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Scientific Awards of the Division IV Technical Sciences of the Polish Academy of Sciences in 2003

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 2003 the Scientific Award Fund of the Division IV was supported by the well known international Siemens company what 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 Electronics:

Passives and passive integrated components, fabricated by means of thick-film technology

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Award for the numerous papers devoted to passives and passive integrated components, fabricated by means of thick-film technology i.e. technology, where components or circuits are screen-printed from proper electronic inks and then fired in proper conditions.

About 10^{12} of capacitors and resistors as well as many, many millions of inductors, varistors, thermistors, fuses, switches, potentiometers and transformers are used by electronic industry every year. Simultaneously the passives, which are very important for modern electronics because their proper properties and application determine correct work of very sophisticated electronic circuits and systems, seem to be underestimated in current research.

The scientific activity has been concentrated on carbon-polymer thick-film resistive microcomposites and their application for integral resistors in MCM-L (laminated multichip modules) as well as on microplanar and microvolume resistors made in LTCC (Low Temperature Co-fired Ceramics) technology. The author presented the role of many material properties and technological factors on electrical properties and stability behaviour of various passives based on polymer or cermet thick-film technology or LTCC one. He proved among others that carbon-polymer thick-film resistive microcomposites will be useful for the newest generation of passives in the nearest twenty years. He also determined basic electrical properties and long-term stability of the smallest LTCC resistors (with 50×50 micrometer active area) and described many electrical properties of investigated resistive films (for example dependence on sheet resistance, $1/f$ noise intensity or voltage susceptibility *versus* volume fraction of functional phase) in the frame of percolation theory.

In the field of Informatics:

Multiple objective metaheuristic algorithms for combinatorial optimisation

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The rewarded research concerns methodology of multiple objective metaheuristics. The works has been published in a monograph "Multiple objective metaheuristic algorithms for combinatorial optimization" and a set of thirteen publications related to this topic. Nine of these publications have been published in journals and proceeding from the Institute for Scientific Information list.

Metaheuristics, e.g. evolutionary algorithm, simulated annealing or tabu search, are templates of algorithms that can be adapted to solving any optimization problem. Metaheuristics proved to be very useful on hard optimization problems that cannot be solved with traditional approaches. Such problems appear e.g. in the fields of engineering design, computer and telecommunication networks design, and production planning. However, in many cases, single objective optimization is not sufficient. For example, designer of a network has to take into account its cost, efficiency and robustness.

Thus, in recent years we are observing an exploding interest multiple objective metaheuristics that allow simultaneous handling of several objectives for hard and large scale optimization problems. The research of Award Winner focuses on the development of new methods based on simulated annealing and hybrid evolutionary algorithms, the methodology of quantitative evaluation of multiple objective metaheuristics, and systematic approaches to adaptation of metaheuristics to a given problem. The results have been applied to a number of problems in the areas of logistics (e.g. vehicle routing) and task scheduling (e.g. software projects scheduling).

In the field of Material Engineering:

Advanced combustion processes for fabrication of ceramics substrate for electronic packages

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Advanced ceramics is crucial in the chemical electronics and armour industries. Improvements of efficiency in the ceramic technology could generate new materials having unique properties. Solid combustion called also Self-Propagating High-Temperature Synthesis (SHS) is such an unconventional technique suitable for fabrication of high purity novel ceramic materials. In particular, an increased thermal conductivity of ceramic substrates for packages could move electronic industry to nanosized technology. Conventional electronic packages and substrates are based on aluminum oxide and cannot operate in nano-circuits due to low thermal conductivity.

The award-winning work was done at two institutions: University of Science and Technology (AGH) Kraków, Faculty of Materials Science and Ceramics (FMSC) and Ryukoku University, High Research Center (HRC), Kyoto, Japan with great contribution of Professor Jerzy Lis from AGH. The technological challenge was to produce an $(AlN\text{-}SiC)_{ss}$ substrate with an extremely high thermal conductivity and very good chemical stability. Well known conventional techniques e.g. hot-pressing are cost-consuming processes because they require over 50 hours and high pressure to produce the $(AlN\text{-}SiC)_{ss}$. In contrast, Dr. Kata research shows a new combustion technology allowed to prepare (AlN-SiC) solid solutions within seconds. The innovative concept is a combustion reaction between silicon nitride, aluminum and carbon (Si_3N_4 + Al + C) powders taking place in powdery bed at nitrogen pressure ranging from 0.1–6.0 MPa. The combustion reaction was initiated locally and the wave propagated spontaneously through the bed in a self-sustaining regime. The work has shown that lower nitrogen pressures produced a more-homogeneous solid solution. It was demonstrated that by addition of Si_3N_4 as a reactant it is possible to synthesise AlN-SiC solid solution in a self sustaining regime under an ambient nitrogen pressure. The study enabled to develop a new low-cost SHS-technology.

In the field of Civil Engineering:

Applications of asymptotic homogenisation method in soil and rock mechanics

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The rewarded monography presents some applications of asymptotic homogenisation method for mathematical modelling of physical processes taking place in soil and rock media. Special emphasis has been put on analysis and modelling of the phenomena associated with saturated soil and rock media, i.e. on filtration, consolidation, sorption and swelling processes.

In Chapter 2 surveys and comparisons different formulation as well as techniques of homogenisation method are introduced. In particular, it details formulation known as smoothing theory and as mathematical homogenisation theory. It discusses basic principles and properties of some techniques, i.e. volume and weight averaging, continuum micro-mechanics, asymptotic homogenisation, two-scale convergence as well as Γ-convergence. Special attention is paid to the asymptotic homogenisation method for periodic structures. Presentation of some methods of effective properties estimation for random media ends the section.

Chapter 3 is devoted to the Biot's poroelasticity theory. First, general relations linking the macroscopic poroelastic coefficients with the averaged micromechanical solutions are recovered. Considering a variational formulation of appropriate boundary value problems stated for the representative volume element, microstructural parameters affecting the values of poroelstic constants are then identified. A strong dependence of the poroelastic coefficients on the internal geometry of pores as well as on the global porosity of the medium is clearly pointed out. Quantitative effect of these parameters on the values of examined coefficients is presented for simplified pores geometries for which numerical calculations have been carried out.

The mathematical modelling of plastic deformation of saturated porous media is a subject of the Chapter 4. First, a mathematical description valid at the pore level is "upscaled" using the asymptotic homogenisation technique. It is shown that proper macroscopic description should involve, besides strain tensor, also the porosity variation as the second kinematic variable. The macroscopic principle of maximum plastic dissipation is formulated. Then validity and limits of the effective stress concept for saturated porous media are studied in the plastic domain. It is proved that, in general, an effective stress tensor fulfilling stress equivalence principle could not be defined for an arbitrary porous medium. The effective stress tensor could be, however, defined for a porous medium composed of homogeneous skeleton. The new formulation method of yield function for saturated material based on yield function for dry material is proposed.

Chapter 5 investigates phenomena of sorption and sorption swelling taking place in saturated porous media. The main result consists in the fact that macroscopic behaviour of rock saturated with gas can be modelled by two different macroscopic descriptions. The appropriate dimensionless number defines their respective ranges of validity.

Examples of application of homogenisation method in engineering practice is the last part of the monograph.

In the field of Machine Design:

Analysing and shaping of dynamic features of electromechanical drive systems

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The work deals with the applicability of optimization methods for solving problems relating to the minimization of the vibration level and for reducing excessive dynamic reactions in electromechanical drive systems with induction motors. Algorithms, that have been developed to select design features, can be also used to aid design work so that proper dynamic properties can be assured and, in consequence, high durability and reliability of the machine are achieved.

The proposed methodology embraces the following steps of testing: formulation of a mathematical model, selection of an objective function that describes the selected dynamic characteristics of a system, sensitivity analysis and optimization with respect to design variables. Because of a complicated character of dynamic phenomena occurring in the systems under consideration it was necessary to make use of an electromechanical model with coupled models: of the mechanical and electrical parts. Methods applicable for the sensitivity analysis of the time function and frequency function were utilized. The set of design variables contained parameters which described design features both of the electrical part and of the mechanical one of a drive. Apart from conventional optimization methods the evolutionary algorithms found application.

The developed algorithms and computer programs have been employed in the course of designing of a long-wall shearer. A method of constructing of the model, sensitivity analysis and the formulation of optimization problems have been presented in the work. A lot of results obtained during simulation tests, in the course of sensitivity analysis and optimization procedure as well as results of measurements of vibration signals taken on a real object are included in the work. Results of the tests carried out on a prototype of the machine, in respect of the system before and after being optimized, show that the vibration level has been lowered both during starting of the machine and during its operation under steady-state conditions.

The applied approach to solving technical problems is of general nature. It combines the advanced research methods with problems of engineering practice and can become successfully widespread ensuring optimum shaping of dynamic properties already at the stage of designing.

In the field of Mechanical Engineering:

Modelling of momentum and heat transfer in bubly two-phase flow

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In the awarded work a new approach to modelling the bubbly flow (without bubble generation) in the boundary layer has been presented. The approach is based on summation of the dissipation energy coming from the shearing turbulent flow in the absence of bubbles and the dissipation contribution from the bubble motion. The model can be solved in approximate way to provide an analytical solution describing the velocity field in the bubbly flow in the boundary layer. Such solution can be obtained in the case of an assumption of constant void fraction distribution. The novel model of void migration has been also proposed. The model is based on two differential equations describing the lateral velocity and bubble diffusion, which enable calculation of void fraction distribution. The model is based on another hypothesis that in the flow there exists additional rotational velocity related to the non-uniform distribution of bubbles in the flow. In considered flows the void distribution can exhibit two distinct behaviours, i.e. near-wall peaking or core peaking. That phenomenon has yet to obtain a proper explanation of physical phenomena involved, however, the proposed model is capable of capturing the cases mentioned above, therefore confirming that the foundations of the model are correct. A good consistency of calculations performed using a new model with experiments has been obtained. Finally, the heat transfer problem has been solved. Generally, the model consists of five differential equations, which enable determination of the velocity profile, shear stresses, lateral velocity, void fraction and temperature profile. Integral characteristics of the model such as friction factor and heat transfer coefficient have also been determined, which are of significant engineering importance in for example design of various installations.

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The evaluation procedure aiming at the determination of the Award'2004 Winners is in progress now.