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Annual scientific awards of the Division IV Technical Sciences of the Polish Academy of Sciences in 2007

For many years it has been a great tradition of the Division IV of Technical Sciences of the Polish Academy of Sciences to recognize the outstanding achievements of young scientists with several Awards related to various fields of technology. The awarded candidates have to satisfy the requirements specified in suitable Regulations. In 2007 the Scientific Award Fund of the Division IV was supported by the well known international Siemens company which significantly augmented the status of the Awards. The list of Awarded Winners and the brief description of their achievements prepared by the authors are as follows.

In the field of Theoretical Mechanics:
Maksymilian T. Huber Prize

Gradient-enhanced continuum models: formulation, discretization and applications

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The Award of the Division IV of the Polish Academy of Science in the field of Theoretical Mechanics has been granted for the monograph "Gradient-enhanced continuum models: formulation, discretization and applications". The monograph reviews and evaluates a set of gradient-dependent continuum theories and their applications in the numerical analysis of localized deformation and failure in quasi-brittle and frictional materials (typically concrete or soil). In particular, isotropic models of plasticity and damage incorporating a gradient-based nonlocal averaging of an internal variable or of an equivalent strain measure are pursued. Small strains are assumed and the interest is mostly limited to static loading. Higher-order continuum theories are often necessary to explain and convenient to simulate the physical behaviour of heterogeneous materials (materials with microstructure).This is especially the case for localization and softening phenomena which have their origin at the lower level of observation, but they are observed in the macroscopic response. The theories incorporate internal length parameters and the gradient terms which represent the microstructural interactions in phenomenological modelling.

The monograph contains an overview of gradient-enhanced models developed in the last four decades and a comparison of those based on a Laplacian of an (inelastic) strain measure, as well as a discussion on the discretization of the selected gradient damage and plasticity models which lead to two-field formulations: the nonlocal (plastic) strain measure is a primary unknown in addition to the displacements. The finite element and element-free Galerkin methods are employed. The latter discretization advantage is that increased continuity requirements, typical for higher-order continua, are easily satisfied.

The issue of material instabilities and application of the non-associated Burzyński-Drucker-Prager gradient plasticity with cohesion hardening in the simulation of shear banding are presented too. A theory of scalar gradient damage coupled to plasticity with isotropic hardening is also discussed. The theory reproduces the strength and stiffness degradation observed experimentally for quasi-brittle materials and is equipped with a crack-closing projection. Then the more practical issue of reinforced concrete modelling is presented. The analysis is focused on the numerical simulation of crack patterns and crack spacing in reinforced bars and beams. Some comparisons and general remarks on concrete modelling are included. One of the monograph chapters presents the strain-space theory of plasticity with an averaged strain measure, which is an alternative to the earlier discussed stress-space formulations. In the reported work consistently linearized Newton algorithms are used to solve multiple one- and two-dimensional examples of localized deformation, including bars in direct tension, specimens in biaxial compression and beams in four-point bending. The last chapter introduces several conclusions on the employed formulations and their efficiency in the numerical simulation of instabilities, localization and failure. Some prospects of future developments are also given.

In the field of Mechanics:
Wacław Olszak Prize

Micromechanics of contact and interphase layers

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Micromechanical analysis of heterogeneous materials allows prediction of their macroscopic behaviour from the known properties, microstructure, and interaction mechanisms of the constituents at the micro-scale. At the same time, it allows determination of the microscopic response at each point of a macroscopic body subjected to external loading. This work, which is the habilitation thesis of the author, is concerned with micromechanical modelling of interfaces and interface layers.

The objective is to develop micromechanical modelling tools that are suitable for the analysis of the class of problems discussed above. The importance and scientific relevance of this objective seems quite obvious, since micromechanics, due to its predictive capabilities, is a very attractive modelling approach which proved to be highly successful in many areas of mechanics. The importance of the addressed topics stems also from the scientific and technological motivations of the specific applications which were analyzed in this work.

Two application areas are addressed, namely micromechanics of rough contact layers and evolution of martensitic microstructures in shape memory alloys. While the two areas are rather different, there are several reasons to discuss them together. First of all, in both cases, interfaces and interfacial phenomena are dealt with. Furthermore, in both cases, the analysis of interfaces involves the corresponding layers: either the layer is a microscopic counterpart of a macroscopic surface, as in the case of contact layers; or the interfaces appear as the entities separating the layers of parent and product phases, as in the case of martensitic microstructures.

In the field of Energetics:
Bohdan Stefanowski Prize

Thermal and flow conditions and pollutant emissions in large-scale circulating fluidized bed boilers

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The article presents the results of experimental tests and analytical studies on the thermal and flow conditions and gaseous pollutant emissions of large-power circulating fluidized bed (CFB) boilers. The experimental tests were carried out on two 670 MW boiler and one 700 MW boiler. The performed analysis included also the results of studies reported in literature, concerning CFB boilers of powers ranging from 12 MW to 1.1 GW. In the combustion chamber of one of the 670 MW boilers, 52 measurement ports were made in the membrane wall fins. The first part of the study was devoted to the characterization of the measurement techniques used in experimental tests. In order to determine the CFB operating conditions, the following probes were introduced into the combustion chamber of the boiler tested: a gas sampling probe, a bed material particle sampling probe, a pressure probe, a capacitive probe and a temperature measuring probe. The subsequent part of the study, which concerns the hydrodynamic conditions in the combustion chamber of a large-scale CFB boiler, addresses the following problems: bed material pressure fluctuations, the distribution of solids volume concentration, the distribution of solids mass flux density, the distribution of particle cluster velocities, and the segregation of particles. The performed analyses of the obtained testing results allowed the determination of the CFB structure in the combustion chamber of the large technical-scale boiler. Particular consideration was given to the effect of grid design on the operation conditions of the bottom combustion chamber part. It was also observed that for large technical-scale CFB boilers considerable vertical and horizontal pressure gradients occurred in the primary air grid region leading, on the one hand, to a blowing of the bed material into the nozzle outlet channels and possibly to its backflow to the windbox and, on the other hand, to a non-uniform fluidization of the lower region. The presence of a strong bed material particle mass flux was also found, which was falling in the vicinity of the combustion chamber walls, and an intensive carrying over of bed material particles towards the cyclone inlet in the other CFB part. Thus, the "core – wall boundary layer" structure was confirmed to exist in the dilute circulating fluidized bed region of the large-power boiler. The analysis of the results showed also a reduction of the share of wall boundary layer surface area in the combustion chamber horizontal section with increasing technical scale of CFB boilers. This effect was a result of the reduction of internal particle circulation within the dilute region with increasing combustion chamber overall dimensions. Moreover, an increase in the velocity of particles falling down in the vicinity of the combustion chamber walls with the increase in hydrodynamic wall boundary layer thickness was observed. The further part of the study includes the analysis of O_2, CO, SO_2, NO and N_2O distribution within the circulating fluidized bed space and presents the effect of thermal and flow conditions on the emission of pollutants forming in the combustion process. It has been found from the obtained testing results that the main region of gaseous pollutant formation is the bottom part of the combustion chamber, i.e. the bottom and dense region, while the gaseous pollutant reduction processes proceed in the upper combustion chamber part, that is in the dilute region. The optimization of the thermal and flow conditions in the bottom combustion chamber part by changing the primary and secondary air share and changing the fuel distribution, as well as increasing the bed material particle circulation between the combustion chamber and the recycle system, showed a reduction in the emissions of CO by 71%, SO_2 by 41% and NO by 19% compared to the standard operation conditions of the boiler tested. Thus, the testing results have confirmed the claim about the influence of combustion chamber overall dimensions on the circulating fluidized bed structure, as well as the claim about the minimization of pollutant emissions from the combustion process carried out in a large-power boiler with the appropriate arrangement of thermal and flow conditions in the circulating fluidized bed structure.

In the field of Chemical Engineering:

Drop breakup and coalescence in intermittent turbulent field

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Liquid-liquid systems are the subject core of investigations presented in this work. The dispersions of not com-

pletely miscible liquids are of great importance in chemical, petroleum, pharmaceutical, and food industries. They are involved in many engineering operations including heterogenic chemical reactions, extraction, emulsion polymerization, emulsification, and fermentation in which dispersed organic phase is a carbon source for microorganisms. Process intensification in multiphase systems depends to a high degree on the dispersed phase drop distribution. Large interfacial area is required to obtain high mass transfer rates, large droplets are required for efficient separation. Drop size distribution can have a profound effect on the quality of polymer (the size of particles) or on the conversion and selectivity of chemical reactions. Therefore, a reliable design of the equipment for performing the mentioned processes should be based on the knowledge of drop size distribution that depends on relative rates of droplet breakage and coalescence. Liquid-liquid dispersions are usually produced in stirred tanks in which the flow is usually turbulent.

In this work mathematical models of droplet breakage and coalescence in turbulent flows are proposed. Together with the population balance equation they allow to predict transient drop size distributions. The behaviour of drops in turbulent field has a very complicated character, in part due to complex character of turbulent flow itself. Namely, the droplet behaviour depends on the microstructure of turbulence including its fine-scale intermittency. Intermittency may be defined as a such state of flow in which highly dissipative structures are embedded into an irrotational flow. In traditional description of the structure of turbulent field Kolmogorov theory is used. This theory neglects the phenomenon of internal intermittency, and therefore, the fluctuation of energy dissipation, vorticity and stresses acting on droplets and connected with this phenomenon. The distribution of energy dissipation rate displays very strong nonuniformities. Mathematical models proposed in this work take into account chaotic aspects of turbulent flows. Intermittent turbulent field is described using multifractal formalism. This allows to take into account different activity of turbulent eddies of the same scale and probability of their appearance. Proper description of complex interactions between turbulence and droplets leading to breakage and coalescence allow to explain many effects observed experimentally (for example the influence of the system scale on breakage rate in geometrically similar systems and equal power input per unit mass) that cannot be explained by classical theories of turbulence. Breakage models proposed in this work allow to predict frequency of droplet breakage for dispersed phase of low as well as high viscosity. In the last case the model also predicts the time and extent of possible droplet deformation. Droplets of diameter falling within the inertial and viscous subranges of turbulence were considered. In the case of coalescence the film drainage mechanisms were identified and coalescence efficiency was determined. It was also shown that apart from fine scale irregularity related to the internal intermittency the non-uniform distribution of locally averaged properties of turbulence in the stirred tank (large-scale inhomogeneity) should be taken into account. The regions of the highest coalescence probability for droplets of different interface mobility were identified. The proposed models of drop break-up and coalescence were validated experimentally. It was shown that they properly predict drop size distributions and their evolution in time.

It has been proved that the model has a universal character which gives the possibility of designing the equipment for processes in which two-phase liquid-liquid systems are involved. It also allows to control the process in a way to get products of a desired quality.

In the field of Biomedical Engineering:

Chosen problems of miniature systems for biochemical analyses

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Recently, the grow of demands in clinical diagnostics, biotechnology, environmental monitoring have a strong effect on rapid development of analytical techniques, including improvement and elaboration of new analytical instruments and methods.

Awarded, thematically consistent series o papers published in 2003–2006 belongs to the main stream of development of analytical techniques, oriented towards miniaturization of analytical instruments as well as elaboration of biosensors adjusted to integration in micro analysis systems such as lab-on-a-chip that may be used as point-of-care analytical devices.

The research ranged three main problems related to development of miniaturized (bio)chemical analyzers: (i) technological aspects of realization of microsystems, in particular components responsible for generation of analytical response e.g. biosensors , microreactors including chemical modification of surface for immobilization of bioreceptors e.g. enzymes, (ii) utilization of silicon technologies for integration of micro analysis system components e.g. microdialysis based integrated microsystem, (iii) elaboration of procedures for micro analysis system control – calibration of biosensors and sampling.

In the field of Transport:

Multiple criteria decision aiding in road transportation

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Different applications of multiple criteria decision aiding (MCDA) in road transportation have been presented in the monograph. The most important multiobjective road transportation decision problems have been solved and general rules for solving transportation decision problems with the application of MCDA methodology have been developed. The research has an analytical and experimental character, and all the tests are computer-based computational experiments.

Based on the survey research a list of the most important road transportation decision problems has been constructed. It has been proved that these problems have multiobjective character. In the next step a thorough analysis of 10 most important road transportation problems has been carried out and original, multiobjective decision models for the problems have been constructed. The decision problems have been formulated in terms of the multiobjective ranking problems and multiobjective optimization problems. In the decision models the interests of different stakeholders, interested in finding a solution for particular problems, have been taken into account.

Each of the decision problems, represented by a certain model, has been solved by a separate solution procedure. In the computational phase different methods and tools have been applied, including: multiobjective ranking methods (Electre III, UTA, AHP), multiobjective metaheuristic procedures (PSA, PMA, MSLS, GA, GLS), specialized multiobjective heuristic procedures (fleet sizing algorithm, MAM procedure, fleet replacement algorithm), multiobjective exact optimization methods (solvers, scalarizing function method, Megros program) and multiobjective analysis methods (LBS, scalarizing function method). In these cases when the decision problems have been formulated as ranking problems the final classifications (rankings) of solutions have been generated, which resulted in the selection of the best solution. In optimization problems the solution procedures have been divided into two phases: generation of non-dominated (Pareto optimal) solutions, and their review and evaluation resulting in the selection of the compromise solution. In the computational experiments phase selected methods and algorithms have been compared and their applicability to solve road transportation decision problems has been characterized. A set of criteria and a formalized universal procedure for evaluating and selecting the transportation decision problems' solution methods have been proposed.

As a result of this analytical and experimental research the algorithm of the solution procedure for complex multiobjective road transportation decision problems has been elaborated. It contains detailed characteristics of all the phases of the road transportation decision problems' solution procedure, i.e.: identification and description of the problem, construction of the mathematical decision model, analysis and selection of solution methods and algorithms, computer implementation of algorithms, computational experiments, review and evaluation of solutions combined with the selection of the compromise solution.

In addition, a concept of a computer decision support system, focused on transportation, has been proposed. The system is based on the multiobjective decision-aid methodology and designed to solve most important road transportation decision problems. The proposed decision models, applied methods and algorithms, as well as produced software have been incorporated into the structure of the system. Its major components, i.e. the data base, the model base and the user's interface have been designed.

The research may by continued in the following directions: extension of the considerations towards rail and bimodal transportation, application of the MCDA methodology in logistics problems and business redesign processes and further development of the computer system towards an intelligent decision support system.

In the field of Machine Design and Exploitation:

Fatigue life of some chosen welded joints

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Opole University of Technology

The paper presents fatigue life calculations for some chosen welded joints. The results were verified on the basis of fatigue tests of steel and aluminium welded joints under uniaxial and multiaxial loading states. Uniaxial loading concerns pure tension-compression and alternating bending under cyclic and random tests of specimens made of steel. One fatigue characteristic can be determined for four considered materials. From the calculations it appears that fatigue strength does not strongly depend on a type of the considered welded joint – it is more dependent on loading type (bending and axial loading). The calculated sum of damages for normal distribution (the Gaussian spectrum) and normal distribution with overloads is included into the scatter band with coefficient 3 according to the Palmgren-Miner hypothesis at the significance level 5%. In the case of the considered welded joints, the mean stress value does not influence the fatigue life. The same fatigue curves have been obtained for symmetric and pulsating loading.

Complex stress states concern loading under combined proportional and non-proportional cyclic bending with torsion. Moreover, for aluminium joints verification was also done under random loading. Evaluating the multiaxial fatigue histories in welded joints by local stresses and strains, we must know the actual local radius at the weld edge. Owing to the fictitious local radius, when – in the worst case – for sharp notches $\rho = 0$ it is possible to calculate coefficients of the notch action for bending, K_{fb} and for torsion, K_{ft}. In this order we must determine fictitious radii of the notch ρ_f for bending and for torsion. In the case of steel welded joints, these radii are $\rho_{fb} = 1.16$ mm for bending and $\rho_{ft} = 0.4$ mm for torsion. The normal and shear strain energy density parameter in the critical plane determined by the energy density parameter of normal and shear strain for steel welded joints gives comparable results. However, if the normal strain energy density parameter is assumed as the critical plane, it is necessary to determine, in an experimental way, the weight function including the shear strain energy density parameter in this plane. Thus, application of the energy criterion defined in the plane determined by the shear strain energy density parameter, is recommended. In the case of aluminium welded joints, satisfactory results of fatigue life calculations were obtained for the criterion of energy parameter in the plane defined by the shear strain energy density parameter. In the case of application of the energy criterion in the plane defined by the normal strain energy density parameter, the obtained calculated

fatigue lives were strongly overestimated in comparison of the experimental results. Application of the maximum shear and normal strain energy density parameter in the critical plane for aluminium welded joints subjected to variable-amplitude bending with torsion seems to be right under the Palmgren-Miner hypothesis and application of the correction coefficient, like in the case of the Serensen-Kogayev hypothesis, which is the quotient of the weighed amplitude of the fatigue curve inclination in energy approach and the maximum amplitude in the history.

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The suitable procedure aiming at the determination of the Award'2008 Winners has just started.

Actualities

On 13 December, 2007 Professor Marian Kaźmierkowski was elected the Corresponding Member of Polish Academy of Science. Since the moment he has also become the Editorial Board Member of the Bulletin of the Polish Academy of Sciences.

Professor Marian P. Kaźmierkowski graduated in 1968 from the Warsaw University of Technology, then he got Ph.D. and Dr. Sc. degrees in Electrical Engineering from the Institute of Control and Industrial Electronics (ICIE) of the Warsaw University of Technology in 1972, and 1981, respectively.

From 1967 to 1969 he was with Electrotechnical Institute, Warsaw-Miedzylesie, Poland and from 1969 to 1972 he was a PhD-Student at the Electrical Engineering Faculty of the Warsaw University of Technology. In 1972–1980 he was an Assistant Professor at ICIE in Warsaw. He stayed with RWTH Aachen in West Germany as an Alexander von Humboldt Fellow within the period of 1980–1983. Since 1987 he has been a Professor and the Director of the Institute of Control and Industrial Electronics in the Warsaw University of Technology.

He was a Visiting Professor at many universities: NTH Trondheim, Norway, in 1986/87; University of Minnesota, Minneapolis, USA, in 1990; University of Padova, Italy, in 1993; Aalborg University, Denmark, in 1990 and 1995; University of Tennessee, Knoxville, USA, in 1998; University of Nevada, Reno, USA, in 2000 and 2001; University of Bologna, Italy in 2004 and 2005; ENSEEIHT/LEEI Toulouse, France in 2006.

Professor Kaźmierkowski was nominated as a Coordinating Professor of the *International Danfoss Professor Program* within the period of 1996–2000 at the Aalborg University, Denmark. From 1996 to 2004 he was an elected member of the State Committee for Scientific Research in Poland. He was also the Director of the *Centre of Excellence on Power Electronics and Intelligent Control for Energy Conservation – PELINCEC* 2003–2006 (European Framework Program V) at ICIE, Warsaw University of Technology, Poland.

He is the author or co-author of over 300 technical papers and reports as well as 13 books and textbooks. He co-authored *Automatic Control of Converter-Fed Drives* (Elsevier, 1994) and co-edited (with R. Krishnan and F. Blaabjerg) and co-authored the compendium *Control in Power Electronics* (Academic Press, 2002). He is engaged in experimental research and theoretical work on electric drives and industrial electronics.

Professor Kaźmierkowski was the recipient of an Honorary Doctorate degree from Aalborg University in 2004, the MISTRZ Grant of the Foundation of Polish Science – FNP (2001–2003), and the Dr Eugene Mittelmann Achievement Award by the IEEE Industrial Electronics Society in 2005. In 2007 he received SIEMENS Research Award.

He was a Chairman of the 1996 IEEE International Symposium on Industrial Electronics held in Warsaw, Poland. He served as Vice-President for Publication, in the IEEE Industrial Electronics Society (1999-2001). He was in the position of the Editor-in-Chief of the IEEE Transactions on Industrial Electronics (2004–2006) as well as a member of many IEEE Committees, Conference Organizing Committees. In 2007 he was the General Co-Chair of the IEEE EUROCON 2007 Conference held in Warsaw. Currently, he is the Past-Chairman of the IEEE Poland Section.

With the exceptional satisfaction we announce that Professor **Kazimierz Thiel**, a full member of the Polish Academy of Sciences, Technical Sciences was honoured with the title of the Doctor Honoris Causa of the Warsaw University of Technology on 14 January 2008. We would like to congratulate Professor K. Thiel and wish him further successes.