to summarise results of a research, which were acquired during the work on a *dissertation*. The research was mainly focused on the area of Cultural Heritage. The dissertation was defended in November 2002.

Progress in information technologies together with development of methods of geodetic documentation brings up question about creation and usage of spatial models of buildings. Dissertation *"Proposal of conception of spatial information system of historical site"* is focused on seeking of possible ways from gathering spatial documentation, to creation of spatial information system (IS). The results of dissertation could be summarised in three parts.

1. Spatial data are the basis of any spatial IS. Therefore, the technology of its acquisition is a key issue. To determine relevant technology, I analysed current status of acquisition of metric documentation, i. e. which data, which format and for which purpose are currently acquired. The analysis showed that even though it is already possible acquire 3D data directly, it is only rarely used, because of higher price of this kind of product. For most of historical sites is available historical plan documentation. Proposed technology is based on this knowledge and it combines usage of archive data and new measurements.

2. When I was making the conception of IS I have to define what kind of data it should contain and on which field of usage it should be oriented. I made research among potential users of the proposed system (the management of sites). The research revealed some facts about current using of IS, about interest in new technologies and about constraints of their wider spreading. Although the used data are continuously digitised, most of them are still in classic paper form. Finance are again the main barrier of wider usage of information technology.

   Another research was focused on presentation of historical sites on Internet in Czech Republic and abroad, noticing mainly use of spatial models and virtual reality.

   Proposed conception of IS builds on results collected during above mentioned researches. The conception of IS has three main areas - subsystems. *These are aimed at management of site, research of site and presentation of site*. The subsystems have the same set of original data. The basic technical requirement is network technology.

3. Conclusions acquired during the previous stages were used in creating of conception of IS for specific site - the baroque theatre at Český Krumlov castle (UNESCO site). I created the scheme of data for each subsystem. I was also concentrating on functionality of subsystems, bearing in mind work with spatial model and spatial information.

The contribution of the dissertation is complex view on the topic. I tried to reflect current trends in spatial information technologies and their application in the area of Cultural Heritage. These trends are concretised in conditions of Czech Republic.

Full text of the dissertation is published on WWW :
*http://gama.fsv.cvut.cz/~hodac/disertace/disertace-titul.htm* .

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# Relationship Between Digital and Physical Models Used in Teaching Processes in Ateliers of Architectural creation

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Project named **Model Methods of Design – Modeling and Imaging Techniques in Architecture** proceeds on the following institutions: Department 516 – MOLAB (Faculty of Architecture) and Department 129 – Department of Architecture (Faculty of Civil Eng.)

The Department of Architecture (Faculty of Civil Eng.) deals with the following topics:

a) Utilization of basic modeling Techniques (classical, physical spatial models of architectonic and urban development)
b) Utilization of model analysis of architectonic objects (classical, physical spatial models of architectonic and urban development)
c) Computer methods of architectonic design – creation of computer models and their visualization.
d) Architectural and historical field research. Data acquisition for 3D models (of the real buildings) creation, see item c).

Certain kinds and types of models are verified during students design activities from the point of view of theoretical categories (for example: model – modeling, model as a form of dialog, semantic – language of architecture, architectonic creation – analysis – synthesis etc.)

Modeling and imaging techniques are used during pedagogical process for awakening the following problems:

- spatial perception and spatial imagination, creativity
- model as a creative instrument of architectural expression
- relation of the physical model to the graphical representation (drawing or computer model) of the conceptual and final idea
- information quality of the model etc.

Now it is developed common electronic base for physical spatial models and computer 3D models having the face similar to the first one. Physical models are transformed to the electronic representation by creating their bit map snap. This representation makes possible to use advantages of the computer processing of the models namely for:

- editing the face of physical models, retrieval of optimal texture, structure and color scheme. This procedure should match main features of the original physical model, its scale and its type.
- merging computer and physical models of buildings and environment (landscape, other buildings etc.)
- nondestructive and space saving storing of physical models

The models with common electronic base are one of possible way for improvement of spatial perception in education of the architectural creation. This type of models can also be used for presentation of the final form of student's tasks.

This type of models can also be used by professional architects for expression of procedures of architectural and urban development.

The presented article completed the following partial contributions:
ad a), ad b) : Dufek, L.: Real and Digital Models in Architecture.
ad c) :. Křemen, J., Hamata, V.: Computer Models of Buildings. Practices, Teaching, Relationships, Perspectives
ad d) : Nesměrák, M. : Architectural and Historical Field Research as a Base for Creation of Digital Models of Architecture

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# Real and Digital Models in Architecture

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The best way how to describe 3D space object is again in description by 3D form model. Objectivity of perception is affected many factors – scale, level of abstraction, material, color, and of course on the first place by observer. Through 3D form model is possible to create to create non-verbal or speech dialog.
Real models made from material such as sculptor clay, gesso, paper or cork, were at all times part of society. Afterwards took place next to the traditional material new material (such as plastics, glue), new techniques and new machinery. During last years is in use digital techniques including many different kind of software.
Purpose or goal of model is still same – to show architect's thoughts on it. In all consequences, from town planning up to detail in scale 1:1. Main question is prize of handwork, which is permanently rising. Classical models can be manufactured only with main part of handworks.
Nowadays digital era is more and more putting into practice digital models. These models are created on PCs, displayed on monitor and printed or plotted. At first it was similar to classical perspective. During time was software improve. Digital model can be viewed from all possible angles outside or inside and light it and generate all shadow automatically, same as reflection of the surrounding area placed on the glass facade. Observer or spectator by means of virtual reality can be involved with the designed object or can be its part. His or her participation can lead same as player in digital games. 3D illusion is taken in on the 2D display or monitor. In the case with use e-glasses, earphones and gloves and other specific facilities the observer become participant of the virtual reality.
During watching on the classical model, observer can apply his or her imagination and fantasy. On the other hand digital model this can hardly offer. Spectator can see here only pre-programmed output, almost on very professional level. Therefore digital models can have persuade and didactic meaning for the laic customers or clients.

Models can be divided by purpose on the study models and final models. This term can be use with the real models and same as digital models.
Author trough study model verify his or her design. Study model is simple, in real form for example only volumes, in digital form for example wire - line. But for laic user must be each model most close to reality. Models have to have staffage explaining scale – peoples, cars, trees. Real model are always individual work, each model is original. Scale is define in advance, change of scale is eliminated. Only details can be even specify. Changes made on real model are very arduous. Real model perception is validated throw thousand years humankind experience.

Digital model perception is easy to use. Globalization rate of digital models are equal as digital technique globalization. Programs use same library elements in whole utilization area. Programs for digital models technique develop top programmer and architects of digital models can start from their product. Simplify creation with program limitation. Perfect digital

model can lap design shortages for laic spectator. The scale is here irrelevant; any changes can be performed very quickly.
Study models are inexpensive. Digital model prize include also software prize. Real model is costliest. Model value does not have to match model prize. We are acquainted historical, documentary, art and didactic value.
We are in era of drastic entry of digitalization. Somebody can estimate that all design including models tend to use digital form. Technical documentation in digital form has a lot of advantages, which are reasonable.
Real models can't be replaced by digital model. Real model need space for deposition, but real model lifetime is long and correspond with material lifetime. Digital model usable life is short and is limited by information media working life.
Real model have own specific task and utilization. Digital models too. Requirement of all architectural competitions demand design form including model. Architectural university works with classical models as well as digitals models. Front architectural studios too.
Good model can underline good design, but only nearly perfect model will not built up good design, good architectural work.
But this is a different story.

Remarks:
1. Term study model is routinely use in architectural design offices
2. Author of term final model is prof. J. Pospíšil, architectural offices use term model, which mean model of final design as well as for model of completed structure.
3. Scale 1:1 can be enforced also for model try-out, which is evaluating suitability or unsuitability building on project site.

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# Computer Models of Buildings. Practices, Teaching, Relationships, Perspectives

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This paper deals with the part of the scientific grant solution, which is focused on the computer modeling in architecture and construction, but which covers quite broad thematic.

Computer models in architecture and construction undertake several tasks.

1. In the process of the new design formation:
   - discussion and communication of the new design conception
   - architectural design
   - construction design
2. When the need of description the existing but damaged or even almost extinct object by means of the model language arise and in the model reconstruction to historically documented form or the form according to an accepted hypothesis. It is possible to set up a computer model even of an unrealized project usually by the well-known architect.

Several types of software modeling tools exist for solving the above tasks. CAD systems represent perhaps the oldest software tool for imaging the construction object during its computer design. The new systems that accompany CAD systems in the recent time can be divided into two main streams. The first tend to the in-depth and more detailed visualization and animated presentation – these systems are usually called virtual reality environments. The second type, in the contrary, tends to the free sketching in 3D space used to express the essential architectonic conception – these ones belong to the free 3D modeler category. When modeling the existing objects it is necessary to obtain their data. We can use available drawings and photos with geodetic data added. Nowadays software tools for construction of polygonal represented computer models from digital photos (bitmaps) taken in a special manner are available.

The solution of the above mentioned scientific grant is based on setting up and verification of methods used to solve the following tasks:

- Creation of complex computer models of buildings abundant in architectural details by means of GDL language in ArchiCAD environment.
- Development of methods for impression of beaux arts style to „cool“ computer models
- Creation and utilization of the material textures looking like real surfaces of the materials of the modeled buildings. Methods of raw data acquisition and their transform to the convenient textures (bit maps)

- Creation of parametric library parts by means of the ZOOM GDL 2 program for applications in ArchiCAD
- 3D modelers testing (RHINOCEROS at this time) from the point of view of availability for the representation of the basic architectonic concept of the proposed building
- Merging of 3D computer models of buildings and environment (landscape, other buildings etc.) by means of ArchiCAD tools and PhotoShop
- Basic tests of creation of computer models of buildings looking like physical models. Composition of computer models with electronic form of physical models
- Setting up of polygonal based computer models derived from photograph snaps (program PhotoModeler), their language translation to CAD system (data format conversion by the PolyTrans program). Also possibilities of reducing complexity of polygonal representation are tested.
- Methods of creation of virtual reality models and their presentation (including Internet).

J. Skácilík and J. Dvořák (PhD. students) have contributed significantly to the solution of this research.

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# Architectural and Historical Field Research as a Base for Creation of Digital Models of Architecture

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Architectural and historical field research is carried on in order to obtain necessary data for creation of digital models of contemporary conditions of researched buildings and their developmental periods in the case of rebuildings or adaptations.

The objective of the research is, together with working out and verification of methods of architectural research of contemporary conditions, measuring and acquiring of photo-documentation of current state and acquiring of images of researched buildings (in the case where it is possible) from the time of their creation till today.
To fulfil the aim of the research there is necessarily worked out detailed history research of the buildings in order to understand particular phases of their development.
The studing of literature is complemented by detailed research of available projects, period images, photos and postcards which has brought the papers documentating the conditions of buildings in researched history period from the point of their architectural form and even sometimes from their colour design.
Together with the field studies and studies of technical literature and historical sources there are studied urban relations or appropriately the changes of original urban relations.

This year the research included the studying of executed architectural, photographical research and measuring of buildings (areas of Veltrusy, Krásný Dvůr, Terezín) which were used for research and educational needs at Faculty of Civil Engineering CTU - there were studied all available basis in technical literature about the afore mentioned buildings.
There were as well studies made on all available graphical basis (engravings, drawings, watercolours and photos or if available postcards) representing researched buildings during their existence in order to determine their original appearance (in the case of damage) or if appropriate their structural development in the case of building adaptations or rebuildings (There was acquired a number of original and published images from the period of 19th – 20th century)

These studies were worked out for already measured buildings (Doric Tempel - Veltrusy, Tempel of friends of countryside and gardens - Veltrusy, Laudon's pavilion - Veltrusy, Pavilion of Marie Terezie - Veltrusy, Chinese pavilion - Krásný Dvůr, Gloriet - Krásný Dvůr, Goethe's pavilion - Krásný Dvůr, Panův Tempel - Krásný Dvůr, Pavilion in the city park - Terezín) and as well for the buildings, which will be measured and researched in the next phase.
Because of damage of some already researched and projected buildings, the consequence of this year's floods, there were worked out (not part of the planned schedule) preparatory studies of the further deteriorations (It seems to be necessary to work out repeatedly architectural research and analysis on buildings next year which were damaged again in chateau's park in Veltrusy and in the city park in Terezín in cooperation with J. Tencar)
These new information are not only important for projecting of their actual conditions but as

well for prospective preservation design of these from architectural point of view (as well in European context) remarkable important buildings.

In 2003, together with architectural and photographical research (in areas of Františkovy Lázně, Karlovy Vary, Mariánské Lázně), there is planned other studies of the technical literature and especially (if possible) of archive materials of already studied building so of the buildings which research is planned (in cooperation with J. Tencar).

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# Model Methods of Design, Model and Presentation Techniques in Architecture

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Research Assignment VZ028 deals with the wide spectrum of disciplines of presentation techniques and modelling in architecture. This assignment includes research and its application to the areas of structural design itself, where these methods serve as the fundamental means in the architectural creation process. Physical presentation methods are compared with those of visual simulation, with relation to two-dimensional graphical methods, in standard model type, in digital shape, and with digital modelling methods as well. The research assignment observes the possibilities of interconnection and mutual complementation between these two trends. At the same time the research assignment deals with the utilization possibilities of a special scanning technique, endoscopies, possibilities of photography and not least with the saving and filing of documentation and outputs, as well as the possibilities of their operational searching and sharing for the purposes of further utilization.

**From the design chronology point of view we distinguish three model categories:**

1/ ***idea model:***

- ***conceptual,*** is the first spontaneous concept of the design idea, its sketch-like improvised formulation that is only rarely executed in a particular scale. The material for construction of these models is chosen with the intention to express the structure idea; the reality is not the priority aspect.
- ***in scale,*** represents the next stage of space articulation. As soon as the scale is determined, it is possible to organize the volume parts in coherence with the land and the required functions and to harmonize them among one another. The basic solution possibilities for the organically growing work are shown very soon - this is a valuable aid for a beginner and a simplifying means for a practitioner.

2/ ***work (sketch) model*** serves the designer in further creative process to achieve the optimum solution by means of tests, variants and comparisons. This model type includes the whole scale from the idea model to the final model and is diverse according to the purpose and utilization. It is hardly necessary to emphasize that for a work model serving for already exact control of the spatial effects of the intended images the scale is a necessary presumption. Although the work model represents the most valuable category of auxiliary means in architectural creation, it is, despite the given examples and quotations of the world-famous architects, very rarely utilized by the designers professional circles, and namely in concluding and detailed works. The more studies and comparisons are carried out in three-dimensional form for each stage of the project developments, the less you can be surprised or upset after the workout of the final model (See the example of the airport in Ildewide – E.Saarinen).

***3/ final model (facsimile)*** focuses upon 2 fields. It is an important aid and basis for managing, administrative and investment compounds for the purposes of optimum decision and situational assessment. So that the practical activities can be realized the state controlling bodies,

corporational and institutional management must give a stimulus and make a decision on this activity and at the end of the designing process to assess, decide and invest billions of crowns per annum into the realization. The field of the construction management, especially in city construction, is very sensitive, first of all because these bodies include professionally diverse staff fully engaged in a number of separate questions, who must address the problems of building development within minimum time and be fully responsible for competent decisions regarding important investments. This model category thus simulates structures and designs in the same form as they were approved and as they should be realized. In themselves they accumulate the results of the whole preceding research by means of work models, and where there was an idea model at the beginning of the way.

**Another, from the qualitative point of view different category, is an experimental model.** For these models the m o d e ll i n g t e c h n i q u e is the determining factor. This includes a complex of theoretical methods (and those applied from other branches). We use measuring appliances and devices by means of which exact measuring and choice are carried out for the purpose of detailed, and partially also artistic solutions from the visual, physical, statical, acoustical, luminous points of view etc. The necessity for the usage of three-dimensional technique as a necessary working method, which enables complex verification and testification in the reduced scale thanks to the enormous development of technology, new materials and technologies, is becoming essential in more and more fields. The construction of water management structures, some branches of mechanics and electronics, chemistry etc., uses this method as their main one. A complete theoretical profession of this method, called *theory of similarity,* has been developed. Among these professions it is a separate scientific discipline nowadays. Its application to a larger extent than nowadays can also influence the participation of exact methods applied for the usage in modelling technology.

The almost boundless content of the construction and creation possibilities makes designing in two dimensions and measuring according to the conventional computation method difficult, despite the help of modern computation technology. The experiments on models are in many cases more conclusive, especially if we have to determine irregular or free forms, tents, framing or cable structures, because these complicated building structures are beyond the exact mathematical calculation. Both the past and present brings a number of examples of these methodological processes.

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# Influence of Strategic Investments on the Regional Development and Its Consequences

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Brownfields are defined by the United States Environmental Protection Agency as "abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination." Vacant industrial sites, gas stations, commercial buildings, and offices all fall under the heading of brownfields.

Brownfields can be found in almost any town or city around the world. Historically, lending institutions, investors, and real estate developers were cautious when dealing with brownfield redevelopment. However, these entities have become more tolerant of potential exposure as they become more knowledgeable of risk.

When we are thinking about brownfileds we can find 3 practical argument for building: First, brownfields were considered to be a ready supply of available land upon which to build, and housing was in large demand. Many of the hundreds of thousands of brownfield sites were not commercially viable because they were too small, badly shaped, poorly linked to infrastructure, or located in residential neighborhoods. In addition, site reviews found that many were not contaminated, or were only slightly contaminated, so that cleaning up the sites for homing would not be prohibitively expensive.

Second, in some cities, brownfields are the only readily available supply of land for new housing, schools, etc.

The third reason to build housing on brownfields is to improve neighborhood quality and the environment. Crime and physical decay kill neighborhoods as well as mentally and physically wound their residents.

Of course there are arguments against building: Incompetence and greed are the biggest threats to rueful brownfield development in neighborhoods. In some projects, city officials are granted permits without going through the essential research on previous site uses. In other cases, where the proper up-front research is conducted, developers may find higher levels of contamination than they originally anticipated. Under these circumstances, developers often ask their funders for more money. In turn, both developers and funders may ask their insurance companies for compensation or try to get money and benefits from state and local governments. In the meantime, the projects may be stopped, resulting in even larger eyesores than before the clean-ups began. Even worse is the possibility that developers would try to hide high levels of site contamination.

Conclusion

Although brownfields can pose a risk and do not offer much aesthetic value, they should not be ruled out when looking to build or develop land. Because they were once inhabited, brownfields are usually located in areas where the infrastructure already exists. The utilities are already in place, such as electricity, water, and sanitary sewer lines, and generally there is easy access to interstates or highways. They can be completely redeveloped and made safe. In fact, many large industries with numerous properties have initiated a proactive approach to redevelop their "orphan" properties.

Many cities are losing their identities because many industries and businesses have left urban areas and relocated to greenfields. Greenfields, which are the opposite of brownfields, are fresh, undeveloped lands and are typically found in suburbs or rural areas. Brownfield initiatives allow cities to redevelop their inner cities and/or industrial centers while preserving precious greenfields from development.

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# PROLAB – Changes of the Real and Virtual Space

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Space laboratory – the target of the project is the realization of the space laboratory on the field of Faculty of Architecture, CTU. Spacelab (called Prolab) is structure that enables space modelling on the scale 1:1 (so-called Full-scale Modelling).

This structure could be used to support and develop space imagination of students, to encourage their ideas and architectural designs, to demonstrate the relation between form of space and construction and light. It enables a practical teaching how to work with materials, interior and stage lighting, study the rules of spread of light and psychical effect of the colours and and observing the influence of the space conditions and its character to human´s psychic.

For construction of the space 3-dimmension models 1:1 could be used principles of existing structural and lighting systems of theatrical or exhibitional spaces. This modelling will approach the work with these systems to the students.

The suppliers of above mentioned technologies will be pleased to seize the occasion to lent these structures and systems to the Prolab for their own prezentation on the academic field. Prezentation will open them the possibility to get new business partners. The occasional rent of the Prolab for expert workshops and schooling is not out of the question. Thanks to its variety the Prolab is placed at occasional theatre scene disposal, screen or photographical studio or exhibitional hall. Wide options of the Prolab enables to be used by the students of other faculties and schools – technical and art subject field. Also the economical conctribution of the lab is not neglective to the faculty budget.

There are many existing space labs on the european national research centres, art schools or technical universities, which function like departments of faculties of architecture. The european space labs are associated by European Full-scale Modelling Association, which arranges international conferences, edits publications about full-scale modelling and secures contact between the labs. The members of the association are labs in Graz, Wien, Copenhagen, Düsseldorf, Wiesbaden, Bologna, Malta, Trondheim in Norway, Wageningen, Amsterdam, Eindhoven, Delft in Netherlands, Lund, Gothenburg, Stockholm in Sweden, Lausanne in Switzerland. The others lands including for example Slovakia, Canada or Venezuela are sided members of the association.

In the term of the year 2002 the grant´s activities, in Department of Interior and Exhbition Design of Faculty of Architecture, consist in setup procedure in spacelab Prolab realization.

There was create the system design to subseme spacelab (and sided skilled workman´s shops) in supposed building program of the new Faculty of Architecture buildings and also to show how usefull spacelab would be.

As the first stage of following Prolab realization there was split-off small room for semi-permanent spacelab on the Interior and Exhibition Design Department of FA, CTU. This room and its equipment will serve mainly lighting design teaching and working – luminaires, illumination, intensity of the light, light colour mixture, stage lighting. Creative lighting begins with the knowledge and experience of natural lighting and how humans respond under different lighting conditions. Add to this, the appropriate equipment and a flexible installation, and the benefits are immediate. Language of light consist of Intensity, Contrast, Directionality, Movement, Shape, Texture, Colour. Targets of lighting design are: to

communicate, to create illusion, to make believable, to evoke emotion, to incite awe and wonder simultaneously decisive rules are make lighting aesthetically pleasing, make it memorable - to create break point, provide variety and changes, simplicity, no sloppy light keep things clean, avoid a „style".

There will be possible, not important that on the small area, introduce basic space arrangement rules in the lab too. At the same time it will help to create image about the importance and functions, of planned big and permanent spacelab Prolab, for getting industrial and academic partners for realization. Form the grant´s budget was got necessary lighting technology and other equipment.

Start of the small lab running is supposed at the beginning of summer term 2003, to be used in this time for teaching as soon as possible

Other work on the project Prolab will continue in the year 2003 with getting subsequent industrial and academic partners, spreading the technical possibilities of present semi-permanent small lab and searching the convenient space for big spacelab.

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# PROLAB – Virtual Exhibition Design – New Effective Tool of Marketing and Communication

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The steady increase of performance of personal computers in last years allowed us to use them in new fields of human activities. An example of such an application is a virtual exhibition. The idea to use this approach is based on the fact that the potential number of visitors could significantly outnumber the number of visitors attending a real exhibition. There are several reasons for this statement: easy accessibility from geographically distant locations, the visitor can choose the time when the virtual exhibition will be attended, it is possible to visit only part of the exhibition and continue later. Last but not least there are no travel expenses connected with attendance of such an exhibition.
The use of virtual exhibitions has also very significant impact on the process of design and creation of a real exhibition. It is possible to create a virtual model of the exhibition and investigate various aspects of the design – like layout of the exhibition as a whole, layout of specific parts of the exhibition, satisfaction of aesthetic criteria (colors, illumination etc.). The manipulation with virtual model of the exhibition is much easier than the manipulation with the real one. This fact makes possible for the designer to experiment with a large number of designs and choose the very best one. In such a way the quality of the final design could be significantly improved.
The idea to use the paradigma of virtual exhibition has been used abroad for several years. Unfortunately in the Czech Republic this techniques is not used neither for virtual visit of a virtual exhibition nor for the design of real exhibitions. The aim of our research is to develop technology that will be easy to use for standard designers (of virtual and real exhibitions). Due to the inter-disciplinarity of the topic two departments from CTU Prague started research in the given field in the framework of project CTU 0216915. The research team consists of experts from the field of architecture and experts in the field of computer science.

The technology used in the framework of our project was virtual reality. Due to the nature of the project we used the approach where the scene (model of the exhibition) is described by means of VRML. This approach relieves us from the usage of expensive 3D browsers as the walkthrough the virtual scene is done by standard means like Cortona and other browsers of this type. Another reason for our choice was the fact that that the model of exhibition can be easily accessed through internet (easy availability of the exhibition).
One of serious problems in this type of application is how to achieve maximum feeling of reality for the user. Of course it is possible to generate model with high level of details by means of which we can achieve the quality of perception that could be close to photorealistic images. This approach has the main drawback – large volume of data necessary for the model description what is a sort of obstacle when transferring the model description to the user. This problem concerns mainly the description of the exhibition stand environment – like a large exhibition hall.

Our solution supports cubic panoramic texturing, so that an illusion of a real exhibition hall can be created. To achieve that , we need only six photos of the real exhibition hall. These photos are mapped onto the inner side of an abstract cube that represents the environment where the virtual exhibition will be installed. The exhibition stands (that create the exhibition) are described by means of primitives available in VRML. Several primitives put together represent e.g. furniture model or some other objects that could be used in modeling the exhibition stand. The use of textures (e.g. representing various materials the furniture or other objects are made from) adds in general high degree of reality to the model created.
Using the panoramic texturing the virtual visitor (avatar) sees not only virtual exhibition stands but also the entire exhibition hall just the way it looks in reality. The use of panoramic textures reduces significantly the volume of data necessary for the model description what is especially important for this type of application.
As it has been already mentioned – the virtual visit to exhibition can be done by means of a standard 3D browser. The approach to the scene modeling has been described in a general way. As a part of our solution a special modeling tool has been designed and implemented. The main stress has been put on its user-friendliness. The main idea is that the individual parts of an exhibition stand will be composed from standard primitives available in VRML. In order to make the stand definition easier, four basic types of geometric primitives specific for this application have been predefined: Panel, Column, Bar and Furniture. Panel is represented by a box, which can be textured (material or a picture like a company logo). Column and bar are elements that divide the space in the stand in accordance with some criteria. They can be textured too. The most interesting and useful type of primitive is Furniture. It is very general and in fact it can mean any VRML 2.0 model. This means that the object (Furniture) could be predefined outside of our modeler and imported into our scene (model). One of important features of this type of objects is the interactivity. In such an object a specific point could be defined that triggers a specific action that can have an animated character. It could e.g. linked up with functionality of the real object the virtual object represents. This adds in a large extent attractivity for visitors of virtual exhibitions.

The system described has been implemented and tested on several virtual exhibitions. The future work will be concentrated on the tests with real users and further development of the system. The systém in its current state is suitable not only for the design of virtual exhibitions but also for educational purposes at CTU – Faculty of Architecture – Department of Interier and Exhibition Architecture.
Existing on-line exhibitions /see references/ present virtual stands like photos or informations about firms with the possibility of watching presentations, contacting persons by e-mail or on-line meetings. Our solution could present the exhibition stand in the real space of the exhibition hall or exhibition ground using cubic panoramic texturing and complete or change the virtual stand design during exhibition.

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# The Influence of Strategic Investments on the Territorial Development of Regions and its Consequences

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Immediately after the velvet revolution in 1989 became the Czech Republic one of the European countries convenient even for foreign investments as far as its territory which needs after the period of socialism many investments of its own which shall to be invested from the public budgets but also from the privat sources.

With reference to the competent influence of particular investments on the economic and territorial development of the region there is a necesity of extensive analysis engaged to the evolution of unenmployment and the average of salaries and a structure of unemployed persons and the citizens who are economicaly active at least in two similar regions concerning geografic position, stucture of citizens and the height of unemployment. In our case we have chosen the regions of Pardubice and Hradec Kralove, especially due to the fact that those regions hardly affects each other and there is also a rivality among them.

Refer to the appreciation of the particular investments we shall take some divergences and mention the foreign industrial investments, foreign investments in services, domestic public and domestic privat investments.

The foreign investment has been by most of our political representatives concerned as benefactory for the economic increase of regions, but in the light of time we can also see the negative face of those investmenst, various in the field of investments in business and services and in the industrial investments.

The majority of the foreign companies gave work to many citizens, but in case of leaving the region with reference to termination of production we can see the alarming impacts to the region. The situation in unemployment becomes aggravate than before incoming of the foreign investor, especially because in relation to the competition strugle become extincted or inoperative a lot of the small factories and companies and there is no reason nor chances or finance to bring them back to life and we can see the insufficiency of Employers. In the area of the territorial development we can find in such regions buildings – commercial halls or stocks on production which is not possible without main charges to reconstruct and use them otherwise, what means that those buildings falls into disrepair and become ruins. There has been also established many of industrial zones which have been not so expensive for construction opposite to the requierement to reconstruct and rebuilt the oldest, not functioning areals.

In the area of business and services we can see almost the invesment into the shopping centres, markets and shopping malls. In the middle of the period of ninetees, i.e. in 1990 – 1996 the main stream of invesments has been into the construction of supermarkets in centres of cities, but also in the suburb of them with reference to the fact that distance has been in relation to the particular territory. It has been shops with the business area of 200 – 800 m2.Those shops became to the locality the possibilities to work but also the competition for the existing business companies. With reference to the dicrease of the potentional of the

citizens to purchase and increase of the offers of products, food or other the Czech Republic become also a very interesting territory for the construction of shopping malls with the business area also of 12 000 m2 and commercial and shopping centres where we can find holding of invesments and more invesments in one. There have been a lot of politicians who took this answer as very interesant for solving of unemployment and competition. Here we can imagine the concrete case of the city of Pardubice, where the facts says that in 2000 the business area in the relation to one citizen has been doubled to the material of the Ministry of Industry "Development and optimalisation of dimensions of the small business chains in the territory". This material has been undertaked from abroad with reference to the appease of the market in this field and showed that the business area is to be trasnmitted, moved or changed to other sortiment and quality of purchasing. The surfeit of the market was as the result of dicrease of the commercial activities from centres of cities, change of the good sortiment by other in not such a quality, let say for "indigen people" and also something what we can say as "anesthetization" of the center of the city which must be the most attractive place even for business companies and for customers. In Hradec Kralove it seems that they have been in this time a bit prudent and carreful and in this period the situation was better than in Pardubice. With reference to the rivality of those neighbour cities but also in Hradec Kralove the politicians wanted to become "better" and they among few years withered all the efforts of their predecessors to save the style of living in the centre. Since 2000 in those two cities has been established new cca 50 000 m2 of the business area for food - 20 000 m2 in Pardubice, what means increase in the amount of cca 38 % and 30 000 m2 in Hradec Kralove, what means increase in the amount of cca 70%. At this time we can speak about the overload of the transport which has not been prepared for such situation, about the liquidation of the small businesses and companies whose are not allowed to compete by prices or by sortiment of products and also last but not least about the dicrease of the culture of shopping.

Concerning to the domestic investments we can not speak in such negative discrepancies to the development of the region, especially to the fact that even their volume could not be omited, those are investments in financial comparison scarcely ever competitive to the foreign, but the regional importance for the region is incomparable. Those investments brings the new working possibilities, but their main goal is to be long-time investments and the investors are willing to stay on the market for a long term. The public investments have the significance in two levels. One of them is to increase the quality of institutions in the Czech Republic (investments into the State administration, courts, public services etc. ) and the second means the increase of the quality of life (infrastructure, housing estate etc.)

Finally we can claim that our analysis brings the question wheather the best solution for the evaluation of the economic situation of regions is "to beat up" the foreign investors without deliberation and with the consequence to slight the domestic investors.

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Section 15

# TRANSPORTATION, LOGISTICS, ECONOMY, MANAGEMENT

# Sociological Analysis of the Production Processes

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Economists commonly view the economic process as one of production and consumption. Production involves the assembling and applying of resources; consumption, the "using up" of the resultant product. Unlike consumption, production does not involve satisfaction of human wants.

By "technical determinants" I refer to certain physical and biological factors associated with the concrete productive process; these include "size of the plant and company; seasonal and cyclical stability of its production pattern; volume, nature, rate of technical change," illumination and noise at the workplace, and the biological limitations on the workers.

These technical determinants affect human activities and interaction in the following ways:

1. The technical arrangements of work determine in large part the degree of physical exertion required from the organism. In the past several decades investigators of fatigue and productivity have studied the significance of temperature, rest pauses, length of work day and work week. The results of these studies are difficult to assess, largely because such factors are so contaminated by social and psychological variables.
2. Technical features of the job influence the pacing of work.
3. Technical arrangements of production influence the level of skill required of workers. A familiar example is the difference in skill level between the craftsman-sometimes requiring years of apprenticeship-and the assembly-line worker-whose skills are elementary and can be learned within a matter of minutes or hours. The loss of skills which resulted from industrialization is a basic cause of the lack of identification with the product often attributed to industrial workers.
4. Technical features determine the degree of complexity of the division of labor. Modern industry has carried worker specialization to a level never before reached in human history.
5. Most important for the study of economic sociology, technical features of work influence the character of social interaction. The physical pattern of work calls for certain kinds of cooperation, communication, and authority on the job. This influence often extends to off-the-job interaction as well.

The introduction of automation may reduce the importance of many variables stressed heavily in modern industrial sociology. Many modern investigations focus on the impact of variables (such as the quality of supervision and the character of informal work groups) on morale and the corresponding impact of morale on worker productivity. Many of these determinants disappear in the automated setting. The morale of work groups has less immediate effect on output, because the machines are controlled automatically in so many respects; nor can the foreman, traditionally a pivotal figure in morale and productivity, influence the level of output in an immediate sense.

Should the conflict be avoided at all costs? Conflict is usually uncomfortable, so people tend to think of it as bad. However, if people handle a conflict with mutual respect and trust and achieve an outcome that is favorable to the organization, conflict can be a positive force.

Conflict and stress are natural parts of human life. Lack of resources in an organization can spur employees to put forth their best efforts to operate efficiently. Lack of conflict may be a sign that employees are complacent, that they have given up on participating, or that the organization suppresses creative thinking.

A high level of conflict tends to be disruptive because it damages morale, interferes with coordination, and prevents employees from efficiently accomplishing their objectives. Logically, then, organizational outcomes should be best with a moderate level of conflict. At a moderate level, conflict may be a source of needed change and can increase employees' motivation to think creatively and do their best.

Many conflicts in organizations arise because people or groups want the same resources such as funding, promotions, desirable work or working conditions, or management attention or approval. If managers conclude that conflict would be a positive force, they may want to stimulate conflict. Stimulation is appropriate when a complex problem needs to be viewed in new ways.

Organizations must care about stress because too much stress may be costly. Too much stress may impair employees' performance. In the social environment, the major sources of stress are the employee's supervisor and coworker. In general, employees are most satisfied with these relationships when superiors and coworkers help reach valued outcome and the parties have a positive attitude toward each other based on shared values, attitudes, or philosophy. Whether stress responses to work overload are damaging over the long run is unclear. A year study found that those who had the greatest hormonal response to increases in workload were healthier, more satisfied with their work, and described by colleagues as more competent. Apparently, they responded to the heavy workload as if it were a stimulating challenge rather than a burden.

At the other extreme, according to the Japanese Health Ministry, about 30,000 workers a year die from a condition called "karoshi", meaning death from overwork. Karoshi appears to be caused by a combination of stress, high blood pressure, and apoplexy. The Japanese government has responded by setting a goal to reduce the number of hours worked in a year from 2,050 to 1,800.

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# Advanced Methods of Flexible Pavement Design and Rehabilitation Enhancement

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The aim of the project was to solve urgent problems associated with the innovation of our approaches to the pavement design and rehabilitation in close cooperation of theoretical and experimental researches with emphasis placed on computational modelling of the road engineered materials structure. The research was performed in two main directions:

(A) enhanced analysis of flexible pavements behaviour based on improved theoretical pavement model with enlarged spectrum of computed information involved in assessment of the factors influencing pavement exploitation process,
(B) determination of basic material parameters of construction materials and development of pavement performance evaluation models via integrated approach combining experimental analysis and computational modelling of composite material structure.

The research results can be grouped in several major branches:

(a) Refinement of the pavement layered computational model by:
- incorporation of transversely isotropic layers in the layered system [4]; the theoretical solution is based on Lekhnickii approach using three harmonic functions, the computer algorithmization is performed using Fourier integral transform representation and asymptotic formulae to improve convergence of the stress/strains finding procedures,
- enhancement of the transfer interface properties controlling stress and strain transfers between adjacent layers [1]: transfer characteristics U allowing physically sound modelling of the layers slipping (improper bonding) and S accounting for stretching properties of reinforcing element possibly built in between the construction layers,
- computational procedures allowing effective determination of the layered model structured objects - values of stresses, displacement and strains simultaneously with values of their derivatives with respect to the basic structural and interface characteristics of the layered model; the structured objects indicate sensitivity of design factors to changes in structural and interface parameters and serve as a basis for the pavement design optimization, reliability and displacement testing considerations.

(b) Structural modelling: the method of multivolume modeling has been used to derive macroscopic (effective) material characteristics of the layers made of composite materials (e.g. asphaltic concrete) or layers of composite composition (block layer). Following enhancements has been accomplished:
- new computational procedures allowing substantial refinement of the microstructural modelling, characteristic volume can be divided up to 200 microstructural blocks with individual material properties,

- generalization allowing to consider inclined interfaces between structural parts, applicable in block layer modelling and modelling of crack evolution in damaged layers of pavement structure.

(c) Contact problem of a slab system of the concrete pavement representative section resting on a layered supporting system [3]:
- computational procedures were developed allowing to quantify process of plate system interaction with layered subgrade as well as the inter-slab interactions due to the reinforcement elements placed across the pavement joints,
- computational process was refined to produce information on stress cycles induced in slabs by passage of vehicles over the representative pavement section as prerequisite for the advanced cost-saving pavement performance evaluation procedure.

(d) Analysis of factors influencing terms under which the current Czech design procedure TP77 is used, the aim being to improve potential of this method by bringing it in agreement with our recent experimental and practical experience with following findings:
- the experimental research results on mechanical properties of asphalt mixes were used to establish procedure allowing TP77 based performance evaluation of pavements with innovative materials (such as high stiffness modulus VMT materials) with the same degree of reliability as possess standard catalogue pavements.

At the present time, the fundamental innovation of the current Czech design procedure is taking place, the presented research results may be used in this process to:
- rational modelling of destructive processes taking place in flexible pavement structure during its exploitation,
- propose a new evaluation procedure for the block pavements using multivolume structural modelling and layered model with transversely isotropic materials,
- lay foundation of the new advanced procedure for design of concrete pavements using actual data on vehicle configuration, traffic stream composition and realistic model of pavement interaction with subgrade and actual role of the joint reinforcing elements,
- realistic modelling of the performance contribution of the stress relieving membranes and reinforcing grids built into the pavement structure,
- realistic modelling of the mechanical impact of the layers with damaged material structure (cracked layers) that form part of the reconstructed pavement.

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# The Role of SMEs in the Regional Development of the Czech Republic

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The role of SMEs in the Czech Republic is the outcome of a long history of economic development and industrialization throughout the last century. The industrial basis went through different stages. The change from disaggregated small-scale manufacturing to relatively concentrated industry, on a private basis, which was the experience of the first half of the last century, was followed by the concentration of state-owned enterprises in the planned economy. The deregulation and privatization of the last decade, however, led to the revitalization of entrepreneurship and the creation of many small or middle-sized enterprises. The market driven economy promptly highlighted enterprises' weak and strong points and the regional context of entrepreneurship became an important indicator of economic performance.

SMEs are important segments of the economic landscape of the Czech Republic, since half of economic production is attributable to SMEs (52,85 %). The main concentration areas of SMEs are *Agriculture*, *Forestry and Fishing*, *Restaurants and Trade*, *Market Services*, and *Construction,* in which sectors the share of small and medium-sized firms in total production is higher than 80 per cent. However, the share of SMEs in total manufacturing production is only 35.25 per cent, according to 2000 figures. This outcome, and several of the problems in manufacturing, is the result of the policies followed in the *planned economy*. The main problems are low economic efficiency, suppression of interest in innovation and technical progress, low productivity, high percentage of wages in the value of production, etc.

The Shares of SMEs in Total Production and Value Added

| SMEs in (year 2000) | Share of SMEs on total[1)] production | Share of SMEs on total[1)] value added | Relative Differences |
|---|---|---|---|
| Industry | 34,2 | 34,7 | 0,5 |
| Non-financial institutions and households | 54,2 | 53,7 | -0,5 |
| Construction | 74,8 | 77,4 | 2,6 |
| Agriculture, forestry and fishing | 83,4 | 81,6 | -1,8 |
| Restaurants and trade | 88,3 | 85,3 | -3 |
| Transport, storage and communications | 46,2 | 23,9 | -22,3 |
| Market services | 87,8 | 82,4 | -5,4 |

*Source:* Czech Statistical Office 2001.

Currently, the incentives to growth have been oriented not only to large-scale industry, services and other segments of the economy, but also to small and middle-sized enterprises. The support provided for the factors promoting development has led to the rediscovery of SMEs as an important instrument of economic progress. The ability of SMEs to operate within the new global economy is more limited, since globally operating enterprises have a greater ability to succeed in the global market and to deal with economic problems. However, there is a need to balance business opportunities between *large* and *small or medium-sized* enterprises, in order to initiate and sustain regional development. It should not be forgotten that SMEs are important not only for their role in economic growth, but also for their contribution to the strengthening of social cohesion.

In spite of the lower value added per worker created by SMEs, the welfare attributes of small entrepreneurship make SMEs important for local and regional development. From the economic point of view, large public enterprises may have a comparative advantage compared with small ones, since they can support the unemployed and the socially handicapped, but SMEs are able to substitute for several public social services in the regions. That is why SME support schemes are cheaper than direct payments of social services and unemployment benefits by governments. SMEs are crucial in the development of the regions. The investment requirements of SMEs are only half as demanding as the investment requirements of large-scale enterprises. Apart from this aspect of SMEs, they are more flexible and have an ability to create changes and innovations. That is why SMEs are the subject of attention, not only in the Czech Republic, but also in the European Union.

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# Internet Information Sources for Development of Product Strategies of Small and Medium-sized Industrial Enterprises

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Currently is the market in such situation, when it is under influence of many various factors among them do play not a negligible role processes of globalization and widespread slow-down of economies of developed countries. It very often comes to a situation at the market that there are competing small and medium-sized producers with big producers at the market and there are coexisting one or few big producers and large number of small or medium-sized producers. All of those producers are naturally doing their best to reach certain market share which means that they try to service group of customers who are on the market. In case of a big producer there is vitally important to service lots of customers but it would be very rare that this big producer would reach completely all market. Usually it is considered as a big success if a producer reaches major part of a market by which we mean that he reaches a set in which is included major part of consumers. Such a producer usually has two basic strategies of taking the market. One of them is reaching of the customers through his products which more or less cover needs of consumers. The other method is some way of an active fight against competence from side of small and medium-sized producers. In reality have those big producers one but very effective gun for the fight against their competitors. The gun is the final price of the product, which must be paid by a final consumer if he or she wants to buy a product.

Large producers have an indisputable advantage of ability to cut down their input costs by pushing down on their suppliers. On the other hand large producers have to produce high number of products in large batches so they set the standard of product but are unable to be sensitive enough to the market. Small and medium-sized producers are able to meet exactly customers' needs and they can better and faster adopt market changes and integrate them to their production strategies. For being able to use the advantage of being such flexible do small and medium-sized producers have to develop very effective product strategies supported by definite amount of information of certain level of quality. The small and medium-sized producer has to solve the problem of systematic gaining and using information to reach competitive advantages with the goal of effective reaching profits. The development of effective product strategies depends on the quality of information that we use and on the quality of the analysis. The goal is then to identify information and information sources and to use them effectively.

To find out important data we have to identify sources that give us needed information. Such information sources we can divide into following groups internal firm sources, eternal firm sources and Internet firm sources. Among internal firm information sources belong mainly accounting and derived sources. Further on we put into this group calculations, budgets, information about research and development, firm performance, sales and economic performances of unit brands and the firm together and past decisions. The most common extern information sources are marketing studies. With their help we can gain information about our market position, our and other customers and about our competitors. Generally said

if a small and medium-sized producer wants to develop an effective and unique production strategy he should be using some source of information that is offering updated data in real time. Because of the fact that small and medium-sized producers have to be cost careful is the Internet the right choice.

As Internet information sources for development of production strategies of small and medium-sized industrial enterprises can be effectively used B2B Exchanges. Observing of running of a B2B Exchange can answer many questions about all factors of products, as are technical level factors, economic level factors and marketing level factors. We can find information for making effective decisions in most important fields of the production strategy as are portfolio strategy, product strategy, promotion strategy, pricing strategy, distribution strategy and development strategy.

When talking about portfolio strategy we should focus on finding information about competent products which exist on the market so we should study selling part o a B2B Exchange but a small and medium-sized producer can study a buying part of a B2B Exchange as well because there are listed needs of consumers of products who demand some qualities and hope that there exists a product on a market that meets their demands. Concerning product and pricing strategy we should focus on prices of competitive products as well as consumers ideal values. There is a straight link between the price level and level of production. We should study promotion strategies of our competitors and the general knowledge of our and competitors products. A very important field is the distribution strategy. Once a company starts to integrate the Internet into what it does, it changes everything. The most important change is the way that the company sells and distributes its products, and then way that the company communicates with other companies. For example, the way it communicates with its suppliers, the way it produces the goods and services it needs and the way it manages its whole supply chain. Finally, the Internet enables companies to move away from fixed pricing to dynamic pricing models (e.g. through the use of B2B Exchanges).

Not only are the B2B Exchanges a great opportunity to change the way the company runs its business but B2B Exchanges are a powerful source of information. For having a reliable information we should study not only selling part of B2B Exchanges which means to compare our products or prototypes with bids our competitors but we should study the buying part of B2B Exchanges as well to learn more about customers needs. We can register ourselves as a virtual consumer to make a demand on some product to study how fast and how flexible the market reacts.

Using B2B Exchanges as a source of information by studying competitors' products and consumers needs or offering a model or prototype product to real consumers to learn their interest in such a product that is a very useful information tool for development of product strategies of small and medium-sized producers. Important is that we gain a definite current information which would be otherwise connected with costs of making a market or consumer research.

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# The Life Cycle Costs Application on an Equipment Renewal

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A theory of means renewal (elements, machines and equipments, means of production, hauling units, complete industrial plants etc.) is relatively wide and complicated area of the operations research. Renewal processes are studied and solved by means of mathematical models mostly with goal of their optimization. The cost items are included in a structure of these models besides other items at their practical construction.

We can say the practical calculations relevant to equipment renewal exclude complete costs. There are rising some other costs or losses during equipment operation. Applied calculations do not count on these costs or losses at the moment. Therefore there is a necessity to look on equipment renewal problem from the all possible costs and losses point of view that they can came into existence in a period of the equipment life, so from the life cycle cost point of view.

One of the problems which solved by the renewal theory deals with it is renewal equipment in consequence of its wear. This problem steers on determination of the equipment economic life in substance. We need to know means lifetime in many cases. Its size is important e.g. for allowance for depreciation determination, it is necessary to operate with it in derivation of important relations in renewal, we have to look on it in deciding about major repair or modernization making and their efficiency and it is important data for determination of the economical most suitable equipment change period above all.

Therefore the first part of the paper is just dedicated to calculation of the equipment economic life at life cycle costs inclusion and this calculation comparison with common aplicating calculations including incomplete costs.

It was dedicated in renewal theory less attention to the problem of the equipment modernizations so far. But these appear as actual equipment renewal solution at the moment because of some enterprises bad economical situation. It is usually too little spoken in connection of modernization making about that at what equipment operating time is suitable to realize this modernization or if it is economically suitable optionally.

Next part of the paper deals with question of the right moment determination for this modernizations realizing, of the new (secondary) equipment life-time determination after modernization and with depreciation rate determination finally, and all above from the life cycle costs point of view.

Wide means choice of all cattegories that is available on world markets exacts of potential users grand question solving – which one from offering is for them most suitable. One of the criterias which future users of these means should decide according it should happen (and it is often done so at the moment) not only purchase costs size, but costs size that user will have to spend in connection with these means keeping especially – called proprietary

costs. These costs may namely be largely different for individual means and exceed purchase costs even while multiplely in whole life-time in absolute summarization.
Therefore next paper section include a model of suitable means choosing for user that should be for him economically most efficient.

We can note there is few enterprises in our republic that they are monitoring and evaluating in detail and systematically a size of all life cycle costs for products offering to customers. It was proved the users usually have most data available, but more interests and workers knowledges of preliminary stages miss about similar processes sometimes.

As a thesis advantage should be mathematical models and costing expression in general which should make possible sequence application on whole scale of concrete cases at certain input assumptions and at condition of knowing these cases input data.

I hope this paper will help to more complex view on problem of the renewal theory by its equipment life cycle costs point of view.

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# Ecological Aspects of Transportation

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This grant was obtained for the establishment of a new subject *"Ecological Aspects of Transportation"* at the Czech Technical University, Faculty of Transportation Sciences. This facultative course is intended above all for students of the fourth year of study and is closed by the skilled credit.

Our faculty is mainly focused on technical sciences but since the transport is one of the main fields that strongly impact our environment, it is necessary to show to our students, future generations of traffic engineers, how does it work – how the transport affects the nature, landscape and the whole environment.

Firstly I would like to give you some more information about a new course *"Ecological Aspects of Transportation"* or *" Transportation and Environment"* (we have to rename this subject because there will be a new subject *"Ecology of Transportation"* in our faculty under the terms of structured study). It is an integrated subject connecting technical and ecological study. Content of this subject aims the negative impacts of transportation, mainly noise and vibration (influence of noise on environment and human health, its intensity and spreading, attributes of the sound waves, measurment and reduction of noise and vibration.), emission (air pollution and its impacts, emission from road transport), water and ground water pollution, occupation of landscape (landscape systems and ecological stability) and barrier effect (green bridges).

Practical exercises run in the field as well as in the Ecological Laboratory at the Department of Transportation Systems in Landscape. Students work in small groups and their tasks lead them into self-activity, teach them how to search information and how to use them. Students learn to use up-to-date technology and machines, for example they measure noise using the Modular Precision Sound Analyser (BZ – 7206) or speed by the Laser Radar LR 90-235/P.

Evaluation of the first semester of the new subject *"Transportation and Environment"*

| Registered Students | | | | |
|---|---|---|---|---|
| Years | 3th year | 4th year | 5th year | Summary |
| | 10 | 19 | 21 | 50 |
| Branch | DI | ME | AI | |
| | 42 | 6 | 2 | 50 |

*where:*

*DI* Transportation Infrastructure
*ME* Management and Economics in Transportation and Communication
*AI* Automation of Transportation and Communication

Secondly I would like to mention some difficulties with environmental study at our faculty. Environmental subjects at the Faculty of Transportation Sciences that I teach:

*Protection of the Nature and Nature Sources*
*Ecology*
*Landscape Ecology*
*Environmental Impact Assessment*
*Waste Management*

Compared with the numbers of technical subjects, it is a drop in the ocean. At the beginning of the course I give a small opinion poll to my students. I ask them about their notions of ecology, ecological activities in their cities, ecological activists and so on. I query them for example: *"What is your take on green organizations and green activists? What is your attitude to waste management and sorting wastes?"* And so forth. It is very interesting to compare these inquiries and to see the changes.

When I started with teaching four years ago, most of my students interpreted ecology like "natural history", the subject that they had known from elementary school or in the worst case like the battle cry or political propaganda. But now their answers, their opinions, are more skilled and captivated. We can see a shift in opinions from *"I do not know, I am not interested in, it is just political slogans"* into *"very important, I want to extend my knowledge of this subject area, I need to know more about it "* et cetera.

There are two main problems in environmental courses that I have to solve. The first one is the unconcern of some of narrowly technical focused students. With this indifference resulting from the technocratic point of view I have been fighting with alternating success.

The second one is the different knowledge of the students in this branch. Students came from different kinds of secondary schools. Some of them attended grammar schools, the others business schools or technical colleges and I have to even up their commands. At the end of the course some students say that the curriculum was very easy but the others think that it was uphill and complicated. Sometimes is very difficult to find the golden mean.

In this short contribution I try to point out the main problems and difficulties with environmental study at the Faculty of Transportation Sciences.

The environmental study is one of the main topics that are discussed in our country by experts and also by general public. But usually all discussions concern environmental study at universities where the students are majoring in the humanities, especially where they are concentrated on environment or ecology.

The environmental study at the technical universities is not a matter of great concern. And it is a pity because the technical activities mainly impact our environment. It is imperative that engineers have the knowledge of nature resources and ecosystems.

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# Application Wireless Technologies in Transportation

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Application wireless technologies (GPRS, DECT, Bluetooth) in transportation will have above all chief meaning for drivers. Possibilities appear above all in offered services. The solution, how to get needed information to drivers, is by means of radio ways. This is the question of sending actual traffic information, dynamic navigation, localization position, etc. Next utilize appears in preferred rescue or police cars on the crossing. As well it will need to communicate inside vehicles with whole series electronic devices. Wireless technologies offer mobility connection among devices and thus much greater comfort. There are on our market a lot of wireless modules, which are controlled by means of AT commands. Above-mentioned three varieties of wireless standards it is possible to one another practically to combine and to complement. Problems can set in the instrumentality of other devices working in the same band. It concludes to rise disturbance and it limits above all reach appropriate devices.

GPRS (General Packet Radio Service) is wireless communication on base of GSM (Global System for Mobile Communications) Network 900 and 1800 MHz. GPRS is based on the principle of utilization so-called pack (package) switching data transmission and it allows connecting to internet with transfer rate from 20 until 40 kbit/s. Package switching increases utilization of spectra and speeds up traffic. Advantage is also payment behind data bulk and not behind time of connecting. Next field of application is data collection from different gauging stations; obtain information about position of company car or controlling of different remote devices. GPRS offers analogy of slower telephone line, with relatively universal usability anywhere in terms of one's of the state, and with limited possibility of roaming in abroad. There are defined four kinds of CSx (Coding Schema) in the standard ETSI (European Telecommunication Standardization Institute). Society T-Mobile implements by sequel CS3 and CS4 for data transmission GPRS. It entails practically double growth transfer rate with compared to contemporary CS1 and CS2. Of course it is possible use CS4 only in places with good signal.

DECT (Digital Enhanced Cordless Telephone) works in band 1880 - 1900 MHz. This band is divided into ten channels, which they are divided further into strings 24 repeating timeslots. Twelve of those timeslots operate traffic from BTS (Base Transceiver Station) to MS (Mobile Station) and second twelve slots use for reverse direction. DECT uses as well as GSM modulation GMSK (Gaussian Minimum Shift Keying). Perhaps substitution of cable for data transmission afloat until the distance about 50 meters in building and 300 meters in opening free space. By one of data modules working in terms of standard DECT is offered of society Siemens. Below mark MD32 hides wireless data nets of short reach. Relatively small thin plate in them hides proprieties of base and mobile station and it presents ideal solving for applications with dataflow round of ones till tens kbps. Data transmission is characterized by very low error rate.

Bluetooth is universal radio system in band 2.4 - 2.48 GHz. It consists of very small network segments (piconet). Technology Bluetooth became at first standard for information transmission among mobile phones. Today this technology is widely spread for the communication among notebooks, mobile phones and PDAs. If you want to use this technology, you need a special adaptor. One of them is, e.g. MSI USB Bluetooth adaptor of

company Microstar. It is connected by the means of interface USB (USB 1.1 and 2.0). Data flow is maximum 723 kbit/sec. The guaranteed reach of device is 10 meters, whereas the adaptor can work in free space approximately to the 200 meters. Power supply is ensured by means of USB port voltage 5V. With the help of mobile phone the access to the cellular nets is possible. The network topology "ad hoc" is applied in the Bluetooth system. This adaptor can communicate with 8 other data stations in the framework of only one piconet of structure. The first device, which sets up the connection, serves the function of the control section (Master). Other data stations constitute Slave units. The function of the Master segment is merely temporary and it wears off after-nullification given nets. Arbitrary data station can communicate at the same time with several pikonets. This network topology is called "Scattered ad hoc". Data station Bluetooth uses transmission with Spread Spectrum (with coded multiplexer). It reduces possibility of mutual interference among single devices, which are working in this band. Optimum solution is frequency skipping of carrier wave FH-SS (Frequency Hopping-Spread Spectrum). Radio transmission is protected in system Bluetooth against error rate. Technology Bluetooth has simple independent protocol and its implementation requires no promotive infrastructure except own devices and peripheries.
The first stage of this project will be practical testing of functionality of radio communication among single data modules. All operating modules are controlled by means of AT commands, transmitted after serial interface V.24. Those modules will be used in real conditions for verification of theoretical knowledge about using wireless technology. It will test the modules in a moving car within the reach of GSM signal connection to Internet and data transmission by the help of combination GPRS phone, Bluetooth and a notebook. Some of the data modules DECT will be set up into the mode of BTS, the other modules will be set up into the mode of MS. The next step will be the placement of stations BTS for coverage of the area of the traffic crossing. After that radio communication among stations MS placed in a moving car and stations BTS will be tested. Thus, the program equipment for measurement of data transmission will be created.

The aim of this project is the application of still not very broadly used technology DECT and also relatively new technologies GPRS and Bluetooth in technical practice. The concrete target of the project will consist of testing modules, suggesting the philosophy of measurement and evaluation of interference influence. Furthermore a method will be developed for giving the right of way on the crossing for public transportation, rescue or police cars, etc. In real conditions, we will focus on transmition capacity, connection to Internet, with real coverage in the framework of the given infrastructure.

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# Risky Alternatives Decision Making under Incomplete Information on Scenarios Probabilities

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Decision making under risk and indefinableness with give a name decision-making situation, in which with offer no-rational tell - world, surroundings etcs., which elects her variant-construction sequence cases 1,2,...,n accidentally with knowns (estimative, statistically ascertained) probability p1,...,pn (decision making under risk) or without them (decision making under indeterminateness).

For lucidity with this situation entraps in the table, where lines forge variant and columns states of the world, whereby with says scenarios. Every variant presents decision, whose consequence is tactful chance quantity, increasing funds depending on state of the world. For every scenario - state of the world exist probability hereof state of the world.

In this case with advise like criterion decision making Bayes criterion mean value, which is product funds criteria for variant decision making pertinent state of the world and his probability.

At entire information about probability scenario we talk of point evaluation variant. However, if information about probability scenario is incomplete, acts with about intervallic evaluation variant.

Task is then to find of such funds probability scenario, for which put on evaluation variant maximum or minimum. This task is possible to solve by using linear programming, where probabilities scenario posture as variables linear programming mathematical model.

Provided that probabilities scenario are not given pointwise, but proceed in interval, then funds these probability, for which put on mean value incidence those that variant maximum or minimum with adventitious like optimum solving two models of linear programming.

Record is, that for any variant is fixed term no one mean value, but interval mean value. The one with then confront with interval mean value the next variant. Variant decision making is preferred as unambiguous, when its low-water mark interval mean value overmatch ceiling interval mean value near collation variant. Choice variant however can be preferred and at that time, when with lags mean value evaluation both variant overlaying.

Explication consists at that, that upper and low-water mark interval mean value was rated for any variant abstractedly from purview evaluation of others variant. That is why isn't out, that to overlaying interval mean value evaluation one couple variant can fetch no funds probability scenario in branch determinate incompleteness information about probability scenario. To pertinent identification preferential relationship between variants the model linear programming is used, whereof with incidence variant recompensing difference incidence couple variant.

Mutual comparison always two variants it is possible to find out dominant variant

(better variant) and dominate variant (worse variant). As far as any variant dominates of all other variant, acts with about optimum variant.

For numerical solving above-mentioned tasks it is possible to use parametric linear programming. It is possible to use common linear programming with utilization sensitiveness news in postoptimalisation as well as.

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# The Channels via which the Foreign Direct Investment Affects the Domestic Economy

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The importance of the foreign direct investment (FDI) for the developing economy seems rather obvious: FDI, among other things brings in new technology, increases employment and gross domestic product and in the longer run generally improves the balance of payment.

The economists spell out a few interrelated channels and often loosely name these channels as spillovers from the FDI to the domestic economy. Here we briefly review the channels:

1. FDI that involves the technological transfers can be a potent source of learning of a new technology and organizational and management methods. Thus the transfer of knowhow may take place trough the turnover of the works and experts from the foreign companies established through FDI to the domestic firms. Moreover, the FDI can serve as an learning place since the skillfull employees in the FDI firms can acquire the necessary knowledge to run their own firms later on.

2. The demonstration affect that arises from the differences in the level of technology and management methody between foreign and domestic firms. The domestic firm can watch and imitate the way the foreign firm operate and thus become more productive. Of course, this may also occur the turnover from foreign to the domestic firm and than the demonstration effect is complementary and closely releated with the learning effects described above. The demonstration effect was at the focus of the early empirical studies of the FDI and it seems to be rather important in accounting for the part of the South-East Asian economic miracle.

3. The competition effect brought about by the presence of FDI in a particular industry has usually (at least in the short run) the ambiguous consequences on the domestics social welfare. On the one hand, it forces the domestic firms to more efficient use of the existing technologies and resources and increases their incentives to adpot new technologies in order to maintain the existing market share or even to survive in the market. On the other hand the inflow of FDI can initiate the massive exit of the less productive domestic firms if the gap in the productivity between the foreign and domestic firms is too large. That may cause adverse welfare effects (at least in the short run).

4. Finally, so called backward and forward linkages effects of FDI if present, have probably the most profound effect on the structure of the economy and thus on its long run social welfare and economic growth rate. Namelz, if foreign firms established through FDI engage in

the intensive transactions with the local supplier and customers, these foreign firms usually impose the discipline and the new rules of the behaviour. Thus even in the absence of a direct involvement on the part of FDI firms, local suppliers are forced to meet demand for higher quality and on-time delivery and to inovate more. Moreover, the foreign firms may provide technical assistance and training to local suppliers or may assist them in purchasing raw material so as to maintain the quality of intermediate goods. That all represents the example of the backward linkages effect. As for the forward linkages, they for instance, occur when the domestic firms seek to purchase the intermediate goods from foreign suppliers that are superior to those obtained from the local suppliers. It is important to note that backward and forward linkages are associated with the notion of so called inter-industry spillovers whereas the other type of spillovers are coined intra-industry spillovers.

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# SW Tools for Engineering Support

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Modern management requires supporting computing tools and techniques like simulation, sensitivity analysis etc. Economic data processing is usually realised by force of spreadsheet calculator. However, these tools are not used in most construction companies enough. The solving of economical problems is usually simplified into calculation, which mostly do not use modern methods and computing support possibilities. The lack is massively presented in extensive calculation divided into separated spreadsheets and formulas. The risk of mistakes is not equal to calculation complicity but arises due to transparency lack. Efficient management requires quick control and base information about relevant items.
The main source of errors seems to be a missing or badly filled cell. It leads to the distortion of facts because in terminal cell you cannot see an influence of blank cells, which make up her. Probability of creation these errors rises especially in case when some data are not available at the entering time and there is an expectation of completion. Software application FaultCell explores single values in cells and sets registration list, where you can find suspicious values with their location.

An application Balance Sensitivity is designed for determination relations among the followed value and its parameters. This tool operates on Excel platform. The sensitivity of single parameters is expressed by two ways. The first method is a colour analysis. User chooses a concrete percentage value for six categories, which means possibility to change the followed value by change of the single parameter more than is a limit for a category. Then is chosen a parameterisation range for parameters and type of changes (fall, grow, absolute). As a result are coloured cells that follow defined sensitivity category. The second way of the sensitivity analysis is a list of singles parameters with their concrete sensitivity expressed by number.

A tool Simulations is designed for comfortable using simulations on a spreadsheet platform. There are tools for automatic searching all parameters, which intervenes to a simulated calculation. Determination of distribution probability for each parameter it is possible by three methods. The first way is via an expert selection. User chooses a verbal valuation of the absolute valuation, the risk of evaluation and the development trend. After this selection is configured a shape of distribution probability. Further method is an empirically distributed function that is composed from data. The third way is smoothing data distribution where data can be smooth more twelve distribution functions. Results of simulations are analysed by

statistic methods. The output gives many statistic values and graphs with info about the simulation process.

Dye Tender Optimiser is a tool for an optimisation of tender budgets. The application works with budgets, which are assembled in spreadsheet programs. Data from the concrete budget are checked in their connection and than is displayed a sensitivity of each parameter expressed by cell colouring. The first parameter for an optimisation is a supposed amount change for each item. The further aspect is a timetable of billing.

A genetic algorithm (GA) is a biologically inspired problem solving method. The basis comes from Charles Darwin's theory of evolution. The basic idea is that chromosomes (string of genes) constantly reproduce. This reproduction occurs at different rates according to natural selection. This natural selection means that the fitter chromosomes reproduce at higher rates than other chromosomes. As far as GAs are concerned the chromosomes represent possible solutions to a given problem. The process of natural selection is selecting which of these solutions are closest to solving the problem and selecting them to continue on to future generations. These selected individuals are then recombined and possibly mutated and the process continues. The end occurs when a termination criterion is met which is probably when a satisfactory solution is discovered or perhaps a time limit is passed.

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# Sustainable Development in Regions

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1) Under given conditions for sustainability it is needed to define not only sets of activities (sets of processes), with which we do work like with material controlled model (P), but also structures of extension (derived) character, i.e. set of operating models (L).
Lets define also a process of management (M), (Beran, 1997 and 1999). To simplify the situation will be the operating model described only in space of content-differentiate components created on base of so called returnable processes Pi = <A, K>, where A represents a set of components with their physical description U, dependence in time D and a set of dependences of content character Q. K are connections between components with their set of physical description V, construction of connections $\Delta$, and starter of connections $\varepsilon$.

2) The application Services is designed for money planning of innovations and services in urban areas. The tool operates on Excel platform. User chooses in a dialog box concrete types of buildings, which are in monitored urban area. The type of building is possible combine from four chosen patterns. Patterns are described by a percentage of particular constructions, a verbal legend and by a view. Individual models are stored in sheets and sum of them creates a concrete urban area. The money planning of innovations and services is shown by single years. Individual values are counted from formulas and there is a possibility to change parameters straight in sheets.

3) Technically economical disciplines have, in many cases, the same philosophy. They help to make major decisions on the calculation base. Solution of these exercises is a dynamical process. This process does not have to have only one solution. Then, it is suitable for solving the dynamic model. Using simulation and optimization eliminates the danger of choosing one solution only as this solution does not have to be the right one. After gaining of more solutions, it is much more easier to identify the problem places. On these positions, the management tools will focus. Dynamic model is able to design regulation interventions or requirement of optimization in the course of constrains.

4) The interrelate pulsation of the world economy, such as long waves and local change processes still plays a marginal role within research field, whereas it seems to be one of the more promising and fruitful directions for study. One of the investigate purpose VZ 6 was seeking for the answer: Can the aerial photographs be one from a promotive argument for the long waves development? There were analysed time series aerial photographs of four towns, were evaluated the areas of roads, industry area, housing area etc., and there were confirmed their cyclical development which is corresponding with Kondrateff long waves.

5) Agenda 21 brings principles of sustainable development that can be used in a sustainable urbanization. These are as follows:

- Efficiency: Resources should not be overexploited. Neither should they be unutilized. Utilization, however, must prescribe full restoration.
- Sufficiency: Resources are to be used for absolutely necessary ends. Their use must aim for the highest marginal returns.
- Consistency: Ecosystems should be managed in a manner that is compatible with each other.

6) The planning process is on of the key elements of project management, which foregoes controlling and managing processes. Planning the project means thinking about and documenting what needs to be done – defining and coordinating specific activities and work tasks, assigning and allocating resources to activities, and developing an acceptable budget. Controlling the project means staying on course – tracking work progress and actual costs, comparing progress and costs to the baseline, devising workarounds, and recommending action. Managing the project means communicating as accurately and timely as possible the schedules progress – what has happened – and what may happen ("what if" analysis).

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# IT (Information technology), support to HR (human resource management )

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IT (Information technology), support to HR (human resource management )

I would like to quote from book effectiveness information system author is Zdenek Molnár [1].

[1] Molnar,Z.: Efektivnost informačních systémů, Grada, Praha 2000
"Very often direct managers to attention selection IS/ IT for loading information system are assembler only on problem of that investment to IS/IT was a full blast efficient, it is. Was reached with smallest expenditure performance requisite aim, for which is IS/IT producer. Only little direct managers to realize, that man is indivisibility part of IS/IT, and that the "human source" is necessity to direct, it is. Mean planing, organiseate, motivate, check, but especially reclaim, it is mean. Make guarantee his personally development. Alone that man will be no weak article from informative infrastructures company. "

Biggest problem in company is changing, "steerage changes". At any changes with company divide in 3 encampments.

10% employers are not agree with change
(Company do not have to lust energy to wok with them.)
10% employers are agree with change
(This group useful for steerage change, company have to given them opportunity to grow.)
80% employers do not know they do not care
(This is very good group to work with and give them lot of opportunities to trust now change.)

From work experience we known that changes at IS/IT or any change, which should have been preferable, many times changes have fallen. Money, which was invest, do not requisite the effect. That is why a selection of management information system HR, I advise in advance discuss with staff and get in them in changes to passage new technology. Firs phase of selection information system should be engage in whole company especially workers how will be include in change rewound.

Before incident to by selection concrete SW system for human resource management we must make clear about what is that human resource and management generally. Here is not only personal accounting, how with many industrial company thing. Human resource management is self-contained unit in any industrial companies. Companies must learn to installation HR into they.

First would like to presentation fusion for appreciation content SW product on CR market for solving personal information system.

EVIDENCE: Systém for personal accounting, and evidence
PERSONÁLNÍ FUNKCE: Systém for evidence + education, selection, assessment
EIS / ŘLZ: Analytic System HR for managing to strategy, planing, HR marketing, managing HR companies.

| | | | EVIDENCE basic: | PERSONÁLNÍ FUNKCE: | EIS / ŘLZ |
|---|---|---|---|---|---|
| | Name of prodact: | Company: | Using for: | | |
| 1. | AsKit 2000+ | INVENTA s.r.o. | yas | yas | yas |
| 8. | mySAP Human Resources | **SAP ČR** | yas | yas | yas |
| 11. | ODYSEA 2001 | A.S.E.I. spol. s r.o. | yas | yas | |
| 2. | JETRO, verze 3.1 | DRINGS, s.r.o. | yas | yas | |
| 9. | Elyasr GLOBAL | Elanor spol. s r.o. | yas | yas | yas |
| 5. | HR plus | MMI, s.r.o. | yas | yas | yas |
| 7. | OrgPublisher | MMI | | yas | yas |
| 4. | HR info | Mmi | yas | yas | |
| 6. | Personal INFO | MMI | | yas | yas |
| 3. | OKinfo | Oksystem, s.r.o. | yas | yas | yas |
| 10. | VEMA PAM | VEMA , s.r.o. | yas | yas | |
| 12. | TARGET 2100 | M – PRO | yas | yas | |
| 13. | Mzdy | UNICOS s.r.o. | yas | | |
| 14. | ABRA | AKTIS a.s. | yas | | |

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# Evaluation of Investments in Information Technology Projets

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The rapid growth of information technology (IT) investments has imposed pressure on management to take into account the risks and payoffs in their investment decision-making. At the same time, they have been confronted with conflicting information regarding the outcome of IT investments. Some researchers and professionals argue that IT will be a key resource for sustainable competitive advantage, or at least complement the creation of distinctive advantages. On the other hand, others suggest that the productivity gains from IT investments are neutral or negative.

Managers facing the evaluation problems of IT investment have used various methods from simple computational formula to very complex techniques that weave both quantitative and qualitative analysis together. Among them, quantitative methods are common in evaluating new technology, but these types of methods that are often used in capital investment analysis do not necessarily capture the entire impact of new technology adoption.

The justification of IT is a complex issue due to many intangibles and non-financial benefits, which are inherent in the implementation of IT. Companies that used traditional approaches to justify the implementation of IT indicated a degree of uncertainty about how to measure the full impact of their investment.

This difficulty is linked to the intangible characteristics of the benefit promised by IT, such as improved communication and control, enhanced capabilities, and competitive advantages. Moreover, the complexity of new technologies such as flexible manufacturing systems and computer-aided engineering and design prevents management from getting a complete picture of the firm's IT portfolio.

There are several strategic purposes for IT investment that can override a negative expectation of economic value. Sometimes, even though the expected economic value is below zero, companies decide willingly to invest in a certain technology to capture the opportunities the investment endows. The reason decision-makers pursue this route is because these investments may involve other options such as growth opportunities. These types of real options can be largely classified into growth, postponement, and abandonment options. Growth options include scaling up, switching up, or scoping up an investment and give the opportunity to exploit a prior investment in a sequential investment. Postponement options involve deferring an investment in order to obtain new and better information about prices, costs, and other market conditions. Abandonment options, which include scaling down, switching down, or scoping down an investment, allow managers to exit from an IT investment before they become too involved. Among these options, postponement and growth options are considered the most important by managers, while the abandonment option is considered less important. Metrics such as the economic value added method and the real option valuation have been recommended by information systems (IS) researchers as a way to understand and facilitate investment decision. These methods focus on the economic value and real option value of IT at

the time of investment justification and provide information on the perceived impacts of the IT investment. The lack of knowledge about real options prevents managers from utilising this salient method to valuate their investment. Real options frequently occur in the managerial decision-making process and managers recognise the importance of securing flexibility in capital investments. Most managers still use the traditional formalised methods, such as NPV and ROI, because they are sceptical of new analytical tools and they have difficulty in renouncing ongoing investments. Few firms have used methodological procedures for thinking of investment flexibility because flexibility is often dealt with informally and in an ad hoc way in firms.

When implementing IT overall consideration must be given to the company's organisational strategy and full support and commitment of the company must be in place before commencing any projects. In particular, an organisations IT manager should have full knowledge of the company's strategy, commitment from management employees are also some of the important issues that need to be considered when contemplating an investment in IT.

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# The Planning and Management of Lifelong Education

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## The role of the institution

The lifelong education is usually based on the distance method. The distance education needs to be differentiated not only from conventional classroom based education but also private study at home. People learn a great deal through their own offers. What distinguishes distance teaching is that is an institution that is consciously teaching its students.

The separation in space and time of teaching and learning is a basic feature of distance education. It worth stressing that this separation is not the exclusive prerogative of distance education systems. Some proportion of learning activities in conventional systems take place apart from the presence of a teacher. Increasingly so as one passes up the scale from school to university education, while many distance education systems include elements of face to face contact with teachers.

The structure of the lifelong education is a measure of education program's responsiveness to learner's individual needs. It expresses the extent to which education objectives, teaching strategies, and evaluation methods are prepared for. Or it can be adapted to the objectives, strategies and evaluation methods of the learner. In highly structured education programme, the objectives and the methods to be used are determined for the learner, and are inflexible.

## Lifelong education is different from conventional education

- A wide range of media is used, some of which are uni-directional but some of which allow for two-way communication.
- Long lead-in times are required to develop and produce materials and courses.
- The long-in times mean that the operational planning horizon is extended over several years, during which time the institution has relatively little scope for implementing radical changes. This places a premium on strategic planning.
- Developing a lifelong taught course using media requires considerable investment in staff time, with the result that individual teachers often have work together to realise the course. Various solutions to this problem have sought (e.g. the course team approach, the academic-editor/ consultant approach).
- The teachers who develop the courses are unable to realise their programmes alone, but instead have to rely on range of non-teaching staff- editors, designers, audio-visual producers, warehouse operatives, etc. - if their programmes are to be produced and delivered to the students. The development processes in particular brigs a range of specialist academic staff together in project teams or as a production line.
- Individual academic staff experiences a loss of control over the products of their labour which is not found in conventional education systems.

- Traditional approaches to budgeting and to the determination of staffing levels are not readily transferable to lifelong education systems.
- The development and production of lifelong teaching materials requires a production management approach.
- The cost structure of lifelong education is different; involving significant investment in course materials and administrative systems before a single student is enrolled in the system.
- Functional divisions dominate the organisational structure.
- Currently, the management of lifelong education requires a greater degree of hierarchical control than is found in conventional education systems.
- Non traditional education systems generally need to show that they are effective and efficient. This places an increased premium on evaluation.

While by no means implying that the planning and management of conventional education is necessarily easy, these features add to the complexity of the management process in lifelong education systems. Greater emphasis is put on hierarchical management and there is lower tolerance of collegial, politicised and anarchic models of academic management. This not the same thing as saying that lifelong education system is an industrialised form of education. The product line analogy does not bear too great a scrutiny.

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# Methods of Strategic Management in Transnational Companies

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From early 90. of the last century, firms couldn't pay attention only to domestic markets, regardless to how great they are. Many industries and businesses had become worldwide and their leading firms reached lower costs and their products became famous. Nowadays, protective policies only delays the entrance of foreign firms to the domestic market, best defense for each firm is global offensive.

Work out strategic marketing and competitive strategy on international level in principle means, work out wider fundamentals, determining in which direction the firm will move on domestic and international level, which aims will be raised to the future and by which means they will be achieved, and that is the classical approach.

Nowadays strategic management presents complex activities, which are created from research of market's condition, needs and wishes of consumers, identification of strong and weak sides, specification of social, political and legislative conditions and determination of source disponibility, which can be chance or threat, and formulate according to acquired informations the aims and the goals of the firm.

Every firm, which enters a competition in a given branch, has its own competitive strategy either clearly formalized or hidden. This strategy could have been evolved explicitly, by planned process, or implicitly, through various functional firm departments.

Analytical procedures in strategy generation

- structural analysis
- competitor analysis
- firm behavior on market

Structural analysis and competitive strategy

When the forces influencing on the competitor in the branch were determined, then effective competitive strategy raised on offensive or defensive steps, so to create sustainable position against functioning of competitor's power.

Structural analysis and branch definition:

Structural analysis deals with competitor widely, over exceed frame of competitors, every branch definition is basically election where to lead the dividing line between established competitors and substitutants among existing firms and entering firms, etc..

One of strategic analysis main kinds is vertical integration, it is a combination of technologically different productions, distribution, marketing or further economic process in the frame of one firm. This integration by managing its risks can be a big firm advantage in its global actuation.

Competitor analysis:

All important current competitors must be surveyed, indeed its also useful to survey future competitors which may enter into the branch.

Competitor analyses has four components

- future aims: On all management levels and at all dimensions
- present-day strategy: How firm leads in current competition
- expectations: Self and branch behavior

- capabilities: Firm's strong and weak sides.

Firm's behavior on market

Firm's behavior on market otherwise market signals is any competitor's act which gives direct or indirect supposition of his intentions, motivation, aims or inner situation. Market signals are indirect communication means on the market and most of the behavior, perhaps the whole behavior can contain information which can help during competitor analysis and strategy formulation.

Strategic management approach during strategic decision making and strategy formation:

1) Where are we now? Strategic and marketing analysis
- marketing auditing and SWOT analysis
- Segmental, productivity and ratio analysis
- approaches to competitor analysis
- approaches to customer analysis

2) Where do we want to be? Strategic direction and strategy formulation
- mission and objectives
- structural, market and environmental analysis
- market segmentation, targeting and positioning

3) How might we get there? Strategic choice
- product and new product strategies
- pricing policies and strategies
- the promotional plan
- the distribution plan

4) Which way is best? Strategic evaluation
- criteria of choice
- modeling approaches

5) How can we ensure arrival? Strategic implementation and control
- problems to overcome
- management controls

Other phenomenon, considerably expanded during the past few years is fusion or acquisition, very valuable is attempt to find probable candidates. Fusion can instantly change weak competitor into decisive, or can strengthen the one with already good position. Aim acquisition prediction branch can be founded on its proprietary situation, on ability to cope with future branch development and on eventual attraction to make buissness in the branch.

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# The Effective Organization

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The term of effective organisation is connected with the most important problems for good function of companies. There is increasing of competition in essential system environment today. Therefore is necessary to create effective organisation and increase its efficiency. In other hand the increasing of efficiency is one of the main problems of both Czech and world companies.

The creation of effective organisation and increasing of organisation efficiency is solved in two approaches.

The base of the first approach is that it is necessary to analyse the efficiency of companies parts and related analysis of various factors which this efficiency of companies parts influence. The analysis is focused on survey of organisation influences. What is at issue is to find weaknesses of the organisation that means the parts of the greatest influence on efficiency of the organisation. We must determine and evaluate these parts rightly. Next we must determine factors which have the main influence on these parts to determine and take necessary and right improvement measures which will lead to the increasing efficiency of the company.

The base of the second approach is that it is necessary to analyse the companies as one unit, which works on objects of companies. This work of companies is able to show in the value chain. The value chain contains all activities of company. There are the primary activities and supporting activities. The primary activities are necessary for all companies and contain input operations, production and duty, output operations, marketing and sale, and services. The support activities support the primary activity and contain infrastructure of company, managing of labour power, technology development and purvey activities. This all activities must create the best unit as possible. This best unit adds competitive advantage and profit to companies.

There are many factors, which influence the efficiency of companies. The first step of creation of effective organisation is find the areas which influence on the efficiency of the company is great. Based on the analysis of these areas we can establish and determine various factors, which influence the efficiency of company very much. There are definitions of superiority and inferiority, quality of communication, coordination, efficiency of parts, contribution to objectives of the company, possibility of checking, number of employers, adaptability on changes, using of skills and capability of employers and education of new employees. These definitions of and determinations of factors are in fact criteria for the evaluation of the organisation efficiency. The influence of each factor on efficiency is different. This influence is possible determine by means of pair comparison of factors.

The next point of analysis is the partial evaluation of organisation by all factors. The evaluation is based on addition of number of points to the factors by condition of organisation. This addition is provided by a descriptor. The descriptor defines relation number of points and the condition of the organisation.

Now we can do aggregation of evaluation. The evaluation is provided by multiplication the numbers of norm weight of factors with numbers of partial evaluation of organisation. From this calculation we obtain evaluated aggregated criterion which sets the evaluation of survey of evaluated parts.

Finally we must perceive that the analysis determines efficiency of various parts of organisation and the influence of various factors on the efficiency of the organisation. What is at issue is the increase the efficiency of company. The analysis shows the point on which we must focus. But firstly there are two approaches for the creation of effective organisation and increasing of organisation efficiency and it is necessary to find out the best solution for these two approaches. And secondly there is infinite process of create effective organisation and increase its efficiency because we must always adapt the analysis to the change of conditions and change of the company.

The top management and the whole staff of organisation in whole parts of company must solve this problem. Only this is the way to survive and have the competition advantage.

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# Expert System for Tendering of Public Construction Orders

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Tendering of public construction orders expects encompassment of extremely complex system mutually interlacing changes. It consists not only in technically exact and fully functional solution, which satisfies criteria generally accepted principle. Essential is also price level and price relation acquaintance. Regarding their particular character, prices are not generally known and price treaty precedes case from case between the owner and contractor. They themselves have generally no interest in that, there would be anything known about their price arrangement, however they would like to have cognizance of most details about prices similar objects. Therefore participants created within the framework of experimental intention MSM 210000006 information system of public construction order's prices.

Price provides significant informative function, however in real economy fulfils price this function only with certain proximity. It is consequence of the fact, that price forming affects different views (e.g. used resources, public interests and environmental). Formation of price-base for the information system must in principle result from prices in public sector already carried out structures, regarding possible diversity in private sector.

It has been known, that price arrangements about construction works and construction objects are particularly complicated. It is impossible to expect, that everyone who deals with public orders is well informed about problems related to them. Therefore we can take advantage of an expert system supporting decision-making, which can with certain limitation substitute specialist in given branch. Or support and improve the quality of his decision-making. Expert system consists of knowledge base an inference mechanism.

Structure and content of the knowledge base should vary according to character of completed orders. Projected database will contain relevant entries about all of (sub-) contractors who the owner ever co-operated with. The base will contain both identification entries of the contractor (business firm, ID no., Tax ID, contacts) and information about completed contracts (contract identification, dates, prices) and final contractors rewiev.

Evaluation of contractor according to particular criterion (completeness and quality of supply, defects and arrears, deadlines achievement) Particular criterion can be considered as linguistic variables an their values can be used as variables of fuzzy linguistic contractor's evaluation model.

It is possible to precise further the evaluating criterion and for each evaluation individually set their weights right in the inference mechanism.

Data will be imported into the system by check-lists and this way will be step-by-step updated information about (sub-) contractors.

Thus proposed expert system can communicate with above mentioned information system of public construction order's prices. Cooperating with each other can these systems transmit data, improve and rationalize their operation.

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# Distribution of Overhead Costs in an Engineering Company

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Marketing alone is not enough to achieve the desired product level and other factors that will lead to profitability.

A major problem in present-day production is how to optimise cutting conditions (cutting speed, depth of cut, feed, and tool life, which are the main cost components) and other working conditions.

For these reasons, the field of the cost component analysis is of great importance, as it combines technical factors, economic factors and also product prices. This article deals with the choice of key aspects of the control and analysis of cost components.

The research was carried out at a company in Prague. In this company, the shop overhead costs were studied, in order to identify the components of this overhead. Basically the costs of foremen were the object of interest. The foremen of the following workshops were studied:

1. Production systems IVU 500R + finishing workshop - mechanical shop
2. Heavy mechanical shop - mechanical shop
3. Light assembly - assembly shop
4. Heavy assembly - assembly shop
5. Group assembly - assembly shop

On the basis of a time study of the different types of work done by the foremen in these workshops, the overhead costs were distributed into two groups, namely a manufacturing production overhead and a general production overhead.

For the general production overhead classification, various activities performed by the foremen were distributed into six groups. These groups were classified as the main factors influencing the activities of the foremen.

Our study led to the following recommendations:

1. The manufacturing production overhead should be calculated on the basis of a number of production operations performed on various products

2. The general production overhead should be calculated on the basis of a number of administrative operations related to the specific product, namely according to the complex of all direct costs for the product

It should be emphasised that overheads consist not only of a considerable part of the foremen's activities, but also include all production management centres with all their costs.

Our study of the production day of the foremen led to the following conclusions:

1. The distribution of overhead costs to a manufacturing production overhead and a general production overhead is important, because it is possible to identify the proper cost drivers for both types of workshop overhead

2. The general production overhead forms a considerable part of the workshop overhead, because it contains not only a considerable part of the foremen's activities but, in addition, the costs of production management centres

3. A study of the daily activities of foremen points to considerable differences in the manufacturing production overhead and in the general production overhead for different foremen. The differences relate closely to the type of production centre and they are relatively time-fixed, which means that they are suitable for use.

4. An unresolved issue is the relationship between these research results and the differentiation of the burden rate in different workshops. This differentiation was performed for the company as a whole, and is used in determining the overall manufacturing cost. If we are to distribute the manufacturing cost as a whole to a manufacturing production overhead and a common production overhead (which was found to be an advantageous solution), it is necessary reconcile these methods.

5. It is recommended to extend this study to the production centres.

Our study shows clearly that overhead calculation is an important issue in present-day cost component calculation.

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# Complex Assessment of the Benefits of Road Infrastructure Development

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Each country's policy is aimed at a harmonious and balanced development of the whole of its territory, eliminating the differences between the level of individual regions and promoting their economic and social development. Lower performance of some regions is caused by their remote position and poor quality of their transport accessibility. These effects result in insufficient exploitation of the territory as a production factor, requiring, moreover, increased assistance through public funding in the form of social services and allowances flowing into the respective region (such as higher expenses related to unemployment benefits).

The definition and expression of the benefits of transport for the national economy has become an issue of great importance in the last several years. The benefits achieved are evaluated as counterbalance to transport costs within the national economy, and their identification is carried out at such a level of knowledge that, with regard to methodology, has gone a long way forward.

We may principally distinguish between two categories of benefits:

- the benefits of transport infrastructure
- the benefits of traffic performances.

The benefits of transport infrastructure consist in the fact that through infrastructure construction or extension traffic conditions are improved, which is reflected by saving resources. The main effects consist in lower operating costs of means of transport, in lower time losses and lower accident and environmental costs. Based upon the savings of costs, the analysis compares transportation costs for the case of implementation and without implementation of the respective investment project. The difference equals the benefits of the improved transport route within the transport infrastructure. This method of evaluating the benefits is traditionally applied in transport planning in analysing the efficiency of infrastructure projects. The costs and benefits for the time of the service life of the designed project are added and discounted at the day of investment.

When talking about the benefits of transport, we associate them with the benefits of traffic performances. The contribution to the national economy (both in personal and freight transport) is shown through the national economic benefits arising due to mobility in terms of a possibility of overcoming distances, affecting thus division of labour and productivity of the inhabitants and the economic system.

Within the framework of the developed research project, existing materials coming from a number of European countries have been studied. They clearly show a need for our own study activity, as well as a necessity for designing methodological procedures applicable within the conditions of the Czech Republic, on the basis of available economic and geographic databases, assessment of the development potential of micro-regions and existing territorial plans of large territorial units.

Varying local levels of transport infrastructure, however, lack their adequate inclusion in the currently applied evaluation procedures within transport planning activities. That is why decisions concerning transport policy keep falling behind well-founded, within the national economy, requirements for construction, further development and behind setting infrastructure

priorities. Such approach to the assessment of investments into infrastructure is, however, provided in the new procedures applied in the EU countries, and it can better consider the basic effects of infrastructure capital on the productivity and well-being of the respective region.

For the reasons mentioned above, it is desirable to express the benefits of new transport infrastructure projects for the socio-economic development of the given territory in two categories:

- **Direct benefits** (namely for transport route users) including in particular:
  - lowered accident rate
  - time gains
  - energy (fuel) savings
  - lowered vehicle wear
- **Indirect benefits** (namely for inhabitants of the affected territory) including in particular:
  - increased number of jobs
  - improved environmental conditions (noise, emissions) for the inhabitants living along existing overcrowded roads
  - assessment of ecological effects on the given territory
  - increased value of the territory through development of commercial and industrial zones
  - increased economic power of settlements and towns due to improved transport accessibility
  - improvements in accessibility of the territory for tourism and recreation of inhabitants
  - stimulation of building activity during the construction and successive maintenance of transport route
  - setting the limits for sustainable development of the territory

**Complex (total) benefits** of transport infrastructure projects may be expressed by the following formula:

$$U^{tot} = \sum_{i=1}^{n} U_i^{dir} + \sum_{j=n+1}^{m} U_j^{indir}$$

where $U^{dir}$ ..... are direct benefits of monitored n-factors

$U^{indir}$ ..... are indirect benefits of monitored m-factors

In order to determine direct benefits, it is advisable to use economic assessment of the given project in comparison with a zero-alternative (such as extended HDM 4 evaluation model). This allows monetary expression within standard categories, i.e.:

- total discounted economic contribution at the end of monitored period (NPV)
- determination of internal return rate (IRR)
- determination of the ratio of net present value (NPV) to costs

In order to determine indirect benefits, basic benefit transformation functions must be derived for up-to-now non-monitored effects, and gradually gauged on the basis of comparative studies with the use of accessible information and database sets coming namely from statistical surveys.

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# Marketing Strategy in Integrated Engineering

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At present, management of production plants has to be able to continuously organize all technical activities. Their complex comprises the following: marketing, logistics, development, construction, technology and production. During designing new products, managers of the production plants have to realize the importance of a complex and systemic analysis of all the above activities reaching from a conception proposal to successful production and also to the sale of the new product.

Knowledge of all the company activities is a key to formulating a marketing strategy that should ensure successful sale of a product. The strategy should not only stimulate the sales but also all activities of the integrated engineering and transfer the customer requirements in the latter. It must reach such a goal that will reflect real capabilities of a company and during realizing the goal will represent a support point in defence against the competition.

Integrated engineering represents a modern attitude in company management that enables to get acquit anted with individual activities leading to the production and sale of a product. This is then the basis for selecting a strategy that will enable the company to become unique on the market thanks to one or more features of the product. Such strategy is a differentiation product strategy, forcing the company to build a unique position to be able to satisfy specific requirements of its customers. There are many means a company utilizing integrated engineering can use to reach the differentiation. They lie in the product itself, in the distribution sales system, marketing attitude and other factors.

Application of integrated engineering in Czech companies shows further possibilities for differentiation. These include a number of conditions: demographical, technical (the ability to produce our own engineering components and the research background), geographical (the middle of Europe, the east-west transportation junction) and historical (machinery has been a part of Czech industry for many centuries). Based on the knowledge of the integrated engineering, the Czech companies have to find such products unique with respect to quality, features, service and shorted delivery deadlines that the rest of the world would not be able to supply in the required quality and use value.

Use value leading to the differentiation of Czech machinery products:

- technical value
- service value
- technological value
- abilities of customer support

An advantage of differentiation is a close relation of the Czech machinery plants to the research teams in universities; such co-operation accelerates development of new products and enables to satisfy the customer needs better.

Execution of the competitive strategy is hindered by underestimating the marketing planning and management, and by legislative limitations in the co-operation between the state, university research and companies. It is impossible to say that the differentiation of products – - and consequently price increase – is a remedy for higher production cost elimination. The company has to strive, in the first place, to reduce cost in all areas not influencing the differentiation. Then they have to find possibilities to reduce costs connected with the differentiation; one of the options is economies of scale after gaining a larger market share. The strategy of creating a unique product in the branch should be easily compatible exactly with relatively low costs and prices comparable with the competition. In respect to strong competition in the machinery branch, it is necessary to make use of all advantages provided by the integrated engineering system. Nevertheless, it is still necessary to try to improve quality of all activities that can minimize loss of all production resources.

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# Innovation of the Road Pavement Catalogue TP 78

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**Road Pavement Catalogue**

At the beginning of 1996, a technical instruction was released by the Ministry of Transport and Communications of the Czech Republic (MTC CR) and the Road and Motorway Directorate of the Czech Republic (RMD CR) as a follow up to ČSN 73 6114 standard called "Road pavements. Basic design provisions" serving for designing road pavements. It is a set of technical conditions TP 78, the Road Pavement Catalogue (hereafter the Catalogue), containing recommended structural types of pavements, compiled on the basis of many-year, both domestic and foreign, practical experience in the construction and exploitation of paved carriageways. The Catalogue equips the user with fast and high-quality design methods allowing for alternative solutions depending on the traffic load class, design level of pavement failure and subbase course material.

Due to rapid technological development in road construction and with regard to the fact that more than five years had passed in 2001 since the Road Pavement Catalogue release, the authors of the Catalogue from the Czech Technical University in Prague were asked by RMD CR with the approval of MTC CR to develop its updated version. This update was to consist namely in extending and complementing the Catalogue by the latest knowledge and facts based on the experience gained during its 5-year practical exploitation, and the results of implemented research projects in the road technology area.

**Catalogue Innovation**

Within the framework of monitoring the users' experience, a group of approximately 100 selected Catalogue users (mostly from the sphere of principal users such as large design and building companies, contractors and administrators, experts and other users) were approached with a survey questionnaire with questions concerning not only the Catalogue itself and activities related to its use, but also other issues dealing with road design and pavement mechanics. The evaluation of feedback obtained made it clear that the users were in general very satisfied with the Catalogue content and lay-out, which, except for an oversight concerning sett pavings, did not include any serious faults. Among the Catalogue strongest points, there is namely technical design correctness and, at the same time, simplicity in using the Catalogue. On the basis of demands submitted by the Catalogue users, great care and a lot of time were also devoted to the "price section" where the developers aimed at removing mutual incompatibility between item prices of individual road building materials (URS price list) and actual prices. It was necessary to carry out fundamental innovation of the URS price list consisting in its extension and complementation to include technologies contained in the set of the ČSN 73 6121-31 standard "Road Pavement Construction" and some new technical conditions of MTC CR (namely TP 109 and TP 151) so that the price lists would really reflect up-to-date situation and correspond to current users' demands.

The Catalogue applies the TP 77 design method based on the principles and procedures of the reliability theory. Despite considerable obstacles encountered during the Catalogue innovation given mostly by an insufficient degree of the design method development,

preparatory work on the Catalogue innovation and creation of a mathematical model of pavement were guided by the following adopted decisions:

(a) in determining material characteristics, the assessment of operating performance of pavements with innovative materials (not included in TP 77) will be based on material analogies,

(b) new pavement constructions will be designed using the "same" degree of operating performance as the pavements included in the Catalogue,

(c) assessment of pavements with cement-bonded layers will presume imperfect interaction of asphalt layers with cement-bonded layers.

The Catalogue update itself, carried out in 2001 – 2002, consisted namely in the following:

- introduction of a new class of traffic load (hereafter TDZ) "Super" and definition of the span of existing TDZ I as based on actual traffic flows of heavy freight vehicles on our roads,
- modification of existing requirements for the efficiency of subgrade soil and unconsolidated structural layers of pavement graded in relation to TDZ, or the type of working surface exploitation,
- extension of catalogue sheets of rigid and flexible pavements constructions by class "S",
- implementation of modern technologies (AKT, VMT, asphalt mix in accordance with TP 109) allowing reduction of road surface thickness or total pavement thickness,
- introduction of stricter requirements for road surface quality namely for constructions for unstable traffic flows,
- extension of TP 78 to include sett constructions with low-thickness paving units allowing the application of the currently most common paving units with a thickness of 80 or 100 mm of moulded vibrated concrete,
- an alternative structural design of pavements with concrete surfaces by introducing an intermediate bitumen layer facilitating load transfer into the subgrade system,
- introduction of technical requirements allowing the exploitation of recycled materials,
- enrichment of potential alternatives of structural modifications – namely in the constructions of BUS stops, parking spaces and roads for non-motorist use,
- taking into account the effect of amendments to ČSN 73 6133 on the conditions of designing and assessing pavement subbase,
- extension of TP 78 to include a table of unit prices of road building materials reflecting the prices of 2002 with a commentary to their use,
- modification and extension of examples of pavement designs including price comparison.

The first complete draft of the updated Catalogue version, developed on the basis of the above-mentioned presumptions, was submitted for approval procedures in March 2002. Since then several rounds of approval debate have passed. After incorporating relevant remarks, this instruction is ready for publication.

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# Design of Field Thoroughfares

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The majority of Czech technical standards for the design of individual road categories, i.e. motorways, roads, local and purpose-built roads, are presently being revised (in connection with the planned accession to the EU). The staff members of the Department of Road Structures, as a renowned workplace engaged in these problems, are, to a greater or lesser extent, involved in the revision of these design standards. One of the instructions currently developed at the Department is the ČSN 73 6109 standard "Design of Field Thoroughfares".

**Standard revision**

Revision of the ČSN 73 6109 standard proved necessary not only because it was outdated (the original branch standard was issued in 1980), but namely due to rapid growth in traffic load (total number of vehicles together with a change in their parameters) and development of modern material technologies.

The standard specifies basic requirements for the planning and design of field thoroughfares, individual elements of field thoroughfares, setting basic conditions for their construction, repairs and maintenance. In developing the standard draft, all allowable design conditions that may appear in the practice of designing field thoroughfares had to be considered. The purpose of field thoroughfares is in particular:

- to provide access to land for owners (property ownership rights exercise) for agricultural production use and transport purposes,
- to provide access to land, i.e. complementation of the existing road network, link important landmarks in free landscape for planning potential routes of tourist paths, cycle paths etc.,
- to provide links to roads, local roads, forest transport networks or other networks of purpose-built routes.

**Purpose and classification of field thoroughfares, their design categories**

Field thoroughfares and accompanying vegetation features add a final touch to landscaping, increase biodiversity (variety of species) of a territory, forming permanent and distinct boundaries to parcels and cadastral units. Depending on their importance and design category (field thoroughfares are expressly designed as single-carriageway roads), field thoroughfares are classified by the standard as:

- primary field thoroughfares, which concentrate traffic from secondary field thoroughfares, are connected to local roads or III-class roads, or exceptionally to II-class roads, or transfer traffic from adjoining lots directly to agricultural farms or farmlands. Primary field thoroughfares are recommended to be designed as single-lane roads with passing sidings and, in justified cases, as two-lane roads. They are always designed as paved roads with drainage and all-year serviceability,
- secondary field thoroughfares, which carry traffic from adjoining lots or farms and are connected to primary field thoroughfares, or may also be connected to local roads, III-class roads, or exceptionally to II-class roads. Secondary field thoroughfares are mostly single-lane roads, usually unpaved, with grass cover, in justified cases paved (with potential rail modification), passing sidings are recommended. Depending on local

conditions, the thoroughfare sections with a low bearing capacity and waterlogged sections are designed as a combination of paved and unpaved sections. In justified cases, the end of a field thoroughfare is designed as a turnabout,

- supplementary field thoroughfares, which provide seasonal road interconnection of land units owned by the same owner, or form boundaries between properties. They are single-lane, and are designed as unpaved, potentially with grass cover. Neither passing sidings nor turnabouts are designed.

Individual design categories of field thoroughfares are shown in table 1.

Table 1 – Design categories of field thoroughfares

| Field thoroughfares | | | |
|---|---|---|---|
| Primary | | Secondary | Supplementary |
| Two-lane | Single-lane | Single-lane | Single-lane |
| P 7.0/50 | P 5.0/30 | P 4.5/30 | P 3.5/30 |
| P 6.5/50 | P 4.5/30 | P 4.0/30 | P 3.25/30 |
| P 6.0/40 | P 4.0/30 | P 3.5/30 | P 3.0/30 |

**Most important changes**

As compared to the original standard, the developed draft revision of ČSN 73 6109 further includes the following most significant changes:

- by introducing stricter requirements concerning material and workmanship quality of individual structural layers (allowing, at the same time, exploitation of recycled materials obtained either by removing or milling off old asphalt layers) and pavement subbase, together with exploitation of a high-quality design method for dimensioning, the pavement quality of field thoroughfares has improved,
- greater emphasis on traffic safety has been reflected in the requirements for the equipment of field thoroughfares (e.g. guiding and catching safety components, traffic signs),
- increased quality and enhanced parameters of road building materials exploited for the construction of field thoroughfare pavements, together with technical parameters of vehicles, have made it possible to increase maximum allowable longitudinal and resulting slopes,
- required design parameters for designing unpaved field thoroughfares have been introduced,
- requirements for designing component structures, namely culverts, bridges etc. have been added,
- special emphasis is put on the landscaping function (forming landscape character) of field thoroughfares within the given territory, together with their ecological, soil-protective (anti-erosion) and water management functions,
- increased permeability of countryside and permeability of agricultural territories by leading marked tourist paths, cycle paths or jogging trails along field thoroughfares.

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# Strategy of Preventive Protection in Construction Industry

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The construction industry has an unequivocal and considerable effect upon the environment: directly, since most development invariably means extensive environmental effects at the project workplace; indirectly, since most services and products used in the construction process consume resources, many of which are non-renewable, or in the case of products some may contribute to adverse environmental effects during their manufacture.

The single largest end products of the construction industry, buildings, greatly affect the environments since they use around two-thirds of all energy used. In addition, the construction of new buildings accounts for around 5 per cent of total energy consumption during their production processes. Moreover, buildings in use and the construction of buildings consume vast quantities of natural resources and are responsible most significantly for many undesirable environmental effects.

The primary tendency of economically developed countries is to control impact of enterprise activities, their products and technologies upon environment. Therefore, enterprises are more and more aiming at management of impacts of their activities, products and services upon environment. Thus, their major priority is sustainability and preservation of further development and prosperity at the effective use of natural resources. In the effort to choose the best measures for environmental protection the enterprise adopt different strategies. Strategies can be divided from the historical point of view into several phases:

1. Strategy of diluting and storing (1950s and 1960s)
2. Strategy of filtration (1970s)
3. Strategy of re-using and recycling (1980s)
4. Strategy of preventive protection (1990s)

Currently, *preventive measures*, which are trying to prevent environmental problems, are preferred to *the control and management strategy* (so called end-technologies that did not solve environmental problems but only postponed them). In reality the preventive strategy is such a mechanism, which prevent pollutants from affecting the environment. Strategy of preventive protection can be divided into basic applications and broader applications. Basic applications are, for example, following:

1. *EIA – Environmental Impact Assessment,* a procedure, which entails formal and systematic collection and analysis of information and data relating to the possible environmental effects of a new or significantly altered projects in relation to the physical, social and economic environment surrounding that development. In the Czech Republic the process EIA is anchored in the Act No. 100/2001 on environmental impact assessment, which is fairly compatible with EU Directive 97/11/EEC.
2. *LCA – Live Cycle Assessment,* an objective process to identify and evaluate quantitatively the negative environmental burdens associated with a given product.

3. *Minimization of waste origin* – identifies and quantifies waste streams and introduces minimization programs, as well as assesses waste management practices.
4. *Environmental Auditing* – is a management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organization, management and equipment are performing with the aim of helping to safeguard the environment by: facilitating management and control of environmental practices and assessing compliance with company policies, which would include meeting regulatory requirements.

Broader applications of the strategy prevention include trends of control of enterprises impacts, their production technologies and products upon environment. Besides national and international legislative also international standards of Environmental Management are being gradually introduced into enterprise structures. Environmental Management Systems are implemented through the series of international ISO 14000 standards that actually determine and define framework for the development of EMS and supporting audit programs. Other tool of EMS implementation into enterprise structure is EMAS (Environmental Management and Audit Scheme).

In the Czech Republic the large construction companies are being slowly implemented EMS through CSN EN ISO 14001. The problem is with SMEs, because neither EMAS nor ISO 14001 have enough modified approach for them. Nevertheless, with approaching integration of the Czech Republic to EU all construction companies will be compelled to pioneer EMS into their structures.

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# Enterprise Selection

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Enterprise selection classifies the international markets, as it is not possible to enter to all world markets at the same time. This process detects potentional opportunities. When we eliminate this process, we stop ourselves all of advantageous possibilities of acquiring new markets.

The first selection level deals with the market in general. The process classified the countries to small or large opportunities and small or large risks. For these purposes we use secondary dates (political, economical, geographical, demographical). The result of using this level is preliminary register of countries in which we can find some opportunities with given level of risk.

The second selection level takes into account the market conditions in selected countries. It concerns oneself with the comprehensive information about its grandness and development, potentional competitors, competitive products and custom and tax policy. The consequence of using this screen is limited list of possible countries.

The third selection level investigates concrete factors influencing our product to entry the market. It cares about exhausting information about competitors, market entry barriers, potentional gains or losses, density and systematizing of distributing canals. When using the third level we obtain the reduced register of comming opportunities.

The fourth selection level, uses the analyses of primary dates (which concern for example: market research, estimation of market growth) create the best conditions for these purposes. Suitable list of countries completes for our market entry.

The fifth selection level represents concrete decision of factories management about entry on foreign markets (from the list adventitious in the fourth level). The decision could be entrance to one or more countries or decision that we stay on our present markets and do not enter to another one.

By decision making in the framework of screening process the countries are selected into groups including countries with the similar characteristics. For each enterprise is attractive to enter into such markets presenting similar characteristics to home market.

Other groupings of countries are different integrations that create by entry into one-member market favoured conditions for entry into other members markets.

As example of other grouping we can use decision-making process in four levels - analytical, strategical, functional and operative decision-making level.

Analytical level is aimed at the analysis of market opportunities. This analyze set up the potentional markets and on the ground of present whole firm strategy choose most fitting markets for the firm expansion. Analytical level classifies the international markets, as it is not possible to enter all world markets at the same time. This process investigates the potentional opportunities. When we eliminate this analytical level, we stop ourselves all advantageous possibilities to expand into new markets.

Strategical level engages the process of adaptation of enterprise strategy by choosing the right one enterprise market strategy for the market, which was chosen to entry. This strategy must be in harmony with the global enterprise strategy. This strategy must take into account the fact of permanent expansion of the globalization process. Segmentation of markets should forerun this level. We must differ our interest spheres for entering the final main segment (consumer market, business-to-business market or government market). Then we choose concrete market segment where we can place our products. Concrete strategy of entry in one selected country is determined especially for the given market, optimalized for the local situation. On the ground of entry study is set marketing mix up, which is in harmony with the system of introducing the product into circular run of goods and awareness of consumers as well.

Functional level in multinational enterprises modifies just used marketing mix into the new marketing mix matched to the conditions and routines in the chosen country. Finding the asked factors of marketing mix to the situation in the concrete country is a base of effective penetration into the foreign market that can bring us in future great gains or big losses when using wrong marketing mix.

Operational level style organization, planning, controlling and financing in accordance with the extension of the enterprise activity.

Concrete strategy of entry in one selected country is determined especially for this market, optimalized for local situation. On the basis of entry study is set marketing mix up in harmony with the gradual system of introducing the product into circular run of goods and awareness of consumers as well.

The last but not least is the fact, that home agency or university elaborate above mentioned entry study. It is the first step for the creation of entrance marketing strategy.

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# Acoustic Emission of Grass-Covered Tram Track

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With the development of city rail transport, which brings many advantages for the environment, big problems with the noise of trams appear mainly in town and city centres with narrow streets and a high population density. In such conditions, no additional protecting constructions are possible, and so the noise must be reduced at its source. Contemporary trend of organization and traffic control in town more and more prefer public mass city transport, especially tram transport to individual automobile transport. Parallel to increasing intensity of tramway transport it is more and more required also expressive decreasing of its noisiness. Measurements of noise pressure levels taken in CR and abroad demonstrate, that lowest noise pressure levels are round tram track with open trackbed. However, this type of tram track construction is on many places in town unusable and some pavement must cover track. In this paper results and comparison of measurements on tram track with grass cover are given

The noise of moving tram consists of many particular noises emitted both by the tram and the track. Some of them depend only on the vehicle and its technical equipment, but the "rolling noise", which represents an essential part of transport noise at relatively slow speeds of trams in city centres (to 40 $km.h^{-1}$), is emitted by all moving or oscillating components of the bogie and the track and depends on the interaction between the wheel and the rail. So it is useless to separate the noise emitted by the vehicle and the track if we can evaluate the influence of the tram track structure on the noise emission from the tram traffic.

Based on requirements of conservationist were tram tracks surrounding Prague Castle modified with grass cover - measurement results were published among others in [1]. Tram track in street Milady Horakove between tram stop Hradčanská and crossing Prašný most stay long time with open trackbed, as grass cover had to be originally built up also in this section.

All measurements were taken during night and carefully care was paid to exclude any other disturbing noise, mainly from another tram, cars, moving people etc. The noise of passing trams was scanned by a Brüel & Kjaer sound level meter Type 2231 and stored on Sony DAT recorder. This signal was subsequently analysed by Brüel & Ono-Sokki CF-930. Excel processor then worked out obtained data from analysis to needed spectra.

Measured section consist of grooved rails NT1, concrete sleepers TB93, elastic clip fastening SKL 14 with direct fixation of rails. It is placed on segregated track surrounded along both sides by street, mostly in straight line. In spring of the year 2002 was construction completed with rubber filler blocks SEDRA and track was embedded with grass cover.

Emission of rolling noise from tram track with construction described above, used in section Hradčanská – Prašný most, is lowest from up to now measured tram track construction in Prague. However several layout was realized suddenly (installation of rubber filling blocks, grass cover and grinding of rail head surface table); therefore it is impossible to tell, how great influence each one of them has had on decrease of noise emission. Positive effect of rubber filling blocks and of grinding was demonstrated on other tram track construction in Prague; effect of only grass cover meanwhile demonstration has not been. When any cover covers open trackbed, noise pressure levels at any time more or less raised. Positive influence on noise reduction on checked section Hradčanská – Prašný most, which however with time disappear,

can have a rough surface and unlevelled grass blocks. In this section there are not used subgravel mats, whose effect on tram tracks is only checked.

Measured equivalent sound pressure levels are shown in following table.

| | Before reconstruction (open trackbed) | After reconstruction (grass cover) | Difference in sound pressure levels "before - after" | After reconstruction (grass cover) check measurement | Difference in sound pressure levels "before - after" |
|---|---|---|---|---|---|
| Time | 12th April 2002 | 22nd June 2002 | | 20th September 2002 | |
| **$L_{eq}$ [dB]** | 89,03 | 82,36 | **6,66** | 82,83 | **6,20** |
| **$L_{Aeq}$ [dB]** | 84,64 | 73,61 | **11,03** | 74,40 | **10,23** |

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# Sustainable Growth of Building Capacities Owing to the Preparation of the Czech Companies for the Access to the EU Building Market

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The structure partial project comprises of seven sections:

- Analysis of EU Building Market

The building market of the European Union is from the volume of construction investments point of view the largest world wide. It is followed by the U.S. and Japanese building markets. However, from the share of construction investments on GDP creation point of view the first position is held by Japan ahead of the EU and the U.S.A. and in the share of construction investments per capita is the sequence Japan, the U.S.A., and the EU.

In the European Union most is invested in Germany in spite of the lengthy economic recession in the last years. Further, there follows Italy, France, Great Britain, and Spain. In these countries roughly 75% of all EU construction investments is concentrated.

The contribution deals with analysis of the building market development in the EU individual countries with emphasis on situation in Germany and in the chosen candidate countries including the Czech Republic.

- The Company and EU

Building companies have to prepare their strategies in appropriate way. With integration is connected a lot of advantages and also many problems and threats. The basic steps of preparation competitive strategy are: the quantification of objectives, analysis of external environment, analysis of branch, analysis of internal conditions and in the end set the strategy and its application. The main problem is the small condition of preparing. Only 12% of building companies started their preparation. The firm which just started are oriented first of all on regulations and technical norms. On this grounds is necessary to inform about necessity of preparation of strategy and pre-plan procedure of firm integration in the best in variations

- The Influence of the Qualitative Economic Information on the Control Effectiveness of the Building Firm

The Economic Processes in the Building Firm and the Information Sources of Effectiveness Evaluation. Accounting - Implement of the Enterprise Strategic Control. The Structure of Accounting - Financial Accounting and Management Accounting - Differences. The Accounting Statement - Balance Sheet, Profit and Loss Account, Notes on the Accounts. The Reliability of the Information System of Financial Accounting. Methods for the Gaining of Information - Controlling. The Evaluation of Capacity and Effectiveness of the Firm, of Economic Results and of the Financial Position of the Firm. Financial Analysis Methods.

- Management of Sub-deliveries

Increase of portion of sub-deliveries in volume of building companies works and their rising influence on economic and other results of constructions and building companies represents a significant factor of sustainable growth of building enterprises life-cycle. However, it requires creation of functional and flexible securing of sub-deliveries management, which can be characterised by tree basic areas of problems – a selection of a subcontractor, sub-deliveries

management, evaluation of sub-deliveries and subcontractors particularly as feedback for their selection and management. That all with the aimed use of project management methods. Each of these areas includes more partial problems. Solution of some of them is solved in this statement.

- Sustainable Growth of Building Capacities –Uncertainty Analysis

At designing of complex systems – an estimate of uncertainty degree. Project of sustainable growth of building capacities features with high uncertainty. On the basis of theoretical knowledge of the modern theory of uncertainty a degree of solution confidence is being established. Two methods of solution, economic and technical, are given here. Under the stated conditions the project based on the technical development is evaluated by a higher degree of confidence.

- Information Systems – Possibilities of Inputting and Working out of Fuzzy Variables

For the correct function of information system it is necessary to identify, analyse and evaluate mutual relationships between individual elements (parts) of these systems. For this analysis we can use method of analysis of systems structure complemented with elements of behaviour analysis, which are based on the principles of the graphs theory. We cannot always precisely quantified mutual relationships – links and in many cases the verbal (vague) utterance is more fitting. In these cases it is possible to apply possibilities of analysis, which are based on the fuzzy variables theory. In this contribution we will attempt to explain the basic principles of such evaluated links of information systems.

- Internet in Building Companies

The Internet is changing the building industries in ways that will offer tremendously positive effects. The implementation of these changes has already and will continue to create challenges that will have to be met to minimize casualties and setbacks.

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# The Role of Human Resource Management in Employees' Development

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Education and learning belong to the most important stimuli for personality development. Nowadays, tough competition puts high requirements for employees´ education. Among HR professionals and scientists grow importance of lifelong education which is supported by top management. Effectiveness of lifelong education is influenced by individual capability to learn and to utilize gained knowledge in day-to-day work. There should exist balance between individual and company needs.

Human resource management (abbr. HRM) plays the key role within company, because it solves following issues:

- globalization, where HRM is looking for hiring and motivation of employees on which company can build up global capabilities,
- company competitiveness, where HRM can provide supplier and customers with education for building end-to-end value chain by e.g. supporting value-chain team,
- profitability and growth, where HRM uses right methodologies for cost cutting or supports revenue growth by changes of company culture,
- permanent change within company, where HRM must effectively solve the needs for rapid company change (transformation, reengineering, downsizing, quality, turnaround, etc.) to sustain in a tough competitive environment,
- technology HRM must cope with influence of the state of art information and communication technology that changes the way of individual work in each job position within company and higher requirements lead to change of employees´ behavior,
- retaining and measurement of intellectual capital, where HRM must source, hire and secure talents and key employees for improving company competitiveness. Further HRM must develop performance management system for measurement of size of intellectual capital influenced by employees´ education.

The author defines the four roles of HRM in education and learning within a company:

Strategy management of education; HRM provides top management with educational strategy that should be in line with company strategy. This educational strategy is compromised of analyzing employees capabilities, setting educational strategy (balance portfolio of educational and training methodologies), implementation of change by fulfillment gaps in company capability, setting key priority with respect of allocated financial sources and measurement system.

Administration of education; HRM ensures administration by setting internal processes, own sources, educational infrastructure (e.g. PCs, class rooms), administration of external and internal educational sources.

Change management of education: HRM´s task is to change company culture that supports employees´ education. It compromises of analyzing company's weaknesses and strengths in education, creation trustworthiness with employees and managers, creation and implementation of action plan.

Operational management of education: HRM proactively monitors every day needs for employees´ education such as process of adaptation for new employees, supporting processes for training sales staff for new products, etc. HRM in co-operation with managers analyses the needs and offers solution and implements it.

Author describes the growing role of HRM in management of intellectual capital, esp. in the area of education that is becoming key company capability to sustain in a tough competitive environment.

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# FDI and the Internationalisation of R&D

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One of the most remarkable features of the last decade has been the rapidly growing internationalisation of most economies in the world. FDI flows still remain one of the most dynamic factors of the global economy and it is expected that they will overtake the growth of both trade and world GDP in next years. The general attitude towards FDI has changed from the suspicious view to the present where almost all economies allow foreign investment and most of them actively encourage inflows of FDI. While this shift in attitude was gradual for the developing economies it was more dramatic for the transition economies. Multinational corporations don't internationalise only production, but are continuing to internationalise also their research and development (R&D) activities. FDI is now an important method by which technology is transferred internationally, resulting in important spillover effects of various kinds for the host economy. And some country environments are more suitable to such investments than others.

Theoretical explanations of FDI flows are known as having certain limitations. The lack of global economic models has supported the use of the Dunning OLI paradigm, based on ownership-specific advantages and internalisation advantages of multinational companies and location-specific advantages offered by host countries. The OLI paradigm has thus consolidated as the theoretical frame that enables the definition of hypotheses and their econometric testing. Because of the complexity of FDI theories, researchers tend to focus on few factors so as to conduct empirical tests, especially examining ownership advantages.

These traditional conceptualisations of investment motivations were made with reference to firms producing and selling physical products, in a world in which the possession of tangible assets was a major source of value creation, and where geographic distance and transportation costs were critical drivers of international expansion. Hence, they focus on the need to get access to physical assets and to markets, and to cut costs, as the major drivers of foreign expansion. However, technology is an intangible asset, so there are at least some grounds to expect that its mobility might be far less influenced by geography than the transfer of tangible goods such as components or finished products.

In fact, research on FDI has historically started from the premise that, for the typical multinational corporation, R&D is likely to be concentrated in the home country and that the global exploitation of the resulting technology assets is best achieved through internationalisation, i.e. either through exports or through the internal transfer of technology to foreign production units owned and controlled by the firm. The tendency of multinational corporations to concentrate their innovatory activities in their home countries - usually for good economic reasons - is confirmed by data on the extent to which the proportion of patents registered by the world's largest firms are attributable to research undertaken by their foreign affiliates.

More recently, there is growing evidence that firms are establishing R&D operations in foreign locations. Research indicates that firms are rapidly increasing their investment to foreign R&D activities. An important reason behind the rapid growth in foreign R&D spending

appears to be a narrowing of the economic and technological gap between most of the developed and some of the developing countries.

The location of foreign R&D is influenced positively by host country economic, institutional, scientific, and telecommunications infrastructure environment. Market size, level of economic development and level of technological advancement are some of the major host country factors that appear to be associated with greater commitment to R&D activities on the part of subsidiaries located within that country.

In addition to economic factors, the quality of political environment, the extent of corruption, and overall economic and political risk, likely influence firm decisions about where to locate R&D and how much to invest in those locations. Similarly, scientific capability and telecommunications infrastructure would also appear to be important to R&D investors. Focusing on subsidiary traits, the likelihood of R&D activities within specific subsidiaries also appears to be greater in those cases where the subsidiaries are high in production value added, high in ratio of exports to total sales, and were acquired rather than set up as greenfield operations. Another possible reason for unequal impacts of closer regional integration on location advantage is the existence of industrial clusters. Clustering creates a market for workers with specialized skills thereby making the local labour market more attractive for them. Clustering also enables firms to use technological spillovers from the research efforts of their competitors as well as other local institutions such as universities and laboratories.

Because of the importance of R&D, the Czech Republic should concentrate on attracting these activities. There are some successes in this area. The Czech Republic spends more resources on R&D than many of its competitor countries and investors are increasingly moving R&D activities to the Czech Republic alongside standard production activities, because Czech R&D capabilities have been proven by existing investments. Many multinationals are running Czech R&D or design centres, including Boxing, Honeywell, Mercedes Benz, Rockwell Automation, Ericsson, Bosch and others. According to a survey of foreign firms in the Czech Republic, 21 % reported significant R&D at their Czech facilities, 40 % reported significant R&D at Czech facilities and subcontractors and 11 % had patented the results of Czech based research. It is quite a good prerequisite for future FDI inflow to R&D in the Czech Republic.

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# Findigs from research on development of technically oriented managers

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Since 1998 our research goal at MIAS has been to analyse management competences of technically oriented managers (TOM) in Czech Republic and to evaluate educational system preparing Czech technical managers for their jobs.

A starting point of the research is an assumption that manager's main task lies in conceptual and managing work. Managers of organisational units responsible for technical tasks are no different from general-purpose managers, because they too carry the responsibility for preparedness of their teams and achievement of both long and short-term goals. Our research focuses on workers, who studied to be technical specialists and were considered successful at these positions. We can safely assume, that their understanding of technical aspects of tasks is sufficient for manager's position. Managing tasks require concentration on management priorities and delegation of technical aspects of problem solving to specialists. This does not mean, that technically educated manager cannot contribute towards technical solution. Rather it means that combining these two tasks jeopardises effective execution of managerial tasks and hence jeopardises achievement of entrepreneurial goals.

In the first stages of our research, we mapped organisational environment in sample companies in Czech Republic. Afterwards, we evaluated knowledge and attitudes towards people leadership and work activities of the examined group.

Findings of the research confirmed that the overall level of HRM work in most of the contacted companies is on a basic level and technically oriented managers are no progressive element in this area.

The findings also showed, that to evaluate candidates and effectiveness of TOMs' development, we will have to focus on deeper personality traits other than knowledge and skills. Ever since R. Boyatzis and his co-workers from McBer company presented results of their research, a number of work competence models which take in to account other personality traits, such as self-concept, motives and traits became available. In 2002 we have been following our up-to date research with quality focused, in-depth interviews with members of the examined group of managers. Our goal was to confirm and refine selected competence model to ensure its appropriateness for evaluating potential of future managers and for better focusing managerial development of technically oriented managers. The competence model was based mainly on personality management competences model of British management standards NVQ and a set of similarly defined competences from the workshop of R. Boyatzis and his co-workers from the McBer company.

Apart from directly questioning the selected group of managers, I used experience of several HR specialist who participate in manager selection and development, who worked with number of technically oriented managers and who observed and evaluated differences between the examined group and other candidates for managerial positions during tenders and development programmes. I evaluated both types of research interviews (with TOMs and HR specialists) in the light of several variants of management competence models.

To analyse TOM´s competences, I chose methodics for reconstruction of marginal situations and activities in in-work and out-of-work environments that are somewhat related either to work with people, or to conceptual approach and decision-making. We asked every respondent

to exactly describe his behaviour in these situations and we clarified with him circumstances and contexts. I have analysed cca 30 in-depth interviews conducted up to date in relation to indicators of management competence models.

Similarly, I have analysed all records of interviews I conducted with the HRM specialists. Afterwards, I compared weaknesses, strengths and habits indicated by the HRM specialists with the recordings of direct interviews, results of our previous research and also with partial results from research of management literature mentioning experiences of TOMs in Western Europe and America. I collected the findings, which appeared in more than one source, including the interview recordings, and set them to basic management competences according to NVQ model.

These are mostly demerits and unproductive habits. There are two reasons for this. The first being the fact that the competence model is an ideal goal to which imperfect people can only come close to. The second reason is that the examined group has its strengths mostly in the area of technical solutions to entrepreneurial projects, which lies beyond the observed competences. As a result, we identified part of potential dangers every candidate to management position or TOM should face to break limits of inefficient usage of their own managerial potential.

My approach is based on viewing manager as an integrated personality with higher ambitions, who must solve complex problems in a limited timeframe. To do that, he must understand, think and act in an organic way and without major flaws. In a simplified manner, it is possible to imagine manager's main tool - his brain - as a chain of individual competences. This tool is as reliable, as is reliable its weakest link, which, when it breaks, causes the whole chain - tool - useless. It is therefore important to learn about common demerits, identify them in potential future managers and TOMs, evaluate them and eventually propose action, which would strengthen the weakest link/competence or direct the candidate to a position of technical specialist rather than to a position of a manager.

Our up-to-date findings confirm i.e. common tendency of TOMs to remain in the position of specialists, who concentrate on direct solutions to tasks assigned to their department. They do so at the expense of their managerial role. As managers, they should focus on creating conditions for problem solvers and make basic decisions. Combination of technical and managerial tasks is sometimes necessary in small companies or small organisational units, but such role is even more demanding on personality competences of managers and specialists in one person. It leads to lower managerial effectiveness of these two-minded workers. It also confirms common underestimation of the social dimension of work, benefits of form and quality of communication to achieving goals of the organisation. The skill of interpersonal communication is a typical representative of "core" work skills commonly underestimated by technically oriented managers, who often fail to recognise its importance and their need for development in this area.

In our further research, we will continue to disclose newly identified demerits and confirm incidence of those demerits that have already been added to the list. This way, we will also refine the model of important managerial competences of TOMs.

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# Decision Aspects of Quality, Ecology and Safety of Product in Integrated Engineering

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The quality, ecological aspects as well as safety of products belong nowadays among factors which have growing importance and influence the functional value of products.

The quality of product represents its ability to fulfil the functions for which the product is determined. Among these properties there are the following characteristics:

Scope of functions
Controllability and readiness
Technical advancement
Advancement and novelty
Creative level

Very important part of quality is the reliability of given product without any doubt. The reliability of product can be defined as the ability to fulfil the asked functions under the condition of the conservation of values stipulated operational indicators. The reliability of the product must be considered in the time and limits given by the agreed technical conditions. The reliability involves:

Trouble free operation
Durability
Maintainability
Repairability
Storage stability

The quality and reliability of products influences the functional value of product and without any doubt even the price of product.

The demands to improve the product quality and reliability can bring the higher expenses of producers.

Ecological aspects of production are linked up with the quality of product and increase the functional value of products. Among ecological points of view belong:

The influence of manufacturing the products to the selected components of environment
Material and energy pretentiousness
The influence of product to the selected components of the environment during its life cycle
The level of energy supply when used the given product
The possibility of easy ecological clearance after finishing product durability

The eco-friendly products, which are excellent with the low energetic consumption without any negative influence to the living environment, have much higher functional value for customers. The level of energetic consumption is marked usually.

The safety of product can be considered as further important quality of product which corresponds with ecological attitude to products. The question of the safety of products doesn't have to be connected with higher production costs. The suitable chosen material or small correction of product can improve the safety of the given product. Several views of safety of products are as follows:

Health undefectivness
Toxic undefectivness
Protection against mechanical injury
Protection against electric power injury
Fireguard protection

As for the qualitative, ecological and safety parameters concerned we must solve them already in the preproduction stages of product development. The first information about qualitative, ecological and safety parameters would be collected and analysed in marketing research and should respect partly the demands of customers, parameters of competitive products and legislative conditions.

The decision making process about the qualitative, ecological and safety parameters of product can be solved in the framework of integrated engineering by means of the decision making model. Such model contains the following activities:

Marketing research and analysis of information in relation to qualitative, ecological attitudes and safety characteristics of product

Conception of constructive solution from the qualitative, ecology and safety point of view

Construction elaboration of chosen variant

Analysis of qualitative, ecological and safety parameters of the proposed product

Technological aspects of construction, technological preparation, production of product prototype

Final verification of the qualitative, safety and ecological parameters of the product

The decision about qualitative, ecological and safety parameters of product having been secured the asked functional values of product when the cost limits were reached

Analysis of the technology level of construction aimed at keeping ecological safety and qualitative parameters

The proposal of the technological variants taking into account the qualitative, ecological and safety parameters of simultaneously manufactured products

The choice of the most suitable variant from the point of view of qualitative, ecological and safety parameters when cost limits were reached

Monitoring and evaluation of qualitative, ecological and safety parameters of produced, sold and used products

Decision making model includes marketing, constructive, technological, economic and control activities. The decision itself is based on the choice of the most suitable variant of solution of qualitative, ecological and safety parameters. In partial stages of decision, the possible variants of decision of qualitative, ecological and safety parameters of the proposed products are determined. On the basis of the stipulated evaluating criterions the best variant is chosen by means of so called multicriterion decision making method.

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# Various Possibilities How to Repair Wooden Elements by Means of Filling

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**What is a filling?** In connection with wooden elements it can mean replacing of locally damaged wood in a wooden element by seal. It can mean inserting the seal into hollows, cracks or joint gaps created during its use and getting older.

Not only **wood** can serve as the seal but also **lutes** (multicompound formable systems – binder, catalyst, filling mass, solvent) or **solid foams** (multicompound liquid systems – polymere skeleton of the foam, expansive part, catalyst, filling mass, solvent).Filling is used at local repair work of non-loadbearing elements or at renewal of pressure strenghth of load-bearing elements.

When the element is stroken by evil-doers at first rotten or damaged wood must be removed (cut away) and then the element is filled. The seal replaces the removed wood.

**Wooden seal** is inserted into damaged element by means of acceptable adhesive or by connecting means. So that to create a wooden seal the same wooden material as the material of damaged element is used. It is very important to keep the same direction of fibres and the width of annual rings. Otherwise the seal should be made from older wood with a similar moisture quality as the repaired element has.

**Lutes** are multicompound formable systems (filling mass, catalyst, binder, solvent,..) which transform into a solid mass after some time. Good lutes must be well formable and they should also have good adhesion to wood. During their getting harder and also when they become hard they shouldn´t change their former shape and volume. Their volume and moisture changes should follow these of damaged wood. They shoud even have the pressure strenghth similar like wood. They are to be flexible enough, so that they couldn´t crack. We mustn´t forget also about their look , possibilities of surface finish, price and so on. Polyuretans filled with wooden sawdust and epoxids filled with fine quartzy sand or wooden particles are the most used lutes.

**Solid foams** are multicompound liquid systems (polymere skeleton of the foam, expansive part, catalyst, solvent,..) which after spraying into a hollow of the element enlarge their volume and become solid. They have one important advantage being compared with lutes : smaller density. It can be very important at reconstruction and repair work of greater objects. Expecially polyuretans are used as solid foams, but also silicons or fenoplasts.

When unregularly damaged zones are repaired it is suitable to use filling by means of wood, lute and adhesive.

At repairing of load-bearing elements with hollows it is necessary to use steel or laminated-glass bars. These serve as semiflexible skeletons – certain analogy of Beta method.

Experiment – Reinprecht, Joščák, 1993

**How to testify deformations of weakened and then filled elements:**

Aim: to calculate and try in practise deflections of wooden elements weakened and filled with a lute.

Metodics: Spruce elements (l x b x h = 500 x 30 x 30mm, w = 12%, 30 pieces) were tested at three stages following each other:

- The exam of former elements
- The exam of locally weakened (perfored) elements – Diameter of weakening = 16 mm.
- The exam of filled elements

The deflection of weakened and filled elements were found:

- In an experimental way
- By means of calculation with following parametres:
  $I_0$ = moment of inertia of a former element( $I_0 = bh^3/12 = 67\ 500mm^4$)
  $I_{LP}$ – moment of inertia of locally perfored element
  $I_T$ – moment of inertia of filled zone (with lute), $I_T = I_0 – I_{LP}$
  $E_T$ – average modulus of elasticity of the lute (polymere-concrete on basis of artificial polymere and wooden particles.($E_T$=1675MPa)

Results: Owing to weakening of elements in pressure or tension zones the deflection increased and simultaneously the experimental growth was similar as the calculated one. At neutral zone the experimentally found deflection was bigger than it had been supposed.

After filling the elements with lutes on basis of epoxid and rezorcin-formaldehyd bitumen and wooden particles their solicity renewed and the stage of renewal approximately followed theoretical calculations. Better renewal of solicity was reached after filling the neutral zones, probably owing to partial penetration of polymere into tension and pressure zones of the element.

Conclusion: Luted seals - epoxid-wooden and fenoplast- wooden can help the damaged elements to get a partial resistance against deflections.

From the point of view of practical application of described methods (wooden seal, lutes, solid foams) we must také into account possibility of acces to the damaged place. Where the element can be take out of the structure or where is space enough around it the wooden seal can be used. In the limited space it is better to use lutes or foams. These methods can also be combined with splice bars - if there is no need to keep the former shape. The splice bars can be wooden or metallic.

From the economical point of view it is always advantageous to use a wooden seal. The use of lutes and solid foams is convenient only there where the shape of structure must be kept – change is impossible – and simultaneously the damaged place isn´t accessible for use of wooden seal.

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# Specification of the Standard Cost Model of New Products

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The approach of cost determination of a new or a remade product by applying the principals of target costing is in general feasible, as it was demonstrated by the example of a new designed recording tachometer in the until now done experimental work. Some outcomes of the previous research period should be paid detailed attention.

First of all it is necessary to define the content and structure of target costs. Under the term of target costs there are very often understood overall unit costs. This is in contradiction with the cost instruments and information that are available to designers, because the designer of a product is able to decide only about product costs, which are closely connected with the product. These costs are called causal costs. A designer is not able to decide about various processing and overhead costs. He should be interested in direct or variable costs and those fixed costs, which have a causal attitude to the product.

The recognition of causal costs is one of the important matters of this research period. It should be accented, that the chosen device is manufactured in an enterprise with a very broad production program. The problem of causal costs has been revealed during the process of cost determination of a heterogeneous production program, where a separation of overhead costs towards a single production unit is very difficult.

The results with the application of target costing as a method usually presented are unsatisfactory mainly in two aspects:

1. The recognition of causal costs of a product.
2. The volume of products under consideration.

The *causal costs of a product* as a very serious matter in cost estimation of new designed products is generally not mentioned in publications concerning cost problems and especially the target costing approach. It is well known that overall costs consist of variable and fixed costs and both of them may split into many items. Part of the cost items can be allocated directly to a product during his design and production period, some of them cannot. This concerns both variable and fixed cost items.

The key problem of allocation costs to a product is a rather theoretical matter closely connected with the possibility of their measuring. It is easy to determinate the costs of material used for the manufacturing of a production unit, because the weight of used material per unit multiplied by the price of a unit of material is called a cost standard. Because of the direct measuring of the cost item of used material per product unit this cost items is called *direct material*. This similarly concerns various other direct cost items as direct labour costs, direct power costs, direct selling costs etc. All these cost items are in whole called direct costs.

The total direct costs (*TDC*) are moving with the number of product units under usual circumstances proportionally[*)]. This can be expressed by a direct proportional function $TDC = f(q) = ADC \times q$, where *ADC* are the average direct costs, $q$ is the number of product units. The *ADC* can be expressed by standard cost items. Does the proportionality of direct costs

[*)] The direct cost as a special type of variable cost may change also progressively or digressively.

mean that the direct costs equal the variable costs? No, it doesn't. Here is a brief explanation to this. The direct costs are usually used as a term of such cost items that are derived from the possibility of direct measurability of them in a single product. But there exist cost items, which are behaving constantly with the changing number of product units. As an example let us take machines with a high initial price that will be used for the manufacturing of the product. The relevant proportion of machine depreciation in respect to a product unit depends on the quantity of product units manufactured in the relevant time period. The problem of quantity of products will be discussed later on.

Depreciation is a type of fixed cost, because it doesn't change during the time period the machines or other long-term assets are going to be exploited. If these machines are not suitable for manufacturing other types of products, or it can be used only in a distinguishable portion for manufacturing, the depreciation costs are evaluated as causal fixed cost. Because depreciation is connected with a special product, it belongs also to the group of direct costs. This concept is commonly not used in calculation practice, and therefore the term of causal costs is introduced. There exist some more items belonging to the group of causal fixed costs as depreciations of special tools, setting up costs, and some more items of processing costs.

There still is a large portion of costs left that belong to uncaused cost, mainly the overhead costs. These costs consist of variable and fixed cost items. Not much attention to this is paid to assigning overheads to products in cost calculation practice, where overheads are charged to products by means of rates and bases of apportionment. It is necessary to change this approach looking for more exact methods of assigning overhead costs to products.

The volume of products must be considered in the phase of designing a new product in relevance to the economies of scale that are tightly connected with the existence of fixed costs. For the application of target costing it seems to be reasonable to transform both direct and overhead costs into variable and fixed costs. In case of a linear total cost function the average cost function $AC = VC + FC/q$ is derived. This function shows the decreasing cost per unit with the growing amount of products. Attaining target costs requires cost planning, which has two key steps: computing the cost gap between attainable and current (drifting) costs and current costs and analysing this cost gap so value engineering and continuous improvement efforts can be focused on closing the gap.

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# Managerial Support of the Product Development Process

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The success of product innovations depends considerably on the quality of the management of the product development process. Experiences indicate that the quality of the management is particularly impressed by the following factors:

- *Corporate policy*
- *Business culture and innovation environment*
- *Corporate flexibility and effective communication*
- *Team work*
- *Availability of resources*
- *Methods of managing innovation processes*

Methods of managing innovation processes are the main topic of the research project "Systems for management of product long-life-cycle effectiveness" which is solved at the Institute of Enterprise Management and Economics, Faculty of Mechanical Engineering, Technical University in Prague. The main objective of this project is to find the various ways of arranging product development process more effectively. Particular interest is applied to approaches leading to integration of various activities concerning market research, product design, processing, costing, etc. Increased attention has been paid to managerial, informational and application potential of the various progressive methods for quality and costs management. The subject of this reading is consideration about managerial potential of the QFD method.

**Basic conception of the QFD method**

QFD method is a multifunction-planning tool that provides a framework for the innovation process. The internal structure of this method consists of four basic phases: I. product planning, II. product parts and components planning, III. processes and production planning, IV. continuous improvement of the product and processes quality. Coupling matrices that show critical product and process information are the basic information and communication medium for each phase.

Most extended is the product planning phase which starts with the identification of customer demands and needs, determination of their degree of importance and comparison the success of the product in satisfying customer demands with competitive products. The subsequent steps include the identification of measurable parameters and the product characteristics that enable customer demands to be satisfied, the determination of the intensity of couplings between customer demands and product parameters, the determination of dependence between individual product parameters and the analyses of product parameters in comparison with the relevant competition.

**QFD Method – significant tool of concurrent engineering**

QFD contributes to all three key elements of concurrent engineering:

- *it uses a cross-function team approach*: it creates a basis for effective cooperation between the development staff and other staff from functional units who participate in the product development process. In order to establish an effective cross functional team it is necessary

to respect mutual ideas and ways of thinking, involvement and initiatives that correspond to the determined incentives, competencies and responsibilities within the team;

- *it supports decision making processes throughout the whole development process*: it fosters both rapid and timely horizontal and vertical information flow, the concurrence of processes and a close cooperation between all subjects participating in the product innovation;
- *it helps to connect all the decision making processes*: it contributes communication between activities of many corporate functional units and leads to the unification of goals and interests of all entities participating in the product development process. Integrated and simultaneous philosophy of the method enables shortening of product development process and optimization of the product quality and features of the product development process.

**Overall evaluation of the QFD method**

The QFD method has been implemented in several corporations such as Toyota Motor Company, Mitsubishi Heavy Industries, General Motors, Texas Instrument, etc. since its creation in 1960. When used properly QFD helps companies design more competitive products, in less time at lower cost and with higher quality. Experience shows that up to 60% cost savings and a 40% reduction in the product development period can be achieved using this method.

The main benefits of the QFD method include its strict focus on the customer in all phases of product development process, the structure and transparency it brings to product development, the improvement of internal cross functional communication and teamwork and the transparent structure of the entire product development process. Systematic planning methodology of the QFD method enables identification of the chain relationships in the product development process and for each phase of this process gives listing about critical factors which should be subject for further detail planning. The correct application of the method results in an increase in the product functionality and quality, a reduction of the danger of subsequent and costly modifications and shortening the entire development process.

A relative disadvantage of the QFD method is its significant complexity and high demand on information inputs. Another disadvantage of the QFD method is that it unilaterally stresses technical options of the design of the product under development while omitting its economic aspects. This reality opens a horizon for further research topics – incorporation of economic aspects into the QFD method and its interconnection with economic limits.

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# Specific Methods and Seven New Tools of Quality Management

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Key words: Affinity Diagram, Relations Diagram, Systematic Dia-Matrix Diagram, Matrix Data-Analysis, Process Decision Program Chart, Arrow Diagram, Risk Assessment, Failure Mode and Effect Analysis, Simultaneous Engineering, Design of Experiments, Value Engineering, Loss Function, House of Quality, Lean Production, Fault Tree Analysis.

When talking about quality management there where taken in account several methods apart from statistical analysis of the production-process, statistical process control, statistical acceptance and seven simple tools for quality control. These methods we call specific, they are not traditional ones an we are going to pay attention to each them individually one after another including seven new quality management tools.

1. Affinity Diagram

The affinity diagram method uses the affinity between partial piecemeal items of verbal data to help understand systematically the structure of the overall problems. This method is used to help better understand problems that must be solved.

2. Relations Diagram

The relations diagram method is used to analyse problems when the causes have complex interrelationships. Making a diagram to show the cause-and-effect relationships and the relationships among different causal factors enables you find the causes of problems and discover methods for solving them. You can also the relations diagram method to pinpoint the elements required to achieve a certain goal.

3. Systematic Diagram

The systematic diagram method is a technique that helps you think systematically about each aspect of solving a problem or achieving a particular goal. It resembles a tree with an increasing number of branches. By developing the root and branch relationships between the various parts of a method, this tool helps you choose the optimal method for achieving your goal.

4. Matrix Diagram

The matrix diagram method is used to how the relationships between results and causes or between objectives and methods, when each of these consists of two or more elements or factors. The results and causes or objectives and methods are arrayed in grid of rows and columns. Identifying the relationships between two elements or factors, where the rows and columns intersect, clarifies the problem and helps find measures for solving it.

5. Matrix Data-Analysis

The matrix data-analysis method arranges the data presented in a matrix diagram so that the large of numbers can be easily seen and comprehanded. The matrix diagram method hepls you arrange information so that your discussion will not skip over important material. It also clarifies the degrees of strenght of the relationship.

6. The Process Decision Program Chart (PDPC)

The process decision program chart (PDPC) method helps us select the best processes to use obtain desired results by evaluating the progress of events and various conceivable outcomes. In the areas of total quality management, we make an effort to plan step by step in order to solve promlems and reach our objectives.

7. Arrow Diagram

An arrow diagram uses a network of arrows to represent the acticities in a daily schedule. The order of the steps of a process and their relation to one another are represented by a network of connected arrows and points (see CPM and PERT in the network-analysis). Some types af daily plans can be designed and manged officiently using arrow diagrams.

Advanced using of these methods are applications of risk assessment, failure mode and effect analysis, simultaneous engineering, design of experiments, value engineeringg, loss function, house of quality, lean production, fault tree analysis.

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# Implementation of the Europe Flight Regulations in Flight Training Organisation of C.T.U.

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**Key words:** European air traffic regulations, airline transportation, radio-communication simulator, communication procedures, air traffic, communication training system, simulation software and system.

The faculty of transportation was founded to provide education for future engineers for the traffic system, needs in an area of the Czech Republic economy. A portion of the education program is consisting of the civil aviation problematic study.
The branch study at the department of air transport, Faculty of transportation, is organized so that the required theoretical knowledge is included in specialized courses so the Faculty of transportation graduate in area Traffic and economy of airline transportation and student is achieved required theoretical knowledge for Airline transport pilot license (ATPL) by Joint Aviation Requirements (Flight Crew License).

There is a very important area of the pilot education, which is represented by the aviation radio-communication training.
Common training systems are carried on theoretical education only. The European regulation JAR-FCL (Flight crew licensing) recommends increase rate of practical training.

This work submitted answer a number of important questions about the application of special procedures for simulation of radio-communication traffic.

The theoretical part of the solution has been verified on an experimental simulator, designed and built for this purpose. The practical experience gained from this has influenced the original solution and has enhanced the theoretical knowledge.

The work represents the result of research carried out between 2000 and 2002. It objectively assesses the possibilities of computers, analyses flight activities and procedures, and, on the basis of these analyses, formulates criteria for design radio-communication simulators.
In scope of this work has been realized simulator for training pilots – students of C.T.U. This simulator is designed for four students and two teachers, who simulate air traffic controllers.

Teacher (Air traffic navigator) creates in central computer common standard and non-standard situation and report instruction by the headset. Students (pilots of planes) have to answer and solve this situation.

This simulator consists of a central communication unit (CCU), main computer (PC-IBM Pentium III), recording units and communication units for students.

There is a new visualization system of air traffic depiction, which provides easy orientation of actual position of controlled planes.
This system consists of the public international aerodrome Praha-Ruzyně and Brno-Tuřany, public domestic aerodrome Vrchlabí, main airways, beacons VOR and NDB, compulsory and non-compulsory reporting points, main standard arrival routes and points, points for area navigation.

There is possible use radio-communication simulator for training in these points:

- Standard flights of single and multi engine planes
- Flights under VMC (Visual meteorogical conditions)
- Flights under IMC (Instrument meteorological conditions)
- Controlled and non-controlled VFR flights
- IFR flights (all parts inclusive of approaches)
- Emergency and safety landings
- Emergency situation: Lost of thrust and engine fire
- Flights in icing conditions
- Flights in the area of turbulent air
- Emergency situation on the board (rapid depressurization, emergency descent, partial or gear up landing, electrical systems failure, etc.)

In view of their accessibility, training value and low cost, radio-communication trainers may be acceptable in the future for a large number of aeronautical operators and will contribute towards improving the quality of flight crew training and towards increasing flight safety.

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# Development of Product Strategies Supported by Information System

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At the present time, in the field of doctor study, which is associated with solving research task Integrated engineering, we have aspired for creation of the information system, which facilitate to product managers their decision making pertinent with the creation of the product strategies.

Proposed information system is based on the structure of the process decision making in the course of the development of the product strategies. This structure contains:

1. Subsystem decision making for products portfolio
2. Subsystem decision making for production
3. Subsystem decision making for product prices
4. Subsystem decision making for promotion
5. Subsystem decision making for distribution
6. Subsystem decision making for product development

Main part of the information system will be information for support of the decision making for the product portfolio. This subsystem information includes information for quantification of the competition intensity and market attraction. This quantification makes possible to analyse competition position of the actual or virtual products and develop basic orientation of the product strategies.

In this connection it is necessity to note, that competition intensity is defined such as weighted average of the technical, economical and marketing competence of the given product. At the same time is the market attraction defined such as weighted average of the technical, economical and marketing attraction of the goal market.

This approach makes possible to identify the structure and methodology for quantifying of the significance and intensity impact of the factors, which throw into the manager's decision making for product portfolio.

The others parts of the information system have been modified in the connection with the individual decision subsystem. Maintaining, accessing, understanding and relying on information are activities that the manager, or any other user of information for development product strategies, must carry out. There are characteristic of information for manager's decision making. In the first place we are pressing for theirs integrity, accuracy and timeliness. Note that the accuracy necessary depends on the purpose for which the information has to be used. No matter how good the tools the manager uses are, it is impossible to build information system without data. As data are so important in modelling, there are therefore several aspects of information that a manager needs to think about. Our

concern has been mainly with the creation of information models and which might be termed their immediate use as part of spreadsheets.

In this connection is need to note, that developing structure of information system is part of the integrated system of the development of product strategies, which is the main part of the research task of the Department of management of enterprise and goals of three theses of the Ing. Vladyka, Ing. Procházka and Ing. Žemlička. Assistant Professor Dolanský provides co-ordination of these theses.

Analytical parts of the information system come out from methodology, developed by Ing. Vladyka, and from computer added model, which student Mr. Šmíd had been developed and verified. Arise from this note, that developing information system is a part of wider complex interconnected project oriented works. Their main goal is to build effective information system for support of the development and implementation of the effective product strategies of the small and middle enterprises.

The main intention of these works has been looked at ways in which the information system together with spreadsheets can be used to help product managers to handle the issues they face in their organisations, by building and the implementation appropriate product strategies to accomplish the competition advantages.

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# Market Capitalization Optimizing

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Market capitalization is defined as multiple of number of shares and its price on stock exchange. Aim of optimizing is to maximize value of shares. In this way is from traditional view, when are processes in industry company related mostly to the profit, different that focus is on relation among industry process and factors that involve share price on the stock exchange. Market capitalization optimizing is based on a presumption that value of company is defined as a price of shares and not by future profit or cash flow discounting.

Any of Czech industry companies have not reached own capital by initial public offer (further IPO) on the primary capital market for last 12 years. In 2001 company Limart, producer of parts for automotive industry, tried to realize IPO on New market of Prague Stock Exchange. This initiative was not successful because of non-sufficient interest of investors.

Main presumption for successful realization of IPO is interest of investors to invest in to the securities of the industry company. Primary request of investors is growth of market capitalization or growth of their investment. They decide about accepting IPO on base of potential growth of investment or market capitalization, but important is also quality of management. Therefore is suitable to management optimizes industry processes not just with relation to the traditional factors like profit of the company, but also to the factors that involve value of market capitalization. By this way, securities of company are more attractive for potential investors, and also is higher probability of successful IPO realization.

There would not happen nonadequate preference just one of factors, because finally it would bring high economic lost for shareholders. One of main potential treatment is extremely focus of management on earnings per share (further just EPS). EPS mania would drive management to over investing of capital in their business and over leveraging their balance sheet and also to using of „over the top“ accounting.

The high attraction of EPS is that it is grounded in what may be called the „accounting model of value“, where a company's stock price is result of multiplying its price to earnings by its earnings per share multiple. This accounting formula suggests that if EPS increase, the stock price will go up. This is just theoretical presumption that is not ever reach on real market.

Price to earnings ratio change all the time in wake of new company information about financial structure, investment and other factors that change in quality of company earnings. That fact alone makes the mere quantity of EPS unreliable gauge of company economic performance and stocks market value.

Because EPS depends on the total number of stocks, in extremely laser focus on EPS is for management impossible to finance new projects, research, development and others by IPO that would be the cheapest way for company financing. Mostly is used in this case debt financing.

In case of low return of investment of industry company's investments is not positively used leverage effect. This effect of debt capital is positively used just in case when is return of investment higher then cost of debt capital. Question stays, how to minimize risk of mentioned problem. Solution would be to EPS should not be used as key factors for economic

performance measure, or as the basis of executive incentive compensation. What is needed in its place is an economic model of value creation that is firmly grounded in the fundamentals of value creation.

From currently known economic models should be suitable Economic Value Added (further EVA), which is based on economic profit measurement. EVA is calculated as a firm's net operating profit after tax, less a charge for using capital, equity as well as debt. If company use own capital is calculated with cost of opportunity or earrings that would company obtain by investment of own capital to the investment instrument with similarly risk level.

To use EVA in Czech industry company will not be automatically improved investor's confidence to would be possible IPO realization. But this way can help shareholders to judge better economic performance of company and earlier react on potential problems.

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# Management processes in technical-economic design, decision-making, fractals and market bubbles

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Technical-economic processes are generally events running in *time* and *space* (factual space of proposal opportunities). Most of these events are related to their economic *life-cycle* and their technical-economic structure. Models of technical-economic events are in their classical analytical form based on description of equations systems, matrix models, or models based on quantitative formulas and use of differential or difference calculus if qualitative descriptions needed. There exist also other models based on theory of graphs (Demel, 2002), symbolical logic and sets (Vlcek, Beran, 1984) but also on cellular automats (Wolfram, 2002), or symbolic verbal oriented models.

Existing models operate mostly on the basis of analytic concepts of description, *quantitative* or selected *qualitative* relations. But most of them do not contain build-in *decision-making* mechanisms or connections to possible *operational management or steering interventions* feasible to be used in a model that enabled design.

Engineers and economists - using simple modeling tools like timetables, budgeting, costing, or financial and management planning – should know, however, where the tools they are using incorporated in spite of hierarchy of sophistication, have their fundamental utility and benefits. A good model of reality is our desirable goal, an apposite, useful reality model. The model that is the right represents a true picture about functions, opportunities and by means of project solution designed *values added*. Economics, despite to technical science, presents values that are partly impermanent (unsustainable). Values are changing in time, vanish and other comes into view. Under conditions for sustainability it is desirable to define not only sets of activities (sets of processes) that operate as a substance (material) transforming *controlled models* (**P**), but also comprehensive (derivative) structures of controlling character, i.e. set of *controlling models (steering models)* (**L**).

Let's delineate synergetic symbiosis of **P** and **L** as *process of management* (**M**), (in *Vlček, J., Beran V.,*1984*, Beran*, 1997 and 1999). To simplify the situation the operating model will be described only in space of quantitative derived components created on the base of so called networked processes $P_i \Rightarrow N_i$=<**A, K**>, where **A** represents a set of components with their physical descriptions **U,** dependences in time ***D*** and a sets of dependences of quantitative character ***Q*****.** **K** is interconnection set between components with their set of physical descriptions **V,** construction of connections $\Delta$, and starter of connections $\varepsilon$.

An attempt to reply to few partial questions is coherent to entry (1) from the time-oriented viewpoint on decision descriptor **D˜,** in briefness. There would be certainly interesting to know, whether in engineering the design-applied procedures possess decision processes with certain particular properties. It is important to comprehend this, especially at that time, when we are looking for explanation and causes of an unexpected project development. A number of successful or unsuccessful fatalities of engineering projects from out hands of homo *economicus* or *technicus* may have its realistic causation out of rational vision, commonly seen. The very character of steering space, its structure in time, may be insofar specific and for applications in engineering design inhomogeneous, that go down to unforeseen *sustainability erosion of life-cycle* of technical work (design). A sequence of decision-making in steering

processes (simplified said management) may have for implementation other rules and place than they are commonly viewed to this time. The reasons are mainly economic limits and indicators; however, their duration is mainly only a fragment of the total technical life-cycle of a designed project. Application of designing (formation) might have proceed other way out in using better rules for selection of their solutions (decisions) inside steering process (**L**), at least better in terms then we are using to thing about these **D -** rules, this is the main and real reason why this article was written.

In the symbolical inscription it is dealt with a notation of *management* like:

$$\mathrm{M}_N = \left\{ \begin{array}{l} \mathrm{M}_i^N \left| \mathbf{M} = \left[ \left\langle \varphi(\mathbf{t},\mathbf{P},\mathbf{L}) \middle| \mathbf{D}^{\sim} \right\rangle \middle| \mathbf{K}^{\sim} \right], \ \mathbf{P} = \langle \mathbf{A},\mathbf{K} \rangle, \right. \\ \quad \mathbf{A} = \left\langle \mathbf{U},\mathbf{D},\mathbf{Q} \right\rangle \\ \quad \mathbf{K} = \langle \mathbf{V},\boldsymbol{\Delta},\boldsymbol{\varepsilon} \rangle \\ \quad \mathbf{L} = \langle \cdot \rangle \\ \quad \mathbf{K}^{\sim} = \left\langle \mathbf{V}^{\sim},\boldsymbol{\Delta}^{\sim},\boldsymbol{\varepsilon}^{\sim} \right\rangle \\ \quad \mathbf{D}^{\sim} = \left\langle \mathbf{F}^{\sim}, \mathrm{d}(\mathbf{h}) \right\rangle \end{array} \right\} . \qquad (1)$$

Lay up yourself several fundamental questions see fig.:

1. Is steering area for decision-making homogenous?
2. Does inhomogeneous decision-making implementation of environment (space, area) influence the decision steering process $\mathbf{D}^{\sim}$?
3. In what extent is decision process $\mathbf{D}^{\sim}$ in time strata $t_x$ interfered by the previous decisions in the former time layer?
4. In what extent will be decision processes $\mathbf{D}^{\sim}$ in time strata $t_{x+n}$ (further future) interfered decision in time nearer layer $t_x$.

Applications of fractals can be one of the interesting stimulations (Mandelbrot 1991).

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# Project Management of Public Construction Contracts

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In terms of Research plan of our department, I was working on creation design of information system about public building order's. This system should tie together on already going system, which is working on internet address www.centralni-adresa.cz and serve to public all public order's and auction. Original system, which has arisen some years ago was essentially improved, but for specific building order's is unusable, because does not contain some basics specifications. This system does not use for scheduling realization building orders and proposal portfolio of project public construction contracts.

Designed system

Basic demand on information system was set thus:

- Easy accessibility
- Simple operation
- Well-arranged provided information and their topicality
- Low purchase price and operating costs

Like optimal solution of these demands is show database operating at internet. Most of submitter and potentially contractors has possibility connect to Internet nowadays and this executed first demand (easy accessibility), head software for using this type database is any Internet browser (MS Internet Explorer, Netscape etc ..), this executed second demand (simple operation) and on-line data processing allows realize next requirements (topicality and rate). Purchase cost on this solution are in comparison with distribution by brochure or sending data disks (diskette or CD) minimal and because new data entry to the database directly contractors and it is necessary perform only their formal verification are very low also operating costs. Last demand on well-arranged provided information it is possible realize thru searching database by different criteria and also by sorting orders as according to point of delivery also according to submitter (eventually contractor) or according to code JKSO or SKP.

Information system would hold following information:

- Name of submitter, ICO, address, contact info.
- Object of order, method of submission OVS, evaluative criteria, number of received offers, most high and lowest supply price.
- Information about selected contractor – name, ICO, address, supply price.
- Date conclusion of a contract, contracting price, termination date.
- Evaluation of order – real price, real termination date.
- Supply budget in electronic shape (in specific data format).

The present state

From designed system is already one segment realized and run in test operation at Internet address www.vsz.cz. From designed system isn't realized segment witch gathering tendering budgets yet.

Data entry is fragmented to the three phase:

- At publish contest (OVS)
  - Information about submitter (name, ICO, address).
  - Information about order (object of order and its description, range of order, point of delivery and contact person).
  - Information about contest (competitive time, evaluative criteria, date, time and place opening cover etc ..).

- After subscription of contract
  - Information about process contests (number of received offers, most high and lowest supply price).
  - Information about selected contractor (name, ICO, address, supply price].
  - Information about contract (date conclusion of a contract, contracting price and termination date).

- after termination of order
  - data about order (real price, real termination date)

This new information system serve significant benefits for submitters also for potential contractors. Should has been this information system finished and supplement for public building orders already operating information system on www.centralni-addresa.cz, it would great effect in using public resources

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# Units Throughput in the Area of Non-linear Processes

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There was an assumption given that the transport units in so far existing conceptions of units throughput in transport nets which enter in an operation on the transport net act predictably according to given rules. It means, that the transport unit (further the customer) demanding the transit through the elements of the transport net (further we name the transit through the elements of transport net as the operation)

- is operated by the element because of vacancy of the operation system
- the operation cannot be proceeded because the operation system is occupied and than following 3 cases may arise:
  - the operation system has an unlimited box and the unlimited line is being generated before the operation system – congestion is being developed
  -the operation system has a box with a limited number of waiting spots. The customers make the line and if the waiting system is occupied, they are rejected
  - if there is no possibility to make a line, the customer is rejected

The congestions on the transport net are always prospected on those spots, that we call "the bottom necks", so on those spots where the throughput is limited both permanently or from some accidental reasons (for example on the artificial construction sites such as bridges or tunnels with lesser width than the feeder road). If we qualify $t_i$ as a intermediate interval between the customers and $\tau$ as the intermediate throughput time through the bottoms necks (service time), the congestion turns always up when the following inequity is valid

$$t_i<\tau \qquad (*)$$

Interval $t_i$ is usually characterized by an exponential probability density. If we know the probability density of the interval $t_i$ we are able to calculate the congestion origin probability from the relation

$$p_k = \int_0^{\tau} \frac{1}{\tau} e^{-\frac{1}{\tau} t_i} \, \mathrm{dt}$$

If this situation happens, the transport unit reach the bottom neck and the waiting in the line can be determined as the intermediate waiting time in the unlimited line before the n-line bulk service system. If it is possible to evaluate the waiting time of the unit in the line, we are able to calculate the loss that happened due to the congestion origin as well (only under the condition that every traffic participant that comes to the line acts standardly).

However this acting is not usual. Usually we can find some participant that isn't acting standardly i.e. he doesn't want to wait so he tries find a parallel road that would enable him to pass the bottom neck. Usually there are many such possibilities and thus the parallel lower hierarchy transport net is being created. Due to the above mentioned acting the participant incites the other participants to the similar acting and than these crowd the parallel lower hierarchy net where the secondary congestion is generated. But the line on the main road usually disappears. This stimulates the repeated usage of the main road. If the conditions are again set up and the transport density exceeds the capacity, the situation repeats (see the

inequity (*)). However the change of line origin with free road and crowded parallel lower hierarchy net depend on the daily period, day in the week, month or the year or even on the weather and is not predictable in the regular cycles. The specific form of turbulence is developed. It´s getting on the non-linear system solutions, i.e the solutions where there ocures the change from the regualtions to chaos, that are necessary to take into account especially when deciding what logistics technology shall be used. It can be assumed, that the solution contributes to sequential implementation of the transport telematic systems. Due to the still increasing load on the transport nets it will be necessary to improve the optimalization procedures and to find the right solutions in the non-linear system models.

The non-linear differential equations system is extremely difficult to solve thus it is substituted by iterative or other methodes. In the present case it is suitable to replace the solution by the operation on the part of the transport net. The method is following:

- If there exists the real transport net with the bottom neck, the calcualtion of parametrs a, b of the probability distribution M has to be unertaken based on the statistical traces.
- We define the researched transport net and the position of the bottom neck and its characteristcs (particularly the number of serviced lines (the number of lanes on the road net) or other restrictions such as speed limit atc.)
- We define the parallel trasport net and bottom neck on this parallel transport net
- We define the possible startup spots of the researched transport net on the parallel transport net (the cusomer usually cannot exit the line anywhere but only on slip roads, i.e. the customer that gets into the line between the bottom neck and the slip road cannot exit the line).

For the simulation the Monte Carlo method is used. Based on the statistical analysis in coincidnce with the voted certainty according to the II. Cebysev inequity we determined the respective probalibities and from them derived generator of random numbers.

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# Product Costing: Starting Target of Development Process or Result of Development?

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The answer to the title question is only one in current times: *both of them*. Product costing has to be presented at least in the figures of cost targets as cost limits *at the starting point of any product development process*. And it must be checked up at the *end of the development process of a new product*, before its production started, if the introductory cost target was achieved. Later it must be evaluated regularly during the routine production period.

The assessment of the up to now experiences from the Project Michadlo confirms that product cost limit (product cost target) cannot be expressed in only one figure. Product costs are composed by a lot of cost elements representing various activities, which are related to the new product development, product and its production technical specification creation, production, distribution, sales, marketing and servicing. Some of them are costs that can be allied to one unit of product (e.g.: greater part of production cost). Some of them have a character of a process budget (e.g.: new product development process cost). Some of them are composed from both of them (e.g.: distribution cost, partly related to the number of units, partly independent on the number of units). This reason, but not only this one, links costs, activities, processes and the scale of production closely together.

This knowledge results into a requirement for a comprehensive analyses of the factors and their costs linked to the activities which are creating each particular process. Let me shortly illustrate it on the new product development process.
The cost limit for product development process depends on numerous factors like: The complexity of development process, the scale of innovation, number of product components, the size of development team, the equipment needed and financial sources available and so on. Often the last factor - financial sources - dominates. The construction of the cost limit for development process has to be made as a typical process budget. Its size depends on the character, difficulties and scope of each activity, from which the process is created.

***Conclusions:***

In the phase of the decision making of setting up the attributes of a new product and of starting product development process have to be established not only:

- Major *utilities attributes*, which are primary and
- Major *technical attributes*, which mainly determine the structure of the product and the manner of the production process,

*but in addition also:*

- *Product cost limit*, which is related to many other basic attributes, above all to:
- *The number of units* to be produced and sold, which leads also to a decision about:
  - A production technology and production special equipment (and to the size of the related cost)
  - The extent of the technical, production and other product descriptions (and to the size of the related cost)

- The manner of servicing the product (and to the size of the related cost)
- The manner of product distribution and marketing (and to the size of the related cost)
- The size of the cost of the product development process
- The size of the cost of the product guarantee repairs
- The size of the cost of the product certification (if needed).

All these and some other costs, for example part of the administrative cost, as well as expected profit, have to be covered by returns from the sales of this particular product.

All above listed costs have to be covered by the sales return. This results into significant conclusions about *the size of the product cost limit*, also called *product cost target* and about the *number of product units* to be produced:

- The product cost limit is derived from the price, which is expected to be paid by the customer (or has already been agreed - in case of individual order)
- The size of production product cost limit has to be essentially lower than the total product cost limit. The lower is the number of produced product units, the greater difference has to be between both values.
- The number of units produced has to be as high as possible (economies of scale)
- The unit cost limit is often equaled to the production unit cost limit, that causes many wrong conclusions
- A lot of essential product costs are fixed direct[1] costs, independent from the number of product unit produced or only with a low dependency on it.

The product cost limit has to be determined at the beginning of the product development process and its size has to be evaluated firstly after finishing the product development process and than regularly, at least once a year, to verify its actual value. Primary reasons for evaluations are:

- To indicate the possible difference in the real value of the product cost and its reasons
- To gain knowledge about the scale of the influence of the reasons for the next new product development process
- To reward employees, which were responsible not to exceed the product cost limit
- To improve the methodology how to operate with a product cost limit (target).

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[1] Direct in the sense to be allied to the certain product

# Planning in the Project Management

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Planning is the activity which is creating bridges between the place we are standing now and the place we want to go. It is a starting point, which foregoes all other management activities. It is so because planning comprises determining of objectives and suggesting various ways how to achieve those objectives. Plan is a document suggesting a rational approach of activities, processes and arrangements in order to achieve defined goals. A determined structure and range of resources should be an integral part of a plan together with time schedule of implementation. There should be also determined level of disposable resources, which should be stated in a document integrating limits of various resources. Such a document is budget.

Although all plans are different, they look different, but they all should be similar in two points. All plans should answer two questions:

- what is to be achieved (definition of objectives)
  (Criteria: definition of priorities, measurability, adequacy),
- how is it to be achieved (activities, resources, terms, responsibilities).

Planning is the important managerial activity aimed at the future development of organization, which determine the ways, resources, terms and responsibility necessary to ensure these objectives.

The plans serve as a direct tool of organization control. The plans of lower level should result from the superior intentions (plans of higher hierarchic level) and organization sources of information. The plans can be sorted according to various criteria – time, level of management process, content, purpose. A structure of drawing-up plans is not unambiguously determined, any organisation assemble its own optimal system of plans.

The planning process is on of the key elements of project management, which foregoes controlling and managing processes. *Planning* the project means thinking about and documenting what needs to be done – defining and coordinating specific activities and work tasks, assigning and allocating resources to activities, and developing an acceptable budget. *Controlling* the project means staying on course – tracking work progress and actual costs, comparing progress and costs to the baseline, devising workarounds, and recommending action. *Managing* the project means communicating as accurately and timely as possible the schedules progress – what has happened – and what may happen ("what if" analysis).

In planning in construction, there are two main levels of planning associated with construction projects. Strategic planning deals with the high-level selection of overall project objectives, including the scope, procurement routes, time-scale and financing options. Operational planning on the other hand allows a more detailed look at the project's resource requirements that is not obvious at the strategic level. Examples of operational plans include a tender plan, feasibility plan, and construction plan. Planning at both strategic and operational levels for a construction project employs various tools and techniques to help the planner achieve better optimisation for the decisions involved.

The most common and widely used techniques suitable for the operational aspect of planning (but equally adaptable for planning at the strategic level) are bar-charts, space-time

diagrams especially for linear constructions, line of balance for repetitive construction work and network analysis, either activity on the node (often referred to as precedence diagrams) or on the arrow (also known as arrow diagrams).

*Bar-chart* – is one of the easiest and the most widely used planning tool for featuring a project information graphically as a list of activities with the start, duration and finish of each activity shown as a "bar" plotted to a time scale. The activity columns make it easy to view or update important activity information in a tabular format. The main disadvantage of manual bar-charts is the inability to update the bar-charts data.

*Space-time diagram* – is a planning technique suitable especially for projects, that are essentially linear in nature, or where there is a considerable repetition of a work package. It presents a pictorial view of how the works should progress on site. It is normally two-dimensional graph that represent time on one axis, and a measure for production on the other axis. Used as a planning tool, it allows the identification of potential constrains in the utilisation of resources or the risk of interference between operations.

*Line of balance schedule* – comprehended as a special kind of space-time diagrams, is a planning technique for repetitive work. The basis of the technique is to find the required resources for each stage or operation so that the following stages are not interfered with and the target output can be achieved.

*Network analysis* – is one of the most sophisticated methods for a project management using the computer calculations. It is based on a graph theory. Networks are collections of nodes connected by oriented lines (arcs, arrows). The planning data in a network are linked through the logic that defines the relationships between the activities. There are two forms of network analysis:

*Arrow diagram* – (activity-on-the-arrow) is network diagram, where activities are represented by the arrows, which are joined together in a logical relationship.

*Precedence diagram* – (activity-on-the-node) is network diagram, where a node represents the activity and the arrow is only the logical relationship.

The following methods can be used at the both types of the network analysis.

*CPM* – (Critical Path Method) is a mathematical model that calculates the total duration of a project based on individual activity duration and dependencies and identifies, which activities are critical. They create the critical (longest) path of the project.

*PERT* – (Program Evaluation Review Technique) is network scheduling system, which uses statistical probabilities to calculate expected durations for each activity and determine the probability of finishing entire project by a certain time.

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# System Dynamics in Project Management

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Project management is used in businesses to accomplish unique outcomes with limited resources. Project organization can be described as a system with many relationships between system elements and an external environment. Project manager has to meet project goals that are designed by company chiefs in changing internal and external environment. Typical change of the internal environment is the turnover of workers that causes problems with the allocation of resources over the project [1,4]. The situation is more difficult in multiple project environment.

Possible approach in describing the system is using system dynamics method. System dynamics is the most used simulation method in the management science together with discrete event methods [2]. It would be possible to build the model of the problem situation and to experiment on computer by varying model parameters. By means of a computer-based model we can carry out many experiments and therefor the information flow is high.

Dynamic modelling of project management is based on using these model elements that are connected to the feedback system [2,3]:
- stocks (level of important variables),
- rates (influence important flows in model),
- decision elements (elements where the decision is done and moved to stocks and rates).

Main flows and additional elements for project management problem that influence results:
Project flow includes: projects in preparation – projects under work – finished projects
Elements: running cost in company
Resource flows includes: needed resources – used resources – known used resources
Elements: selection of physical resources, selection of supplier
Manpower flow includes. people just recruited – skilled people
Elements: selection of people, training, supervision, level of wages, unemployment rate, quality of education
Subcontractor flow includes: subcontractors used in projects
Elements influencing most flows: general economic situation, competition in certain field of economic, inflation rate, situation of company's market.

More attention needs manpower flow. For many companies that use as main production process projects, the key problem is the need for skilled employees. The ability to attract skilled workers is the advantage in long term strategy as well as in solving ad hoc problems with new projects.

Another problem is high labour turnover which is typical for consultancy companies and IT companies. Manpower is influenced by the recruit rate that ensures in the model positive flow and leave rate that causes decreasing of workers in the company.

The recruit rate depends on the required growth and on the economic situation as well as on the situation of working power market. The leave rate depends on the type of company and needs the investigation of the certain problem situation.

Delays in the system are typical for the system dynamics problems. Typical situation in the described problem is hiring new workers to fill free position, but it means the delay in projects because the company has to find new employees and often also has to train them.

To obtain output parameters the level equation has to be added to the model [2]. Basic format of the equation is:

$$\text{Parameter level (t)} = \text{Parameter level (t-1)} + D \,.\, ( In^{t}_{t-1} - Out^{t}_{t-1} )$$

where
Parameter level (t) is value of calculated parameter at time *t*
Parameter level (t-1) is value of calculated parameter at time *t-1*
D is time increment
$In^{t}_{t-1}$ is the input rate in time interval from *t* to *t-1*
$Out^{t}_{t-1}$ is the output rate in time interval from *t* to *t-1*.

System dynamics in this case can help in the decision making process. Benefits by using this model:

- The design of buying rate for resources to fill a specified amount of work.
- The design of recruitment rate for the manpower.
- The identification of the project work amount (number of projects) performed at the same time.
- The design of the share of the training capacity between new workers and current workers.
- The identification of the recruit process importance.

The result of the research is the first design of the model that will be completed by additional elements and run on the computer.

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# The ITS Applications Using the GNSS System

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Basic objective of the creation of the transport-telematics architecture is the achievement of the interoperability between individual telematics applications, including maximum use of available infrastructure by all telematics applications while keeping systems requirements on individual telematics applications (technical requirements: safety, reliability, availability, integrity, etc.; transport related requirements: transport comfort, minimisation of external requirements of the transport related process, maintaining of transport policy objectives at national and European level, etc.). The task also covers the selection of representative telematics applications that show identical systems requirements. Among individual representative ITS applications using GNSS the following may be included:

- securing the movement of means of transport on a transport infrastructure (from the point of view of systems parameters on the GNSS it is a question of securing the accuracy, reliability, availability, integrity, etc., in exactly defined points of the transport infrastructure – the application lays high demands both on the locator proper and the information transmission and processing systems; the solution should comply with the "fail-safe" principle; as typical transport telematics applications we may refer to railway safeguarding technology, monitoring the transport of dangerous goods or monitoring the movement of means of transport on an airport area,

- navigation of the means of transport on a transport network (from the point of view of systems parameters it is a matter of coverage with a signal, time lag at on-line navigation, requirements on exact working maps of the entire Czech Republic, requirements on speed of information processing both in a mobile unit and the processing centre, requirements on the minimisation of the delay in establishing the position – TTF); as typical transport telematics applications the following may be referred to: navigation of safety and rescue units to the localised accident place or dynamic or on-line automobile navigation,

- monitoring and operating the maintenance of transport networks (from the point of view of systems requirements is particularly a matter of an exact transport infrastructure information retrieval, interoperability of individual GIS systems of various organisations dealing with maintenance, achievement of high statistical accuracy in establishing a position); as typical transport telematics applications the following may be referred to: mapping the river channel by means of a measuring ship Valentýna or measuring the carriageway parameters by means of special measuring vehicles,

- monitoring the movement of persons and goods on a transport infrastructure (from the point of view of systems requirements it is a matter of transmission and central processing of large amount of information from resources with various accuracy, fast identification of individual sub-sets of the objects of transport, sophisticated information processing in the centre, for instance, the "Floating Car Data"); as typical

transport telematics applications the following may be referred to: the use of taxi cabs, public transport passenger vehicles or other utility vehicles equipped with the GNSS systems for traffic flow modelling or the use of localised mobile telephones for modelling the mobility of persons,

- transport infrastructure charging according to its utilisation (from the point of view of systems parameters it is a matter of reliability, integrity and time lag because the GNSS system is used for the calculation of the amount of the charge and, furthermore, the application places demands on the "fail-safe" principle in terms of the distance covered – if there is an uncertainty about correct charging of the driver, the distance covered is not taken account of); as typical transport telematics application we may give the electronic charging of the transport infrastructure according to vehicle parameters and distance covered.

The next step following the architecture design is a cluster analysis of individual requirements on individual subsystems of transport telematics chain, including the locator, according to pre-defined criteria. The selection of criteria makes a substantial part of the design because if the architecture is to play an integrative and optimisation role it is necessary to look for stabile optimisation criteria, for instance, the selection of the most exacting criteria of all the representative applications, weighted average of all the most exacting criteria, etc.

The result of the architecture should be a design of individual subsystems and functional blocks, including the definition of their systems parameters. From the viewpoint of the construction of the locator proper it is possible to consider a single universal locator fulfilling the most exacting systems parameters, the creation of several locator classes according to a set of systems parameters, creation of a modular locator where the addition of another module entails the increase of systems requirements, etc.

The same principle may be applied in designing the telecommunications environment between a mobile unit and information-processing centre (unified radio band frequency for all transport telematics applications, combination of individual transmission systems, combination of fixed and radio networks, etc.). In analogy with the case of the locator the design of the telecommunications environment may be divided into several classes or, as the case may be, the transmission environment may be designed in a modular way when higher systems requirements on the information transmission may be achieved by adding additional modules.

Similar situation applies for the processing centres, the user charging, etc. It is necessary to consider whether each transport mode has to have a completed information processing centre available, whether there is an opportunity for sharing such centres or whether the implementation of geographical optimisation of the processing centres needs to be undertaken, etc. However, in the case of various variants of the design of the locator, transmission environment or processing centre, the systems parameters of individual representatives of transport telematics applications have to be guaranteed.

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# Transport of Dangerous and Oversized Goods

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In the combined transport field the research in this area shall focus on the testing of the telematics application which deal with the monitoring and optimal management of the transport of dangerous and oversize goods on various transport infrastructures (transport infrastructures for various transport modes, transport terminals, etc.). The presented solution relates both to the selection of the route for the dangerous or oversize goods and the monitoring of the actual movement along the chosen route, including an automatic reporting of the position or, if appropriate, other vehicle parameters during the transport process in the case of an accident.

The chosen telematics application shows increased systems requirements for, in particular, the integrity, availability, reliability and the time lag (dynamics) of the telematics application as a whole, which includes collection of in-vehicle information, including data on the actual position of the vehicle with dangerous or oversize goods, transmission of information to the processing center, information processing in the processing center – exact accident location into a digital map, selection of other data in other databases – meteorological information, etc., and informing the IZS brigades.

As an argument for not underestimating the dangerous goods accidents we enclose a statistics of accidents in the Czech Republic where 4.9% of all interventions of fire and rescue brigades were related to dangerous goods accidents, including crude oil breakdowns, in the period of 1996 – 2001. The accidents during the transport of dangerous goods, excluding the accidents indicated as crude oil breakdowns, covered 1% of all interventions in the same period.

Tab. 1 Number of events involving an intervention of units of fire brigades 1997-2001

| YEAR | | | | | |
|---|---|---|---|---|---|
| **Type of event** | **1997** | **1998** | **1999** | **2000** | **2001** |
| Fires | 20 612 | 23 078 | 20 002 | 20 088 | 16 421 |
| Traffic accidents | 1 287 | 14 614 | 16 559 | 15 388 | 18 536 |
| Dangerous materials | 852 | 690 | 705 | 627 | 560 |
| Crude oil breakdowns | 2,33 | 2779 | 3147 | 3 141 | 3 596 |
| Activities on water areas | 1195 | 403 | 390 | 529 | 399 |
| Pumping water | 4750 | 1417 | 1795 | 2,168 | 2 228 |
| Technological support | 2305 | 1270 | 1634 | 1 696 | 1 272 |
| Technical support | 24274 | 24809 | 26076 | 27 699 | 32 679 |
| Other technological interventions | 1935 | 1284 | 1523 | 1 922 | 1 555 |

| | | | | | |
|---|---|---|---|---|---|
| False alarms | 7637 | 7521 | 7884 | 7 580 | 8 237 |

The telematics system supporting the transport of dangerous goods is designed in order to be utilizable in the transport of goods by road, rail and also by combined transport. The system will register all entities involved in such transport and, furthermore, it will register all transport units designed for the transport of dangerous goods. All entities as well as the transport units will have to dispose of a valid authorization for the transport of dangerous goods, which will be checked by the system and the entities concerned (public and private) will be warned as to discrepancies, if any.

The suggested telematics application for monitoring the transports of dangerous goods is interesting from the point of view of the locator technology proper because high requirements will be placed on the locator, particularly as regards:

- availability of the position information – as an example we may refer to the rise of an accident in a tunnel when the processing center inevitably needs exact localization of the accident because of the rescue work management (arrival of rescue units to the opposite side of the tunnel may involve catastrophic consequences),

- position localization accuracy – especially in case of an accident because it is necessary to establish in which motorway direction the accident took place (a sophisticated processing of historical values directly by the locator will require many information from which the direction of the movement of the freight, the speed of the movement of the freight at the breakthrough, etc, could be inferred),

- dynamics of information processing – in case of the pilot project various information processing dynamics with the use of a sophisticated approach to information processing in a typically distributed information system will be tested,

- parameters of digital working maps, like the accuracy, attributes of manoeuvres on the network (one-way streets, heights of bridges, bearing capacity of bridges, etc.), integration of individual working maps from various public and private institutions in the field of, for instance, environment, police, integrated rescue system, etc.

In designing the described application all the advantages of the new Galileo system will be used – the application is a typical representative of the so called guaranteed telematics service (the parameters of this service as a whole must fulfil the pre-defined systems requirements – the performance requirements) relating to the monitoring of the movement of mobile means on a transport infrastructure.

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# Evaluation of the State of the Public Space in Cities after Overflow

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The research works resulted in presentation at the currently method for evaluation of the state and damages on the technical utilities (sewerage, water and gas distribution pipelines, heating networks, cables and other municipal networks, different ducts, incl. roads, pavements, parking-sites, urban furniture etc.) located in the public space of the cities and villages (general of the seats) after the overflow as a method of solution of a special problem „ black-box“ (in these cases we usually have not necessary information's enough).

Attack of water (operates during and after the overflow) accelerates the processes of worning-out and old-making, reduces the vitality of all parts of the technical utilities (simply, individually and in complicated, different combinated, directly and indirectly influences).

State of the legislative documents and technical regulations, standards and codes for the technical utilities in the Czech Republic is not in correspondence with requirements of the co-ordination of all interests in the public space of the seats, especially for the situation during and after the overflow too. One of examples shows table 1. – different variances of the parameters for basic space co-ordination of the urban networks.

Consistent analysis of all important problems in large connections gives several interesting results incl. the necessity of the complete co-ordination all objects in the public space already in the masterplan.

| Parameter (m)/Background: | | Protection zone (m) (according to the law and professional standards or rules) | Minimal distance of parallel lines (m) according to the ČSN 73 6005 | Minimal distance according to the stability of parallel lines (m) [4] | Parameters of manipulation zone (m) [4] on the terrain (under ground) | |
|---|---|---|---|---|---|---|
| Kind of line: | | | | | min. | max. |
| Telecommunica-tions cables | freely laytreaded | 1,50 | 0,30 up to 0,80 (1,00)[2] | 0,50 up to 1,00 | (0,30) cca 0,50 | (0,60) cca 1,00 and more |
| | in protective construction | 1,50 | 0,10 up to 0,80 (1,00)[2] | 0,50 up to 1,00 | (0,40) cca 0,50 | (1,00) cca 1,00 and more |
| Energetic cables | up to 110 kV | 1,00 | 0,15 up to 1,00 | 0,50 up to 1,00 and more | (0,40) cca 0,70 | (0,80) cca 1,50 and more |
| | above 110 kV incl. | 3,00 | 0,20 up to 2,00 | 0,50 up to 2,00 and more | (0,50) cca 0,70 | (1,00) cca 2,00 and more |
| | in protective construction | not specified | it possible to reduce | 0,50 up to 2,00 and more | (0,60) cca 1,00 | (1,50) cca 2,50 and more |
| Central heating pipes (all kinds of laying of the pipes) | | 2,50 | 0,30 up to 1,00 (2,00)[3] (2,00 in case 110 kV) | 0,50 up to 2,00 and more | (1,00) cca 1,50 | (1,50) cca 2,50 and more |

| | | | | | | |
|---|---|---|---|---|---|---|
| Gas pipes | LP + MP | 1,00[1)] | do 0,005 MPa<br>0,40 up to 1,00 | 0,80 up to 1,50 and more | (1,00) cca 2,00 | (1,50) cca 3,00 and more |
| | other | 4,00[1)] | do 0,4 MPa<br>0,40 up to 1,00 | 1,00 up to 2,50 and more | (1,00) cca 2,50 | (2,00) cca 4,00 and more |
| Water pipes | | 1,50 (for DN ≤ DN 500)<br>3,00 (for DN > DN 500) | 0,40 up to 1,00 | 1,00 up to 2,50 and more | (1,00) cca 3,00 | (2,00) cca 5,00 and more |
| Sewage and urban drainage pipes | | 1,50 (for DN ≤ DN 500)<br>3,00 (for DN > DN 500) | 0,30 up to 1,00 | 1,50 up to 3,50 and more | (1,50) cca 3,50 | (3,00) cca 6,00 and more |
| Kableducts | | not specified | 0,10 up to 1,00<br>(1,20)[2)] | 1,00 up to 2,00 and more | (0,80) cca 2,50 | (1,50) cca 4,00 and more |
| Ducts | | not specified | (0,00)[4)]<br>0,30 up to 1,00<br>(1,20)[2)] | 3,00 up to 5,00 and more | (3,00) cca 5,00 | (4,00) cca 7,00 and more |

**Notices to the table 1. :**

1) In extraordinary cases up to 200 m.
2) In case of track of tramway.
3) In case of energetic cable 220 kV.
4) Numeral values are the results of the special casting.

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# INDEX

Adamec, J., 682
Adámek, T., 878, 880
Alexandrová, J., 982
Anderle, P., 682
Andreovský, J., 706
Antoš, P., 666
Assefa Lemma Asresahegn, 760
Aubrecht, L., 96, 98
Aubrecht, P., 278
Aubrechtová, K., 1052

Bach, P., 754
Bakstein, H., 240
Baloun, J., 206
Barvíř, P., 64, 68
Basiev, T., 172, 174
Bauerová, D., 362
Baše, M., 1088
Bašta, J., 638, 640
Bedlovičová, D., 926, 944
Bednář, P., 1104, 1106
Belda, K., 226
Benda, V., 760, 762
Beneš, M., 922
Beneš, M., 74
Beneš, M., 48
Bensch, J., 598
Beran, T., 328
Beran, V., 1020, 1116, 1130, 1132, 1186
Beranová, L., 794
Berka, L., 536
Berka, V., 1130
Berka, Z., 336, 820
Bečka, J., 730
Bečvář, M., 318, 354
Bittnar, Z., 980
Blažej, J., 490, 502, 512
Blažek, R., 1070
Bloch, M., 296
Bláha, J., 1124
Bláhová, I., 66
Bláhová, M., 896
Bodnár, M., 94
Bosáček, V., 568
Bouda, J., 822
Bouda, V., 546
Bouzek, M., 270
Bouška, P., 606, 940, 944
Bozenhard, M., 862
Brandejsová, E., 820
Branderský, D., 1104
Brothánek, M., 66, 162, 164
Brož, J., 748
Brož, K., 654, 808
Brož, P., 1066
Bryknar, Z., 122, 156
Brát, M., 252
Bubeník, F., 24, 1050
Bubák, A., 756
Budinský, R., 106
Buhr, K., 800
Bulínová, M., 728
Burda, P., 42
Burdík, Č., 74
Burgetová, E., 926, 944
Buš, L., 366
Buček, J., 304
Bálek, R., 118, 140
Bém, P., 832
Bíla, J., 310, 314
Bílek, P., 282
Bína, V., 116
Böhm, J., 226
Březina, I., 212
Břeň, D., 102, 104, 254

Cabalka, M., 858
Capoušek, L., 1180
Cejp, J., 532, 534, 540, 548, 552, 600
Cejp, J., 370
Cerman, A., 418
Chadzitaskos, G., 74
Chludil, J., 200
Chládek, J., 546
Chmelenský, J., 798
Chmelík, F., 78
Chod, J., 1022
Chvojková, P., 1000
Chvátil, D., 824
Chyský, J., 362, 742
Cháb, V., 842
Cikrle, P., 944
Cimbál, P., 268
Cipra, M., 786
Ctibor, P., 564
Cvek, J., 884
Císařovský, P., 564
Císlerová, M., 970, 1038

Čambál, M., 782
Čapek, P., 590
Čechák, T., 178, 336, 818, 820, 828, 876
Čejka, T., 944
Čenský, T., 650, 682, 684
Černoch, T., 582
Černý, F., 110, 124, 560
Černý, J., 22, 26
Černý, M., 1046, 1064
Černý, P., 166, 172, 174
Černý, P., 456, 458
Černý, R., 516, 518, 520, 522, 524, 526, 528, 932, 934, 938
Čeřovský, Z., 788
Čábelka, M., 258
Čáp, K., 746

Daněk, M., 306, 374
Denk, T., 576

Diels, J., 150
Dierolf, V., 590
Diviš, M., 642
Dlask, P., 1020, 1116, 1130, 1132
Dlouhá, M., 142, 144, 460, 544, 568
Dobeš, J., 670
Dobeš, J., 906
Dolanský, J., 852, 858
Dolanský, V., 1118, 1182
Dombrovský, A., 92, 150
Donát, A., 890
Doroschenko, M., 172, 174
Dostál, M., 740
Dostál, M., 836
Dostál, T., 962, 964, 966
Dostálek, M., 908
Dostálová, S., 836
Dostálová, T., 902
Doubrava, K., 688, 702, 744
Drahoš, V., 436
Draxler, K., 784
Draxler, M., 672
Drchal, J., 316
Drchalová, J., 528
Drtinová, B., 858
Drška, L., 116, 168, 176, 344
Dráb, M., 460
Dufek, J., 836
Dufek, L., 1092, 1094
Dunovský, J., 564
Dušek, J., 256, 908
Duška, M., 976
Dvořák, J., 698
Dvořák, J., 38
Dvořák, J., 358, 700
Dvořák, M., 182
Dvořák, P., 876
Dvořák, V., 1092
Dvořák, V., 402
Dvořáková, H., 38
Dynda, V., 210
Dynybyl, V., 722

Ďaďo, S., 424

Ebel, M., 1080
Eck, V., 870
Eisner, J., 638
Ertl, O., 380

Farag Elnagahy, 242, 244
Fejtová, M., 292, 870
Fiala, P., 130, 132, 134
Fidler, V., 182, 184, 414
Filip, J., 324
Fischer, J., 442
Fischer, M., 1084
Fišer, P., 312
Foit, J., 494
Fošumpaur, P., 1014, 1016, 1018
Fošumpaurová, P., 1018
Fořt, J., 670
Franc, V., 234
Freiberg, F., 1176
Frková, J., 1116, 1130, 1132
Frolík, S., 1004
Fürst, J., 670

Ganev, N., 592, 680, 732
Gayer, M., 322
Godignon, P., 510
Goldmann, T., 886
Gorodinskij, V., 128
Gosmanová, G., 592
Gregerová, M., 944
Grimm, C., 182
Grym, J., 550
Grünwald, A., 990, 1014, 1016, 1036, 1054, 1056, 1058
Gurovič, J., 110, 124, 530, 560

Habel, J., 804, 806
Haindl, M., 324
Hajasoa B. Tata, 392
Halama, J., 670
Halaška, I., 370
Halámka, Z., 788
Hamal, K., 490, 502, 512
Hamata, V., 1096

Handová, Z., 930
Hanus, D., 650, 682, 684
Hanykýř, V., 606
Hanzálek, O., 866
Hanžl, V., 506
Haušild, P., 78, 538, 604, 646
Havelka, P., 1202
Havlan, M., 466, 468
Havlíček, M., 74
Havlíček, R., 644
Hazdra, P., 426, 428, 430, 446, 510
Hačkajlová, L., 1130, 1144
Hejnová, P., 852
Heller, J., 882
Heller, J., 728
Hemerka, J., 652, 764
Herman, A., 770
Herza, J., 900
Hexner, M., 1088
Himmlová, L., 886
Hlava, M., 1012
Hlavatý, L., 74
Hlavatý, T., 238
Hlavička, J., 312, 352
Hlaváč, J., 342
Hlaváček, T., 1144, 1188
Hlinovský, V., 810
Hnojil, J., 38
Hnátek, M., 348
Hodač, J., 1090
Hodík, J., 262
Hofman, P., 308
Hofreiter, M., 266
Holický, M., 1026, 1028
Holub, J., 472
Holý, S., 678, 680, 688, 698, 702, 744, 896, 914
Homola, P., 580
Honzík, M., 776
Honzík, O., 548
Honzík, P., 450
Horažďovský, T., 128
Horká, H., 330, 1022
Horký, I., 1086
Horný, L., 878, 880, 882, 898
Horák, Z., 910

Horáková, B., 1162
Horáková, K., 1164
Horáček, K., 562
Horčík, R., 28
Hospodka, J., 506
Houša, J., 768
Houšová, D., 902
Hozman, J., 872
Hošek, J., 400
Hrad, J., 196
Hradecký, Z., 486, 496
Hrbáček, J., 876
Hrubý, J., 400
Hrzina, P., 760
Hudec, B., 320
Hudousek, L., 548
Hulicius, E., 446
Huml, J., 654
Huml, M., 258
Husník, L., 474, 480, 482
Husák, M., 508
Hyhlík, T., 664
Hájek, P., 958, 1004, 1006, 1008
Hájek, V., 1162
Hánek Jr., P., 1050
Hánek, P., 1050, 1070
Hánková, D., 942
Hřebejk, B., 1180
Hříbek, P., 94
Hůla, M., 1072
Hüttel, I., 530, 560

Ingerle, J., 410

Jakob, M., 192
Jakovenko, J., 508
Jakubše, J., 1162
Jakubíková, A., 1032
Janda, M., 738
Jandejsek, F., 924
Janek, M., 916
Janeček, M., 580
Janko, L., 684
Janků, L., 292, 870
Janoušek, J., 382
Janoušek, J., 800
Jančárek, A., 412, 916
Jančík, L., 718, 722
Jarušková, D., 946
Jelen, J., 136
Jelen, V., 1162
Jelínek, I., 188, 250, 272, 392
Jelínek, M., 906
Jelínek, M., 42
Jelínek, V., 1022
Jelínková, H., 166, 172, 174, 488, 902
Jerie, J., 650
Jeriová, Z., 176
Jettmar, J., 946, 994
Jex, I., 74
Ježek, Š., 570
Jeřichová, Z., 974
Jeřábek, I., 600
Jeřábek, K., 1040, 1062
Jiang Sun, 660, 668
Jilemnická, L., 1130, 1132, 1156
Jirků, S., 644
Jirout, T., 716
Jirsák, M., 968
Jirák, Z., 142
Jiřina, M., 280
Jiřičková, M., 520, 522
Jiříček, O., 66, 162, 164
John, J., 856
Jonáš, V., 224
Jorda, X., 510
Juha, L., 120
Jungfu Hu, 512
Jurkovič, A., 1072
Jurman, J., 1040
Jurč, R., 126
Jáchim, M., 318
Jäger, M., 318, 332

Kabele, K., 1004
Kabrhel, M., 1030
Kadleček, D., 364
Kaiser, J., 434
Kaizr, V., 84, 102, 104
Kalousek, J., 1004
Kalvoda, L., 416, 460, 542, 544
Kameník, M., 1180
Kapičková, O., 1022
Kaplan, I., 1088
Karlický, P., 1148
Karlík, M., 78, 578, 580, 582
Karovičová, I., 564
Kasal, R., 990
Kasíková, S., 330, 1022
Katovský, K., 830
Katsumasa Iwai, 166, 488
Kavan, M., 1112
Kašpar, M., 1070
Kačer, M., 372
Kačmařík, P., 470
Keslerová, R., 40
Kittnar, O., 878
Klaban, J., 356
Klepal, M., 496
Klečka, T., 944
Klima, M., 504
Klimo, O., 116
Kliský, V., 816
Kloboučeк, B., 1022
Klupák, V., 836
Klusoň, J., 336, 818, 828
Kléma, J., 228, 912
Klíma, M., 276
Klíma, M., 360, 434
Klír, D., 68, 148
Knopfelmacher, O., 542
Knápek, J., 802
Kobylka, D., 822, 826, 846
Kohout, K., 364
Koišová, D., 1074
Kokol, P., 912
Kolesnikov, D., 124
Koller, J., 96
Kolros, A., 844, 848
Koláčková, J., 982
Kolář, J., 296, 352
Kolář, P., 768
Komiakova, A., 172
Komárek, M., 448

Komárek, P., 194
Komínková, D., 930, 936
Konvičková, S., 888, 894
Kopecký, F., 1200
Kopecký, L., 602
Kopelent, V., 874
Koranda, P., 902
Kortanová, M., 1190
Kosek, R., 796
Kostková, J., 230
Koudelka, P., 964
Kovalský, J., 1010
Kovář, P., 444, 470
Kovářová, A., 1022
Kovářík, O., 554, 556
Kozel, K., 40, 656, 670
Kožíšek, J., 1178
Kočandrlová, M., 22
Kočárník, P., 786
Kořínek, Z., 562
Kratochvil, J., 130, 134
Kratochvíl, J., 70, 72, 112, 114
Kraus, I., 592, 680, 732
Kravárik, J., 64, 68, 148
Kreidl, M., 264
Kreim, R., 1168
Krejčiříková, H., 946
Kropík, M., 822, 834, 840, 842
Král, J., 968
Král, J., 864
Král, O., 948
Krása, J., 120
Kubalík, J., 302, 912
Kubalík, P., 304
Kubart, T., 138, 160, 484, 584, 586
Kubačák, A., 742
Kubeš, P., 64, 68, 148
Kubeček, V., 92, 150, 152
Kubát, B., 1122
Kubátová, H., 306, 352
Kuběnka, J., 552
Kubík, J., 408
Kucejová, G., 1074
Kuchařík, M., 176
Kuhnová, G., 916
Kulhánek, P., 104
Kulich, M., 350
Kuliš, Z., 688
Kuna, A., 418
Kuneš, M., 374
Kunz, J., 594, 596, 598
Kunčar, R., 746
Kužel, J., 652, 764
Kučera, P., 30, 48
Kučerová, A., 316
Kuře, P., 1136
Květoň, M., 130
Kvítek, T., 970
Kyptová, R., 1134
Křemen, J., 1092, 1096
Křemen, V., 292
Křepel, J., 814
Křivková, I., 22
Křivánek, J., 208
Křička, J., 730
Kříž, M., 464
Kříž, M., 836
Kůla, V., 644, 786

Ladra, J., 974, 1044
Lahoda, J., 286
Lain, M., 976
Landa, M., 170
Lauschmann, H., 558, 732
Lažanský, J., 302
Lehovec, F., 946, 1148
Lejčková, K., 194
Lepš, M., 316, 978, 980
Levade, C., 72
Lhotská, L., 426, 912
Limpouch, J., 116, 176
Linkeová, I., 34
Liska, R., 176
Lohan, J., 734
Lohonka, R., 70, 72
Lojík, V., 206
Ludvíková, M., 30
Lukeš, J., 220
Lukeš, M., 450
Lukáš, R., 416, 544
Lukášová, P., 416, 544
Luxemburk, F., 940, 954, 1114, 1152
Línková, L., 984
Lísal, M., 106
Lízalová, B., 854
Lórencz, R., 338, 340, 342

Macek, K., 532, 540
Macháč, J., 298, 456
Macková, A., 124, 590
Macák, T., 1138
Macík, K., 1174
Maděra, J., 932
Maier, K., 1072, 1088
Majed Ayoubi, 1140
Majlingová, O., 128
Maleček, K., 1022
Malá, Z., 52, 54, 56
Malát, P., 1158
Malátek, M., 408
Maléř, Z., 720, 724
Mansfeldová, A., 1086
Marczi, T., 720, 724
Mareš, J., 58
Mareš, P., 1142
Mareš, T., 648, 712
Marková, J., 1026, 1028
Martinec, D., 44
Maryška, J., 46
Masařík, J., 462
Materna, A., 576, 588
Materna, A., 944
Matička, O., 36
Matějka, K., 822, 826, 832, 834, 836, 842
Mačkal, A., 446
Mejsnarová, J., 1088
Melichar, B., 236, 286, 326
Melichar, J., 706
Melichar, K., 446
Mencl, V., 944
Mezera, P., 1092
Michl, M., 184
Miffek, K., 782
Mikš, A., 86, 88, 90, 714

Mikšík, P., 338
Milisdörfer, L., 836
Milka, D., 820
Miléř, V., 320
Mindl, P., 774, 788
Mitsunobu Miyagi, 166, 488
Mičušík, B., 232
Miřejovský, J., 552
Mlejnek, P., 500
Mlích, A., 546
Mocek, V., 410
Mofreh Ahmed Hogo, 368
Mokso, R., 918
Mondschein, P., 928, 940, 954
Morávek, A., 250
Moudar Ahmad, 998
Mrkvica, J., 452, 456
Mukařovský, J., 1004
Murafa, N., 536
Musil, L., 36
Musílek, L., 178
Muzikář, Z., 306
Mužík, J., 1088
Mádlová, D., 1146
Málek, J., 806
Mázl, R., 204
Míkovec, Z., 218, 276
Mňuk, P., 462
Múčka, V., 58, 816, 852, 854
Müller, K., 296

Nacu, P., 1072, 1108
Nahodil, D., 364
Najdek, D., 130
Navrkal, T., 952
Nedbal, I., 558, 578, 582, 594, 596, 604
Nekvindová, P., 590
Nesměrák, M., 1098
Neubergová, K., 1122
Neumann, P., 1172
Neumann, P., 506
Nikl, M., 58
Nohava, J., 572, 574
Nop, P., 534
Novotný Jr., J., 876
Novotný, B., 940, 954, 1114, 1152
Novotný, J., 42
Novotný, M., 780
Novotný, M., 318
Novotný, O., 756, 768
Novák, D., 870
Novák, F., 386
Novák, J., 494
Novák, J., 80, 82, 86, 88, 90, 708, 714
Novák, J., 992, 1004, 1006
Novák, J., 1162
Novák, L., 362, 782
Novák, M., 376
Novák, P., 746
Novák, P., 914
Novák, R., 160
Novák, R., 54, 138, 440, 484, 552, 584, 586
Nováková, D., 52, 54, 56
Nováková, H., 962
Nožička, J., 676, 682
Nábělková, J., 930
Němec, M., 166, 488, 902
Němec, M., 856
Němec, V., 824
Němeček, D., 1072, 1102
Němeček, J., 316
Němeček, J., 864
Nývlt, Z., 498

Obdržálek, Š., 288
Oberstein, I., 1088
Oliva, V., 576
Ondráček, M., 756, 768
Ota, M., 188
Otáhal, J., 914

Pajdla, T., 44, 232, 240
Palamarčuk, D., 110, 560
Palouš, J., 912
Pangrác, J., 446
Papežová, S., 914
Papuga, J., 686
Patera, A., 1048
Pauk, L., 492
Pavelka, J., 790
Pavelka, V., 788
Pavlík, J., 938
Pavlík, L., 194
Pavlík, M., 1008
Pavlík, Z., 932, 934
Pavlíková, M., 1004, 1008
Pavlíček, J., 202
Pašek, J., 104, 254
Pašek, J., 944
Pašta, J., 488
Pačesová, H., 1128
Paříková, P., 966, 982
Pech, M., 840
Pechač, P., 496
Pejchal, J., 58
Pejter, J., 776
Pekárek, S., 62, 158
Pelantová, E., 74
Pelešková, M., 1104, 1106
Petera, K., 740
Petrák, J., 746
Petrák, M., 746
Pfeifer, P., 476, 478
Pitelka, J., 476
Plachý, T., 694
Platil, A., 408
Pleskot, D., 398
Plíhal, M., 462
Podlešáková, T., 1074
Poděbradská, J., 524, 526
Pohl, J., 750
Pokorný, T., 1076
Polcar, T., 138, 484, 584, 586
Polcar, T., 326
Polnický, J., 1062
Polák, M., 694
Poláková, D., 854
Polášek, M., 656
Popenková, M., 1010
Pospíchal, P., 718
Pospíšil, J., 1070
Pospíšil, J., 1100
Pospíšil, J., 54
Pospíšil, M., 58, 816, 852, 854

Pospíšil, P., 944
Pospíšil, S., 968
Potůček, Z., 122, 156
Poušek, L., 906
Prahl, J., 582
Prajer, M., 1150
Prajzler, V., 530
Pražská, M., 856
Procházka, I., 490, 502, 512
Procházka, J., 1118
Procházka, J., 946
Procházka, J., 658
Procházka, Z., 554, 556
Procházková, O., 550
Prokop, V., 40
Prostějovská, Z., 1162
Proška, J., 864
Prskavec, L., 36
Ptáček, D., 280
Ptáček, P., 122
Pume, D., 606
Puričer, P., 420
Párová, M., 1042
Páta, P., 274
Píchal, J., 154
Píč, V., 432
Přeučil, L., 202, 204, 238, 350
Přeučil, M., 194
Přibyl, M., 690
Přibyl, P., 394
Přiklopil, A., 768
Přikrylová, V., 1056
Příbaňová, L., 882

Quan Tran Hung, 762

Racek, S., 352
Rataj, J., 832, 836
Rebollo, J., 510
Rezbárik, J., 856
Richter, I., 130, 132, 134
Ridziková, A., 180
Rieger, F., 716, 748
Ritschl, E., 650
Rosenkrancová, J., 888
Rosenkranz, J., 158
Rosmanit, M., 988
Rothkrantz, L., 302
Rott, J., 504
Rotter, T., 972
Roubík, K., 256, 874, 892
Roztočil, J., 404
Rožánek, M., 892
Rund, F., 450
Runčík, J., 570
Ryan, A., 734
Rybín, J., 738
Ryjáček, P., 950
Růžička, J., 1004, 1034
Růžička, J., 300
Růžička, M., 660, 668, 686, 720, 724
Růžička, P., 710

Řezáč, K., 104
Říha, A., 260
Říha, B., 194
Říha, J., 654
Římal, J., 1022, 1024

Sandmann, C., 590
Schmidt, J., 318
Scholz, M., 68
Schroeder, J., 182
Schröfel, J., 436, 530, 590
Schwarzer, J., 752, 952
Sedláková, V., 330
Sedláček, M., 778, 780
Sedláček, P., 768
Sedláček, R., 112
Sedláček, R., 888, 894
Sedláčková, S., 1060
Seidelmann, L., 98
Seidl, L., 334, 470
Seidl, M., 996
Severýn, O., 46
Siegl, J., 538, 554, 556, 566, 574, 578, 582, 594, 596
Silber, R., 58, 816, 852, 854
Sklenka, Ľ., 822, 834
Skornjakov, V., 172, 174
Skřehot, P., 856
Slavík, P., 218, 276, 1106
Slavík, S., 720, 724
Slavíček, M., 990, 1036, 1054, 1056, 1058
Slavíčková, K., 990, 1036, 1054, 1056, 1058
Slašťanová, V., 726
Slepička, D., 448
Slámová, M., 580
Smirnov, L., 144
Smolek, K., 60
Smolík, J., 756, 768
Sněhota, M., 1038
Sněhota, P., 146
Sobota, J., 1180
Sochor, M., 910
Sojka, J., 736
Sokol, Z., 922
Solar, M., 560
Solařík, P., 454
Sopko, B., 1022
Soukup, M., 838
Soukup, P., 258
Sousedík, B., 42
Spěváček, V., 876
Starý, R., 848
Stavovčík, B., 1180
Steidl, J., 562
Stintz, A., 150
Studenovský, K., 400
Studnička, J., 946
Svoboda, K., 828
Svoboda, O., 766
Svoboda, P., 1012, 1044, 1172
Svoboda, V., 1190
Svoboda, V., 74
Svoboda, Z., 1052
Svrček, A., 364
Svátek, V., 840
Sváček, P., 32
Svítek, M., 1198, 1200
Synek, L., 790
Sůra, A., 478
Sýkora, J., 1088
Sýkora, M., 986

Šajner, V., 1120
Šaršeová, M., 1054
Šedivý, M., 466

Šejnoha, J., 946
Ševčenko, M., 346
Šibrava, Z., 30
Šilar, Z., 272
Šilhán, J., 804
Šimek, D., 674
Šimečková, J., 178
Šimák, B., 242
Šimáně, Č., 824
Šimík, R., 390
Šiňor, M., 116, 168, 170, 176
Škereň, M., 130, 132
Škoda, L., 336
Škvor, J., 422, 438
Škvor, Z., 406, 426, 492
Škvor, Z., 422, 438
Šlegrová, Z., 118, 140
Šmíd, R., 264, 904
Šmídová, E., 194
Šnorek, M., 252, 368
Šoch, M., 378
Šorf, M., 292, 870
Šourek, B., 640, 808
Španiel, M., 642, 672, 674, 686, 690, 698
Špaček, J., 420
Špačková, H., 1160
Špirek, T., 752
Špirková, J., 590
Špulák, P., 184
Šrytr, P., 1202
Štamberg, K., 862
Štefan, M., 214, 216
Štefanová, P., 942
Štekl, I., 76
Štengl, P., 222
Štěpán, P., 350
Šulc, B., 358, 384
Šulc, J., 166, 172, 174, 488, 902
Šumbera, J., 558
Šťastná, G., 930, 936
Šťastný, B., 1036, 1054, 1056, 1058
Šťovíček, P., 74
Šára, R., 230
Šístek, J., 406
Talácko, J., 750
Tamáš, J., 384
Tatýrek, V., 1144, 1188
Teufel, D., 382
Theiner, R., 600, 650
Thinová, L., 818, 820
Thőndel, E., 644
Tichánek, R., 642
Tocháček, M., 194
Tolar, J., 74
Toman, J., 524, 526, 938
Tomaszewski, K., 68
Tománková, J., 1130, 1132, 1194
Totová, M., 520
Tovarová, L., 972
Trojek, T., 178, 818, 860
Troníček, Z., 290
Tušla, P., 800
Tvrdík, P., 366
Tywoniak, J., 992, 1004, 1006, 1008, 1052
Tůma, M., 960

Ubik, S., 246
Uher, O., 660, 668
Uhlíř, I., 782
Urlich, P., 1078

Vacek, J., 696
Vacek, K., 128
Vacek, V., 54, 100, 106, 440
Vacková, S., 124, 128, 560
Vaclavek, L., 734
Vagner, L., 236
Valenta, F., 890
Valenta, P., 1048
Valentin, J., 954
Valentová, J., 1048
Valášek, M., 214, 226
Vanderschaeve, G., 70, 72
Vandrovec, P., 212
Vaniš, L., 1126
Vaněk, P., 1084
Vaněk, T., 284
Vaníček, T., 190
Vaníčková, L., 190
Varga, D., 404
Vašenda, P., 1106
Vašíček, J., 802
Vařečka, J., 280
Vedral, J., 464
Vejdělek, J., 424
Vejražka, F., 444, 470
Vellvehi, M., 510
Vepřek, K., 1088
Veselka, T., 804
Veselá, J., 962
Večeř, P., 264
Vilímek, M., 890
Vinař, O., 1104, 1106
Vinš, V., 440
Viskup, R., 120
Vlk, T., 370
Vlček, J., 914
Vlčková, K., 1054, 1056
Vobecká, M., 330
Vobecký, J., 124, 430, 510
Vobecký, M., 844
Vobořilová, P., 956
Vodička, J., 1184
Vodrážka, J., 388
Vodák, F., 1022
Vogel, T., 970
Vognar, M., 824
Vohralík, M., 46
Vojtěch, J., 246
Vokálová, J., 1162
Vokřínek, J., 248
Voleník, K., 534
Volf, J., 896, 914
Voltr, J., 864
Vondřich, J., 644
Vonka, M., 1006
Vopálenský, M., 500
Vopálka, D., 858, 862
Vorel, I., 1088
Vorel, J., 1082
Vorel, M., 662
Vorel, V., 946, 948
Voštová, V., 1040

Voženílek, P., 800
Vraný, T., 988
Vratislav, S., 142, 144, 416, 460, 542, 544, 568
Vrba, M., 414
Vrba, P., 412
Vrbová, M., 412, 414, 916
Vrána, K., 964, 966
Vtípil, J., 898
Vysoký, P., 394
Vytlačil, D., 1002, 1196
Váchal, P., 176
Václavík, J., 744
Vála, L., 76
Váška, J., 966, 1032
Včelák, J., 442
Vébr, L., 1152, 1154
Vítek, K., 680, 688, 690, 692, 702, 744, 896
Vítek, O., 656

Wald, F., 922, 924
Wasserbauer, R., 944, 958
Weinberg, O., 688, 744
Witzany, J., 944, 946
Wohlmuthová, A., 30

Yang FuMin, 512
Yi-Wei Shi, 166, 488
Yuji Matsuura, 166, 488
Yukio Abeb, 166

Zahradnický, T., 340
Zahradník, J., 1166, 1170
Zajíc, J., 1088
Zaoralová, J., 1022
Začal, R., 1004
Zděnek, J., 294
Zehentner, J., 298
Zeithammerová, J., 1054, 1056
Zeman, J., 980
Zeman, J., 822, 826
Zeman, J., 678
Zeman, T., 198
Zemánek, S., 970
Zerbst, J., 182
Zezulová, E., 1004
Zindulka, O., 30
Znamenáček, K., 644
Zoriy, M., 110
Zralý, M., 1192
Zverev, P., 172, 174
Zvoníček, K., 150, 152
Zábrodský, V., 874
Zácha, P., 212
Záliš, K., 792, 794, 796, 798
Zíb, A., 826
Zýka, J., 566

Železný, F., 228
Žemlička, P., 1182
Žára, J., 200
Žáček, M., 104, 108
Žďánský, K., 128