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6th International Congress of the Serbian Society of Mechanics: Review

Mihailo Lazarević [1)]

This paper presents the most important information and describes the activities of the 6th Congress of the Serbian Society of Mechanics which was held on mountain Tara, on 19- 21 June, 2017. The Congress was organized by the Serbian Society of Mechanics. Brief summaries of the plenary lectures and some of 99 accepted papers, which admittedly attracted the most interest were shown as well.

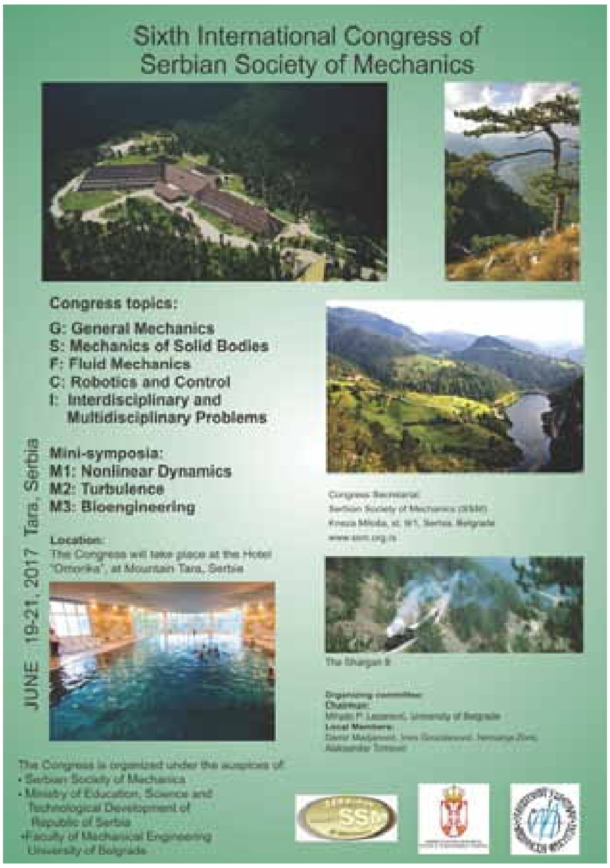
Key words: **mechanics, theoretical mehanics, applied mechanics, fluid mechanics, kinematics, dynamics, robotics, biomechanics, international scientific conference, Serbia.**

THE International Congress of the Serbian Society of Mechanics is regularly held every second year and comprehensively and multidisciplinary considers current conditions and further development trends in the area of theoretical and applied mechanics.The Serbian Society of Mechanics is a voluntary, non-governmental, non-profit, professional scientific organization with a long tradition, (see http://www.ssm.org.rs/).

The logo of the Serbian Society of Mechanics

This year, the 6th International Congress of the Serbian Society of Mechanics was held from 19th to 21st June, 2017, on mountain Tara, located in the western part of Serbia, with an average altitude of 1200 m. Since 1981, Tara has declared a national park that, among other rare plant species, has famous endemic Picea omorika (*Serbian spruce*), discovered and named by the Serbian botanist Josif Pančić. This traditional meeting of scientists and engineers, researchers, experts in the field of theoretical and applied mechanics and other related areas was organized by the Serbian Society of Mechanics (SSM) and under the patronage of the Faculty of Mechanical Engineering, University of Belgrade. Also, the 6th Congress was sponsored by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

The objectives of this 6th Congress was to review and discuss some of the latest trends in various fields of theoretical and applied mechanics. By presenting the original high-level work and bringing together the experts and young researchers, it aims to promote the exchange of ideas in the topics of mutual interests, to establish links between scientific communities with the complementary activities and to encourage them for collaboration in times to come. During three days, many high-quality and original papers from current research projects were presented, as well as papers on research already applied in practice or that referring to forecasting and further developments in theoretical and applied mechanics. At the 6th Congress of SSM - 2017, 97 papers were presented with more than 250 authors and co-authors.



All papers were reviewed and presented in the following 5 thematic sections:

[1)] University of Belgrade, Faculty of Mechanical Engineering, Department of Mechanics, Kraljice Marije 16, 11020 Belgrade 35, SERBIA
Correspondence to: Mihailo Lazarević; e-mail: mlazarevic@mas.bg.ac.rs

- General Mechanics,
- Fluid Mechanics,
- Mechanics of Solid Bodies,
- Control and Robotics,
- Interdisciplinary and Multidisciplinary Areas.

During three days of work during the Congress, 15 sessions were held in four halls. Also, the 3 Mini-symposia were organized as follows:

- *Nonlinear dynamics* **(***Organizer*: *Katica Stevanović-Hedrih,* Mathematical Institute of the SASA, Belgrade, *Co-Organizer*: *Ivana Atanasovska*, Mathematical Institute of the SASA, Belgrade)
- *Turbulence* **(***Organizer*: *Djordje Čantrak,* Fac. of Mech. Eng., University of Belgrade, Serbia)
- *Bioengineering* **(***Organizer*: *Nenad Filipović,* Fac. of Eng., University of Kragujevac, Kragujevac, Serbia)

In addition to them, 7 invited plenary lectures were held by the authors from Russia, Greece, Italy, USA, Germany, Serbia and the Republika Srpska, BIH. The full versions of all these contributions were recorded on the attached electronic storage device. The Congress was officially opened and the participants were welcomed at the Forum Pallace Hall, Hotel Omorika, by Mihailo P. Lazarević, President of the Serbian Society of Mechanics and the Congress Chair of the 6^{th} Congress of SDM, Full Professor at the Faculty of Mechanical Engineering, University of Belgrade, Belgrade.

The opening of the 6th Congress

The first plenary lecture was held by the Academician and Professor Felix L. Chernousko, Institute for Problems in Mechanics, Russian Academy of Sciences, Moscow Institute of Physics and Technology, Moscow, Russia. The Academician Felix Chernousko graduated from the Moscow Institute of Physics and Technology with honor. He received his Ph.D. and Doctor of Sciences degrees for his research on dynamics of satellites and spaceship. He works at the Institute for Problems in Mechanics of the Russian Academy of Sciences since 1968 as a Head of Laboratory, and since 2004 until 2015 as the Director of the Institute. Since 2015, he is a principal researcher at this Institute. Also, Chernousko is a Professor of the Moscow Institute of Physics and Technology. He has published more than 400 papers and 15 books on mechanics, control theory and robotics. He is a Full Member of the Russian Academy of Sciences, Russian Academy of Engineering, Serbian Academy of Sciences and Arts, European Academy of Sciences, International Academy of Astronautics, Fellow of European Mechanics Society. Professor Chernousko is awarded with the Russian State Prize for Science and Technology (twice), Koerber Prize for European Science, Alexander von Humboldt Research Award (Germany), Chaplygin Gold Medal and Andronov Prize of the Russian Academy of Sciences.

The first plenary lecture was held by the Academician and Professor Felix L. Chernousko, Institute for Problems in Mechanics, Russian Academy of Sciences, Moscow Institute of Physics and Technology, Moscow, RUSSIA.

Locomotion of mobile robotic systems: dynamics and optimization

This lecture presents the problem of the locomotion of mobile robotic systems. It is based on the research fulfilled recently at the Institute for Problems in Mechanics of the Russian Academy of Sciences, where the results on dynamics and control of locomotion for certain types of mobile robotic systems are described and discussed. Particularly, the systems that move on surfaces and inside media due to a special periodic change of their configuration are considered.

Namely, locomotion of the mobile systems can occur along surfaces in the presence of dry friction forces or inside resistive media. The resistance forces are directed against the velocity of the moving body and depend on the velocity value. Both linear and quadratic dependences are considered; the resistance forces may be either isotropic or anisotropic, i.e. dependent on the direction of motion. The following types of the mobile robotic systems are examined: multilink snake-like systems; multibody systems in quasi-static motion; systems consisting of several interacting bodies; fish-like, frog-like, and boat-like systems swimming in fluids: systems containing moving internal masses. Dynamics of these systems subjected to various resistance forces, both isotropic and anisotropic, is investigated, including dry friction forces obeying the Coulomb′s law and forces directed against the velocity of the moving body and proportional to the velocity value or its square. Possible modes of locomotion and control algorithms are discussed. In a similar way, both longitudinal and lateral periodic motions of a three-link system as well as its rotation on the spot are constructed as the sequences of slow and fast phases.

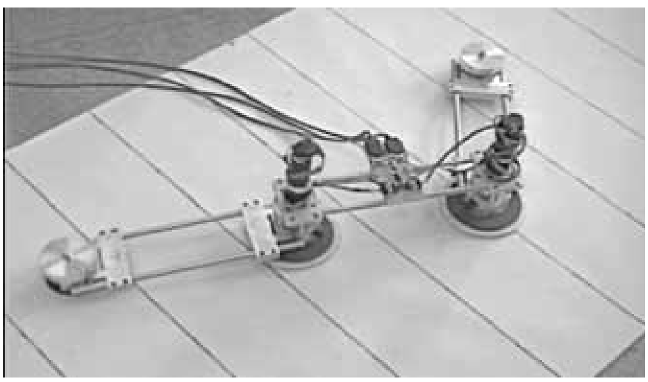


Figure 1. An experimental model of a three-link system

It is shown that both the two-member and three-member linkages can be transferred from the initial position and configuration to any prescribed terminal position and configuration in the horizontal plane. The corresponding relationships are obtained, and the locomotion speed is evaluated. Experimental models of multilink mechanisms implementing the proposed motions are created and tested, see Fig.1. Also, it is shown that systems containing internal moving masses have no direct biological analogs. These systems do not need external devices such as legs, wheels, tracks, propellers, etc. They can be even made hermetic; they need a only energy source for movement of internal masses and, of course, the resistance force of the outer medium. Such robots may be useful for motions inside vulnerable or hazardous media. Besides, optimization for various types of mobile robots is considered. Optimal values of geometrical and mechanical parameters as well as optimal controls are obtained that provide the maximum locomotion speed or minimum energy consumption. The results of the experiments and computer simulation are discussed. Experimental devices that can serve as prototypes of mobile robots are described.

The second plenary lecture was given by the Academician and Professor Pol D. Spanos, Ryon Chair in Engineering, Brown School of Engineering, Rice University, Houston, TX, USA.

He is a corresponding member of the National Academy of Greece (Academy of Athens); and a member (academe) of the National Academy of Engineering (USA). He received many awards, prizes and medals such as: (NSF) Presidential Young Investigator, Pi Tau Sigma and a Larson medalist, a Huber Prize, A. M. Freudenthal Medalist, a Newmark Medalist; Theodore Von Karman medalist, etc. His research efforts focus on the dynamics and vibrations of the structural and mechanical systems under a variety of loads. Systems exhibiting nonlinear behavior and/or exposed to hazard/risk inducing conditions receive a particular attention. His group is also interested in fatigue and fracture issues of modern composite materials, and in signal processing algorithms for dynamic effects in biomedical applications. He has published more than 300 technical papers and has authored/edited 18 books and conference volumes. He serves on the editorial boards of many journals and he is the Editor-in-Chief of the International Journal of Non-Linear Mechanics (launched in 1965) and the Managing Co-Editor of the Journal of Probabilistic Engineering Mechanics (launched in 1985).

Randomly Excited Nonlinear Dynamic Systems Endowed with Fractional Derivatives Elements

In this lecture, the problem of determining approximately the response statistics of randomly excited nonlinear systems endowed with fractional derivative elements is investigated. The problem is relevant to a number of physical themes where, for instance, the viscoelastic behavior of materials or the effect of appended elements can be described via fractional operators. The paper considers three specific examples: the vibration of a Duffing oscillator; the large vibrations of a beam; and the large vibrations of a rectangular plate. It is shown that for each problem the approximate response statistics determined via a statistical linearization based approach can be estimated. Specifically, it was found that an approximate solution can be obtained by replacing the original nonlinear system with an equivalent linear one. The parameters of this surrogate linear system are estimated by minimizing the mean square error between the nonlinear equation of motion and the linear one. Then, iterative procedures are implemented to estimate efficiently the response statistics. The analytical results are validated via pertinent Monte Carlo studies. The approach has the appealing feature of being applicable to a wide class of stochastic mechanics problems involving the fractional operators.

The second plenary lecture was given by the Academician and Professor Pol D. Spanos, Ryon Chair in Engineering, Brown School of Engineering, Rice University, Houston, TX, USA

The third plenary lecture was given by Dr.Giuseppe Saccomandi, Dipartimento di Ingegneria, Universit`a degli Studi Perugia, Italy & School of Mathematics, Statistics and Applied Mathematics NUI Glaway, Ireland.

The third plenary lecture was given by Dr. Giuseppe Saccomandi, Dipartimento di Ingegneria, Universit`a degli Studi Perugia, Italy & School of Mathematics, Statistics and Applied Mathematics NUI Glaway, IRELAND.

Ut vis sic tensio

The mechanical properties of rubber-like materials have been offering an outstanding challenge to the solid mechanics community for a long time. The behavior of such materials is quite difficult to predict because of rubber self-organizes into mesoscopic physical structures that play a prominent role in determining their complex, history-dependent and strongly nonlinear response. In this framework, one of the main problems is to find a functional form of the elastic strain-energy that best describes the experimental data in a mathematically feasible way. When we deal with a nonlinear theory we face a mare magnum: any functional form can be a priori a constitutive equation. Experimental data are not sufficient to restrict in a definitive way the possible functional forms. Only the power of hypothetical deductive method of mathematical modeling can truly help.The goal of his discussion is to give a general overview of all the underpinnings of this problem summarizing the work done by his co-authors and himself during a long period and contained mainly in the above-mentioned paper and other two papers: the 2004 paper with Ogden and Sgura, and the recent review with Puglisi.

The fourth plenary lecture was given by Dr. J. Jovanović, Institute of Fluid Mechanics, Friedrich-Alexander University Erlangen-Nuremberg, Erlangen, Germany.

Design of the anti-turbulence surface for producing maximum drag reduction effect

The concept of a micropatterned surface morphology capable of producing self-stabilization of turbulence in wall-bounded flows is considered which acts to restructure fluctuations towards the limiting state where these must be entirely suppressed. Direct numerical simulations of turbulence in a groove-modified channel consisting of flat and grooved walls were performed at a Reynolds number Rem' 5000 based on the bulk velocity and the full channel height. Simulations were performed for highly disturbed initial flow conditions leading to the almost instantaneous appearance of turbulence in channels with flat walls. In an attempt to ensure persistence of the laminar flow, the surface morphology was designed in the form of profiled grooves aligned with the flow direction and embedded in the wall. Such grooves are presumed to allow development of only the statistically axisymmetric disturbances. In contrast to the rapid production of turbulence along a flat wall, it was found that such development was suppressed over a grooved wall for a remarkably long period of time. Owing to the difference in the flow structure, friction drag over the grooved wall was more than 60% lower than that over the flat wall. Using simulation databases, the anisotropy of turbulence was evaluated to yield insights into structural changes in the flow permitting self-sustaining of the laminar regime, leading to the drag reduction effect. Anisotropy-invariant mapping supports the conclusion, emerging from the analytic considerations, that persistence of the laminar regime is due to statistical axisymmetry in the velocity fluctuations.

The fourth plenary lecture was given by Dr. J. Jovanović, Institute of Fluid Mechanics, Friedrich-Alexander University Erlangen-Nuremberg, Erlangen, GERMANY.

The fifth plenary lecture was given by Dr.Themis P.Exarchos, Foundation for Research and Technology Hellas, Institute of Molecular Biology and Biotechnology, Dept. of Biomedical Research, University Campus of Ioannina, Ioannina, Greece.

Personalized site-specific models of atherosclerotic plaque progression (Themis P. Exarchos, Antonis Sakellarios, Panagiotis Siogkas, Nikos Tachos,George Rigas, Nenad Filipovic, Silvia Rocchiccioli, Gualtiero Pelosi, Oberdan Parodi and Dimitrios I. Fotiadis)

In this paper, authors present an integrated approach for risk stratification, plaque prediction and treatment for patients with a coronary atherosclerotic disease, in the framework of the SMARTool project. The SMARTool combines the results of two previous FP7 projects, in terms of models (VPH project ARTreat - FP7-224297 - Multi-level patient-specific artery and atherogenesis model for outcome prediction, decision support treatment, and virtual hand-on training) and of existing data (Health project EVINCI - FP7-222915 - Evaluation of integrated cardiac Imaging), aiming to develop a platform based on the cloud technology, for clinical decision support to the management of patients with coronary artery disease (CAD). By standardizing and integrating heterogeneous health data, including those from key enabling technologies, and existing patient/artery specific multiscale and multilevel predictive models, the platform supports the application of a novel clinical decision support system (CDSS) for a better prevention of coronary heart disease (CHD) and of major adverse cardiovascular events (MACE), and support the treatment and design of therapeutic interventions.

The fifth plenary lecture was given by Dr. Themis P. Exarchos, University Campus of Ioannina, Ioannina, GREECE.

Despite the application of the established medical and surgical therapies, CAD continues to present a major global public health challenge. To address residual cardiovascular risk, the research is focusing on the development of new strategies designed to prevent or delay the progression of the CAD. The rationale for using coronary imaging is based on the concept that atherosclerotic plaque is the pathological substrate underlying the occurrence of acute coronary events. This is a consolidated evidence based on the finding that both the extent of CAD at baseline and its rate of progression are independently associated with the adverse outcomes in CHD patients. Thus, interventions that slow the progression of CAD can also improve clinical outcomes, due to the tight association between CAD extent and progression rate, with the direct effect on cardiovascular morbidity and mortality. This relation has prompted health care authorities to permit labeling of therapies for CHD patients on the basis of their effects on CAD progression.

The sixth plenary lecture was given by Dr. Valentina Golubović-Bugarski, University of Banja Luka, Faculty of Mechanical Engineering, Banja Luka, Republika Srpska, Bosnia and Herzegovina.

Identification of dynamic properties of mechanical structure from measured vibration responses (Valentina Golubović-Bugarski, Ognjen Mijatović, Matija Guzijan-Dilber,Manuel Desančić, Aleksandar Borković)

Technological progress and demands of modern life have imposed the need for the development of modern structures that are light weight, but at the same time have high damping capacity and stiffness. The consequences of these requirements are increased dynamic problems related to vibration, noise and fatigue of structures. The structures constructed from beam elements connected with bolts, rivets or welds can meet these requirements. Structural joints can significantly reduce the level of vibration and therefore have become a subject of interest to many researchers, especially research of damping that occurs in the joints. This paper presented a detailed experimental and numerical investigation performed on a beam element separated from an assembly structure.The objective was to determine the damping characteristics of the beam element varying the type of a joint (bolted and welded) and mass added at the free end of the beam (1 kg and 2 kg). For this purpose different beam models with welded and bolted joints were experimentally tested by means of modal testing and free decay testing. Numerical analysis was performed in the Abaqus software and an experimental investigation was done by modal testing and free-vibration test of the structure. Finally, when matching criteria are met, detected stiffness, damping and mass properties will be applied for the dynamic response of the complex multi-story model.

The sixth plenary lecture was given by Dr. Valentina Golubović-Bugarski,University of Banja Luka, Faculty of Mechanical Engineering, Banja Luka, Republika Srpska, BOSNIA AND HERZEGOVINA

The seventh plenary lecture was given by Dr. Dragan Milosavljević, Faculty of Engineering, University of Kragujevac, Kragujevac, Serbia.

The seventh plenary lecture was given by dr. Dragan Milosavljević, Faculty of Engineering, University of Kragujevac, Kragujevac,SERBIA.

Dynamical behavior of composite materials reinforced with strong fibers

The aim of this paper is to demonstrate that fibre reinforced material with a constraint of inextensibility may serve as first approximation in considering laminates built with materials reinforced with strong fibres. It is shown that this mathematical idealization allows easy calculation of dispersion curves but the boundary layers which carry infinite normal stresses and discontinuous shear stresses must be postulated. Material with inextensible fibres may serve as the first approximation in the analysis of composite laminates. For an ideal fibre reinforced composite, which is imposed with inextensibility condition, we obtained equations from which it is easy to obtain a frequency spectrum for waves with wave normal in the plane parallel to stress-free faces of a multilayered plate with an arbitrary angle to the referential direction in mid plane of the plate.

Also, the two young authors competed for the "*Rastko Stojanović*'' award at the 6th International Congress of the Serbian Society of Mechanics (*Jela Burazer, PhD student at the Faculty of Mechanical Engineering, University of Belgrade* and *Aleksandar Tomović, teaching assistant, and PhD student at the same faculty*). After their presentations, the commission has decided that the authors share the award, the*"Rastko Stojanović"* diploma.

"Rastko Stojanović" diploma

Colleague Burazer presented the paper with the title - Numerical research of energy separation in a cylinder wake.

In this paper, a problem of the energy separation in a cylinder wake is considered. Two flow conditions are being considered. In the first one, the velocity in the wake is only deformed, while in the second one a turbulent vortex street is formed and vortices are detaching from the cylinder. Two different solvers from the open source package OpenFOAM are used in order to capture the phenomenon of energy separation. One of these solvers is modified for the purpose of calculation in a particular case of the vortex street flow. The energy equation based on the internal energy present in this solver is replaced by the energy equation written in the form of a total enthalpy. The other solver has been previously tested in the vortex tube flow, and can also capture the energy separation in the wake of the cylinder. In both cylinder wake flow conditions, a twodimensional computational domain is assumed. The standard k-ε model is used for computations and good agreement between the experimental results and the ones from computations is obtained in the case of the velocity deformation in the wake flow. Previous research findings are also confirmed in the case of vortex street flow.

The second author, Tomović, considered the synchronous axial and bending vibration problem of elastic beams with variable cross-sectional profile and inhomogeneous material and conjugated boundary conditions. The orthogonality conditions of mode shapes are derived for the case with no repeated natural frequencies, along with the constants for the corresponding time function. In that manner, the response of the beam to initial excitations is covered in the theoretical aspect. The numerical background for solving the problem is explained based on the theory of numerical "shooting" method and boundary conditions of a considered mechanical case. The case of beams with no attached end masses and rigid bodies is considered in this paper. Also, one numerical example is presented to accompany the theoretical considerations.

The list of all the papers and authors as well as other information concerning 6th Congress of the Serbian Society of Mechanics, 2017 can be found on the website: http://www.ssm.org.rs/congress_2017/home.html. Some of the most interesting papers are presented below. The papers have been selected considering their overall quality, applicability in practice, support by experimental work, as well as taking into account the discussions they prompted.

Mini-symposia – Nonlinear Dynamics (M1)

Lecturers of mini-symposia - Nonlinear Dynamics (M1)

Phase portrait and energy surfaces of non-linear systems with one degree of freedom: characteristic examples (Katica R. (Stevanović) Hedrih, Math. Ins. of SASA, Belgrade, Serbia, Univ. of Niš, Fac. of Mech. Eng. Niš)

In this paper the characteristic examples of phase portrait and energy surfaces of non-linear systems with one degree of freedom are presented. For the conservative non-linear mechanical system with one degree of freedom describing by an ordinary non-linear differential equation, equation of the phase trajectory and energy integral are derived. For three characteristic examples of heavy mass particle motion along the circle in the stationary vertical plane, which as well rotate around the vertical centric and eccentric axis with constant angular velocity, equations of phase trajectories are derived. For these three models of dynamics, total mechanics energy surfaces are graphically presented with an explanation how to obtain the phase trajectory portraits. The models of dynamics are known, but graphically presented examples of total mechanical energy surfaces are new and very important for the methodology of university teaching, transfer, and dissemination knowledge on the scientific level in the area of non-linear dynamics.

*On the Saturn's precession (*P. Krasilnikov, R. Amelin, Moscow Aviation Institute, Moscow, Russia)

In this paper the authors considered problem of the *Saturn's precession.* Moreover, the authors investigated the influence of the Sun, the Jupiter, the Saturn's satellites on the Saturn's tilt and precession frequency. It is known that under the Sun attraction the dynamically symmetric planet makes a regular precession about the normal to its orbit plane. It is also known that the planet's satellites have a significant influence on the planet rotations. Because of the slow convergence of the gravitational potential series, the general theory of the planet rotations with considering its satellites gravity is absent. With considering the Sun and planets satellites gravitational torques, the Saturn's precession frequency is obtained. Strong support for this frequency comes from the assumption that the Saturn and its satellites rotate as a unit. Ward and Hamilton offer an explanation for a large tilt of the Saturn's spin axis owing to gravitational perturbations of the Saturn by the planet Neptune. However, these researches do not take into account the Saturn's gravitational torques, which greater the Neptune's perturbations.

Nonlinear dynamic stability of a functionally graded nonlocal nanobeam in thermal environment by using Incremental harmonic balance method (D. Z. Karličić, M. S. Cajić, Mathematical Institute of the Serbian Academy of Sciences and Arts, Belgrade, Serbia)

In this paper, the authors investigate the nonlinear dynamic stability of a functionally graded (FG) nanobeam with geometric nonlinearity embedded in the Kelvin-Voigt viscoelastic medium. The material properties of the FG nanobeam vary continuously through thickness direction, which is based on the power-low distribution. By using the d'Alembert principle, a nonlinear partial differential equation is obtained for transverse motion of the FG nanobeam subjected to parametric excitations and thermal load. In order to analyze instability regions of the FG nanobeam, the incremental harmonic balance (IHB) method is introduced to obtain iterative relationship for the frequency and amplitude of time-varying axial load. It is shown that the nonlocal parameter, temperature changes and stiffness coefficient of the viscoelastic medium have significant effects on the vibration behavior and stability of the FG nanobeam.

*Numerical analysis of finite hypo-elastic cyclic deformation with small and moderate rotations (*M.Trajković-Milenković, Fac. of Civil Eng. and Arch., Univ.y of Niš; Otto T. Bruhns, Ins. of Mech.,Ruhr-Universität Bochum, Bochum, Germany; D. Šumarac, Univ.of Belgrade, Fac. of Civil Eng., Belgrade)

In this paper, the authors presented a numerical analysis of a finite hypo-elastic cyclic deformation with small and moderate rotations. For the most of engineering materials subjected to finite elastoplastic deformations, the elastic part of deformation may be small in comparison to the plastic deformation part. However, since this elastic part can significantly influence the result of the total deformation, it must be properly formulated and this holds especially true for large deformation cyclic processes when small errors may accumulate. The aim of this paper is to prove through one characteristic numerical problem of cyclic deformation that the logarithmic rate has a unique property that its implementation in the hypoelastic constitutive relations for the case of pure elastic deformation results as a path-independent and non-dissipative process contrarily to usually used objective rates. The article shows that the logarithmic rate is an appropriate choice in modelling large deformations where shear influence is predominant.

Dynamics of complex systems consist of deformable bodies

In contact - the new approach (I.D. Atanasovska, Math. Ins. of Serbian Academy of Sciences and Arts,Belgrade; D. B. Momčilović, Ins. for materials testing IMS, Belgrade)

This paper presents a new approach for solving the non-linear dynamics of complex mechanical systems, which contains two or more deformable bodies in contact. The analyzed problem is characterized with continuous changes of the contact areas' geometry, friction, load distribution and other parameters. The comprehensive and unique procedure for solving the dynamics of mechanical systems with deformable bodies in contact presented with the appropriate algorithm gives the simplified framework for analysis of all the mechanical systems of this type. In this framework, the flow chart of the algorithm of a new approach for nonlinear dynamics of multi-body contact systems is developed and described in this paper.

Elastic s-type cable-suspended parallel robot in presence of second mode (Lj. B. Kevac, et al., Univ. of Belgrade, School of Elec. Eng., Belgrade)

In this paper, the mathematical model of the elastic S-type Cable-Suspended Parallel Robot -eSCPR system is presented. This mathematical model involves the elastic property of the ropes,which significantly increases the number of degrees of freedom and complexity of the eSCPR system. The novelty of the eSCPR system's mathematical model is the relationship between each motors angular position and the elastic deformations of the corresponding rope, which is expressed as the fictitious coordinates. The direct and inverse kinematics is solved by using those fictitious coordinates. The Lagrange principle of the virtual work and Lagrange's equations of the second order are expressed with a Jacobian matrix. Two case studies of the eSCPR were analyzed and presented using the OGTOM program package.

Some considerations about voltammogram as bifurcations

Diagram in electrochemical oscillatory systems (N.I.Potkonjak**,** *et al.,* Univ. of Belgrade, Vinča Inst. of Nuclear Sciences, Chem. Dynamics Lab., Belgrade)

The Cu|1M TFA electrochemical system was investigated by the linear sweep and cyclic voltammetry. Looking from the non-linear dynamics perspective, the current-potential (*I-E*) polarization curve (voltammogram) can be devided into three regions. Whereby, two of them can be characterized as the region of stable steady-states. The region of oscillatory states is the third one. The oscillatory region is located in-between the stable steady-state regions, it separates them. Presented results have shown that voltammogram of an electrochemical oscillatory system can be observed as a bifurcation diagram, relevant for bifurcation analysis.

Mini-symposia Turbulence (M2)

Numerical computations of turbulent flow through orifice flow meter (A.S.Ćoćić, et al., Univ. of Belgrade, Fac. of Mech. Eng., Belgrade)

Turbulent, incompressible flow through orifice flow meter is numerically investigated using the OpenFOAM software. Turbulence is modeled using RANS approach, and three turbulence models are tested: standard k -ε , k -ω and Launder Sharma model. Results for pressure drop on the orifice are compared to the experimental results and good agreement is found for all turbulent models, with the most accurate results obtained with k -ε model. Velocity and pressure distribution in the whole computational domain is analyzed, with a special attention to the region in proximity to the orifice where primary and secondary vortex structures are detected. Additionally, numerical computations are also performed on an automatically generated mesh using snappy HexMesh utility and similar results for the pressure drop are obtained as the ones on the block-structured grid.

Computational analysis of horizontal-axis wind turbine by different rans turbulence models (J.Svorcan, et al., Univ. of Belgrade, Fac. of Mech. Eng., Belgrade)

The aim of this paper is numerous numerical investigations of isolated horizontal-axis wind turbine rotor consisting of three blades have been performed in ANSYS FLUENT 16.2. The flow field is modeled by Reynolds Averaged Navier-Stokes (RANS) equations where two different turbulent models are tried: Spalart-Allmaras and k-ω SST. For resolving the rotational motion of the blades both Moving frame of the reference and Sliding mesh approaches were employed. Both computational approaches are briefly explained and obtained numerical results are compared to the available experimental data. Presented results include fluid flow visualizations in the form of pressure and velocity contours, sectional pressure distributions and values of power and thrust force coefficients for a range of operational regimes.

MHD steady and unsteady flow past a circular cylinder **(**Ž.M.Stamenković, et al., Fac. of Mech. Eng., Univ. of Niš. Niš).

The present study has been undertaken to understand the effects of a magnetic field on steady and unsteady flow past a circular cylinder where several cases are considered. First, laminar 2D flow and magnetohydrodynamic (MHD) laminar flow over a circular cylinder are analyzed in order to validate the model of magnetic field influence on electrically conducting fluid flow. Laminar flow regimes were examined for the Reynolds numbers ranging up to 250 based on the cylinder diameter. The second part of the paper is focused on MHD turbulence suppression for two-dimensional turbulent flow around the circular cylinder. The simulations are performed using ANSYS CFX software where simulations results are obtained with laminar model of the flow and SST turbulence model. The nature of the flow has been examined through several parameters: lengths of recirculation zone, vortex shedding, separation point, drag, lift and pressure coefficients.

Possibility of vortex structures control by modulation of the nozzle exit velocity using low-amplitude oscillations (D.Cvetinović et al. Univ. of Belgrade, Vinca Ins. of Nuclear Sciences, Belgrade)

The subject of this paper is the submerged, round, unconfined turbulent axisymmetric jet,which issues from nozzles with different geometries and impinges to the flat heated plate positioned normally to the jet axis. In the paper the ability to control eddy structures in the jet by sound modulations of velocity at the nozzle exit was demonstarted, and some features of modulated jet, interesting for usage in technological processes were explored. The aim of the experimental investigations, mathematical modelling and numerical simulations is to widely investigate the properties and the vortex structures of modified and unmodified jet, that are assumed to have great importance in the heat transfer process. Primary vortices, which roll-up in the jet shear layer, induce an unsteady flow separation at the wall, prohibiting the heat transfer between the wall and the fluid jet. Thus, controlling of the vortex structures in a turbulent jet necessarily leads to the control of the heat transfer from the jet to the wall, and vice versa. It is found that the vortex roll-up can be controlled by adding a small amplitude modulation of the nozzle exit velocity using an external source of low-amplitude oscillations or self-sustained oscillations generated in the operation of the specially designed whistler nozzles.

Reynolds number influence on integral and statistical characteristics of the turbulent swirl flow in straight conical diffuser (D.B.Ilić, et al., Univ. of Belgrade, Fac. of Mech. Eng. Belgrade)

Results of the experimental investigations of the turbulent swirl flow in straight conical diffuser are presented in this paper. Diffusers have the inlet diameter 0.4 m and total divergence angle 8.6. The incompressible swirl flow field is generated by the axial fan with outer diameter 0.397 m. Measurements are performed in one measuring sections downstream the axial fan impeller, i.e. in conical diffuser ($z/R0$ = 1) with one-component laser Doppler anemometry (LDA) system, for four flow regimes. Axial and circumferential velocities are measured, the Reynolds numbers (149857 – 216916) calculated on the basis of the average axial velocity where integral parameters, such as volume flow rate, average circulation and swirl number are also determined. Statistical characteristics are calculated such as the level of turbulence, skewness and flatness factors.The highest levels of turbulence for axial velocity are reached in the region $0.4 < r/R < 0.6$, where $D = 2R$. The highest levels of turbulence for circumferential velocity are reached in the region around $r/R \approx 0.4$ for lower values of circulation, respectively in the core region for higher values of circulation.

Experimental and numerical analysis of flow field and ventilation performance in a traffic tunnel ventilated by axial fans (M.B.Šekularac, Univ. of Montenegro, Fac. of Mech. Eng., Podgorica, Montenegro; N.Z.Janković, Univ. of Belgrade, Fac. of Mech. Eng., Belgrade)

The focus of this paper is the airflow in a bi-directional traffic, two-lane tunnel. The model consists of two parallel tunnel tubes, where the main tunnel has the geometry of a scaled road traffic-tunnel. The second tunnel has a smaller size and is circular in cross-section, used only to simulate airflow towards an evacuation tunnel tube. Thus the two tunnels are connected by the evacuation passages, equipped with adjustable escape doors. By a combination of experimental and numerical work, the air flow-field and the performance of the ventilation system are investigated. The velocity field and its turbulence properties exiting the fans were determined experimentally using hot-wire anemometry. These data were further processed to be used in the tunnel flow computations by CFD. The efficiency of momentum transfer (*ηi, Kempf factor*) of the longitudinal tunnel ventilation is determined. The effect that the imposed boundary conditions and the level of their detail, have within a CFD computation of tunnel airflow, with respect to the accuracy, velocity distribution and computed *ηi* . Finally a traffic-loaded (traffic „*jam*") case of the flow is studied through the experiment and CFD. The difficulty in assessing the required thrust of the plant in traffic-jam tunnel conditions is discussed, and the ventilation efficiency is estimated. Based on the later results, the two limiting shapes of the axial velocity distribution with respect to height above the road, in this type of tunnel and traffic, are estimated.

Numerical research of swirl-free flow in a azad diffuser (Dj.M.Novković, et al., Fac. of Tech. Sciences, Univ. of Priština, Kosovska Mitrovica)

The paper presents numerical calculations of a swirl-free air flow in a straight conical diffuser named Azad diffuser where three different RANS based turbulence models are used. Calculations are performed using OpenFOAM CFD software under the assumption of a steady state incompressible air flow. The aim of the paper is to show a more detailed analysis of the flow in the coaxial part of the diffuser where approximately shear-free flow conditions exist. Comparison of the first and second-order turbulence closure models is performed especially in this flow zone. The results obtained by these models are also compared with the experimentally obtained results. Influence of shear-free flow conditions in the coaxial part of the diffuser on the efficiency of the first and second-order closure models is analyzed. The paper also shows the importance of the turbulent kinetic energy distribution in cross sections of the diffuser on the accuracy of used turbulence models.

Cavitation in venturi nozzle – numerical prediction of cavitation parameters (J.B.Bogdanović-Jovanović, et al., Univ. of Niš, Fac. of Mech. Eng., Niš)

A sudden increase of local velocity values and a pressure drop below the value of saturated vapor pressure lead to the cavitation phenomenon in a Venturi nozzle. Due to the importance of Venturi nozzles in the engineering practice, it is important to predict the appearance of cavitation and to determine the cavitation parameters. With the appropriate measuring equipment this could be done experimentally, but also, with fewer resources, it can be done using numerical simulations of the fluid flow in the Venturi nozzle. Therefore, the results obtained by conducted numerous numerical simulations, for different flow regimes of the Venturi nozzle (Reynolds number in the throat of Venturi vary from 2.8· 104 to 4.2· 104) are presented in the paper. The analysis of two-phase flow in a Venturi nozzle was performed, with a focus on the movement of a vapor phase in a fluid domain. The resulting flow parameters enable determination of the cavitation number and loss coefficient in the nozzle. The results were compared to the relevant experimental results.

Mini-symposia Bioengineering (M3)

Computational modeling for plaque progression and fractional flow reserve in the coronary arteries (Nenad Filipović, et al., Fac. of Eng., Univ. of Kragujevac, Serbia)

In this study authors compared computer simulation of plaque development and Fractional Flow Reserve (FFR) with the real clinical data from a specific patient. The Navier-Stokes and continuity equations were used for blood flow and pressure distribution for FFR. The Darcy law was used for model blood filtration, Kedem-Katchalsky equations for the solute and flux exchanges between the lumen and the intima. The system of three additional reaction diffusion equations that models the inflammatory process and lesion growth model in the intima was used. The measured FFR threshold was 0.78 and computational 0.80 where authors found a good correlation between real and computed FFR results on the patient. Some examples of plaque formation and progression for the specific patient for left coronary artery are presented. Determination of plaque progression and FFR with computer simulation for a specific patient shows a potential benefit for risk prediction of disease progression.

Convection-diffusion transport model using composite smeared finite element (M.Kojić, et al., Bioengineering Research and Development Center BioIRC Kragujevac).

In this paper, the convection–diffusion transport model using composite smeared finite element is considered.The mass exchange from blood vessels to tissue and vice versa occurs through blood vessel walls. Due to geometrical complexity and heterogeneity of the capillary systems, it is not feasible to model *in silico* individual capillaries for the entire organ domains. Hence, there is a need for simplified and robust computational models that address mass transport in capillary-tissue systems. Authors introduced a smeared modeling concept for gradient-driven mass transport and formulated a new composite smeared finite element (CSFE). The introduced CSFE is composed of two volumetric parts - capillary and tissue domains, and has 4 nodal DOF's: pressure and concentration for each of the two domains. The domains are coupled by connectivity elements at each node. The smeared concept is implemented into our implicit-iterative FE scheme and into FE package PAK. Examples tested for the purpose of this study illustrate the accuracy of the CSFE element, the robustness of the introduced methodology and its applicability in real physiological conditions.

Resonance as a potential mechanism for homolog chromosomes separation trough biomechanical oscillatory model of mitotic spindle (Andjelka N. Hedrih, Math. Ins. of SASA, Belgrade, Serbia; Katica (Stevanović) Hedrih, Math.

Ins. of SASA, Belgrade, Univ. of Nis, Fac. of Mech. Eng., Niš)

The aim of this work was to consider a mitotic spindle as a system of coupled oscillators and to analyze the conditions for sister chromatid separation in anaphase trough the biomechanical oscillatory model of mitotic spindle. An oscillatory model of the mitotic spindle is presented and conditions for resonance as a mechanism for homolog chromosomes separation in anaphase is analyzed and discussed. Compare to the complicated and complex molecular models, that describes metaphase and anaphase separately, the oscillatory model of mitotic spindle offers different biomechanical approach replacing complex molecular structures with biomechanical elements. Mechanism of different chromatid separation times in different chromosomes, as well as age related aberration in mitotic spindle functioning, could be explained with a proposed oscillatory model of the mitotic spindle.

Field of correction factors for smeared finite element (Miljan Milosevic, *et al.,* Bioengineering Research and Development Center BioIRC Kragujevac, Kragujevac, Serbia)

A motivation for this paper came from the need for simplified and robust computational models that address mass transport in the capillary-tissue systems. Recently introduced composite smeared finite element (CSFE) provides a new methodology of modeling complex diffusion transport in capillary and tissue domain. The formulated smeared methodology is tested with respect to accuracy on appropriate characteristic simple examples, and proved an improved accuracy for a tissue domain with complex capillary geometries. The presented procedure for calculation of the correction factors of the wall diffusion coefficient offers a possibility of accurate modeling of heterogeneous properties of the capillary tissue domain, which is important for practical applications. The use of correction factors improves the accuracy of the smeared model and allows using this methodology in various applications: drug delivery within domains with complex capillary structures. Field of correction factors also includes partitioning effects at the wall/tissue interface which is very important for various hydrophobic drugs that are recently being highly used in cancer treatment.

Application of DPD method on modeling semicircular Canals (Milica Nikolić, Nenad Filipović, Univ. of Kragujevac, Fac. of Eng., Kragujevac)

In this paper, authors presented modeling of semi-circular canals using Dissipative Particle Dynamics (DPD). The role of the Semi Circular Canals (SCC) is to secure balance, specifically rotational motion. Translational motion is regulated with an utricle, which is placed in a vestibule. Semicircular canals are positioned in three orthogonal planes, and during the rotational motion, fluid moves inside the canals, exposes pressure on the cupula − membrane inside the canal, which activates nerves and sends information about the change of the position to the brain. Three planes of the SCC provide information about rotation around each axis. Movement of the fluid inside the canal and deformation of the cupula were modeled with DPD method, which is the first time that this discrete method is used for modeling of SCC. Displacement of the cupula was analyzed and compared to the existing data from the literature, as well as force on the membrane.

Eye tracking algorithm and computational modeling in prediction of benign paroxysmal positional vertigo disease **(**Velibor Isailović, et al. BioIRC, Kragujevac, Serbia; Fac. of Eng., Univ. of Kragujevac)

One of the most common vertigo disorders is a benign paroxysmal positional vertigo (BPPV). A reliable method to diagnose BPPV is tracking the eye movements and observation of involuntary oscillations of eye (translational and/or rotational) - nystagmus. The authors used an in-house developed computer application for the eye motion detection, both translations as well as rotations. Also, the authors have developed a numerical model of the semicircular canals (SCC) by using fluid-structure interaction of the particles, wall, cupula deformation and endolymph fluid flow. Numerical model for fluid is based on the Navier-Stokes equations and continuity equations with Arbitrary-Lagrangian Eulerian (ALE) formulation for mesh motion. Numerical model for solid is based on the Newtonian dynamics equation. Coupling of fluid with cupula deformation is achieved by a fluid-structure interaction. Different size and number of particles with their full interaction between themselves, wall and cupula deformation are used. The results obtained by numerical simulation are compared with the real patient data for right anterior vHIT test. This technology can be used for a prediction of BPPV disorder.

General Mechanics

On linear anisotropic elasticity damage tensor (J.Jarić, Fac. of Math., Univ. of Belgrade; D. Kuzmanović, Univ. of Belgrade, Fac. of Transport and Traffic Eng., Belgrade).

In this paper, the anisotropic linear damage mechanics is presented starting from the principle of the strain equivalence. In the previous authors' paper (Jaric et al. (2013)) damage tensor components are derived in terms of elastic parameters of undamaged (virgin) material in closed form solution. Here, making use of this paper, authors derived elasticity tensor as a function of damage tensor also in a closed form. The procedure authors have presented here was applied for several crystal classes which were subjected to hexagonal, orthotropic, tetragonal, cubic and isotropic damage. As an example an isotropic system is considered in order to present some possibility to evaluate its damage parameters.

Extended classical theory of impacts by kinematics and dynamics of two rolling bodies in skew collision (K.(Stevanović) Hedrih, Math. Ins. of SASA, Belgrade, Serbia, Univ. of Niš, Fac. of Mech. Eng., Niš).

Extension of the classical theory of impacts by kinematics and dynamics of two rolling bodies in skew collision is formulated. Hypothesis of conservation of the sum of the angular momentum of two rolling bodies in skew collision is introduced. New definition of the coefficient of the restitution is defined using angular velocities of the body rolling before and after skew collision. Expressions of outgoing angular velocities of the rolling bodies after skew collision are derived.

The separation variables for the generalized Kowalevski top via discriminantly separable polynomials (V.Dragović, K.Kukić, Math. Ins. SASA, Belgrade).

In this paper the authors considered a few well known integrable systems, such as the famous Kowalevski top, the Sokolov system as a kind of generalization of the Kowalevski top and the so-called Jurdjevic elastic and obtained the separation variables from the corresponding discriminantly separable polynomials. Also, they developed an algorithm for an explicit integration of a whole class of systems based on discriminantly separated polynomials (*the Kowalevski type systems)*. Finally, they classified discriminantly separable polynomials in three variables and of degree two in each of them, and gave them a geometric interpretation as corresponding pencils of the conics.

Energy dissipation analysis of a column like structure during earthquake excitation (N.M.Grahovac, M.M.Zigić, University of Novi Sad, Faculty of Tech. Sciences, Novi Sad)

In this paper the authors analyze the energy dissipation of a structure consisting of two rigid blocks and passive systems of seismic protection. The structure is subjected to a horizontal earthquake excitation. A viscoelastic and a friction damper are used to dissipate seismic energy and protect the construction and the fractional calculus and the set-valued Coulomb friction law are applied to model the dampers. Governing equations are posed in form of a differential inclusion and a fractional differential equation.The solutions are obtained and compared for different real seismic records.

Contact symmetries and Noether theorem for time dependent holonomic and nonholonomic systems (B.Jovanović, Math. Ins. of SASA, Belgade)

The author considers Noether symmetries within Hamiltonian setting as transformations that preserve Poincare-Cartan form, i.e. as symmetries of characteristic line bundles of nondegenerate 1-forms. In case when the Poincare-Cartan form is contact, the explicit expression for the symmetries in the inverse Noether theorem is given. Also, as an application, author studied Noether symmetries of time-dependent nonholonomic mechanical systems. As special cases, he got a time-dependent variant of the classical nonholonomic Noether theorem, Noether theorem with gauge symmetries and moving energy integral.

Integration of SO(n-2) and SO(n-3) symmetric tops (V.Dragović, B.Gajić, B.Jovanović, Math. Ins. SASA, Belgrade)

The Euler equations of a motion of *n*-dimensional free symmetric rigid body around a fixed point, restricted to the invariant subspace given by the zero values of the corresponding linear Noether integrals are studied. Authors study the cases of the *SO(n-2)* symmetry and *SO(n-3)* – symmetry. In the first case we proved that the motion can be expressed in terms of elliptic functions. They performed the algebro-geometric integration procedure. In case of the – symmetry, they prove the solvability of the problem by using a Kozlov's result on the Euler-Jacobi-Lie theorem.

Global minimum time for the brachistochronic motion of a Particle in an arbitrary field of potential forces (R.Radulović et al., Univ. of Belgrade Faculty of Mech. Eng., Belgrade)

The problem of the brachistochronic motion of a particle in space in the field of known potential forces is considered. The brachistochrone problem is formulated as an optimal control task, where the particle velocity projections are taken as control variables. The problem considered is reduced to solving the corresponding two-point boundary–value problem (TPBVP) and the appropriate numerical procedure to apply in determining the solutions to the TPBVP is based on the shooting method. The paper presents the procedure for estimating the interval of initial values of the conjugate vector coordinates. Based on the given estimation, it may be claimed that all solutions to the corresponding TPBVP are certainly located within given intervals, and thereby also the global minimum time for the brachistochronic motion of a particle. In case of multiple solutions of the principle of maximum, the global minimum is the solution corresponding to the minimum time.

Vibro-impact system based on forced oscillations of heavy mass particle along a rough cicloid (S.Jović, Univ. of Priština, Fac. of Tech. Sciences, Kosovska Mitrovica).

This paper analyzes the motion trajectory of vibro-impact system based on the oscillator moving along the rough cycloid line in the vertical plane, under the action of an external single-frequency force. Non-ideality of the bond originates of sliding the *Coulomb's* type friction force with coefficient $\mu = tg\alpha o$. The oscillator consists of one heavy mass particle whose forced motion is limited by two angular elongation fixed limiters. The differential equation of motion of the analyzed vibro-impact system, which belongs to the group of common second order non-homogenous non-linear differential equations, can not be solved explicitly (in a closed form). For its approximate solving, the software packages Matematica 7 and MATLAB R2008a are used .

Rutting problem for rubber wheel motion over HMA asphalt concrete pavement (Lj.T.Kudrjavceva, *et al.* Dep. of Civil Eng., The State Univ. of Novi Pazar, Novi Pazar).

In this researh paper, the motion of a rubber wheel over a *hot mix asphalt (HMA)* on a straight paved road is considered. A highly irregular microstructure of the asphalt concrete is covered by the hierarchical approach. Perzyna's model is compared with the tensor generator quasi rate independent (QRI) model. The second is superior to its possibility to cover properly diverse multiaxial nonproportional stress-strain histories. An endochronic thermodynamics approach with the classical Perzyna's constitutive equations is used with plastic work as a fundamental irreversible time measure. For both models Vakulenko's thermodynamic time, in its extended form, the appropriate for aging is incorporated. However, due to the availability of experimental data the first model is applied to rutting problem through Abaqus FEM code with material user subroutine developed by the authors. An explicit integration procedure using the Banach fixed-point theorem iterations is proposed and employed. Hyperelastic viscoplastic behavior is considered and some preliminary results are presented.

A note on damage-fragmentation transition of slender taylor projectiles: size effect and scaling behavior, (S.Mastilović, Union − Nikola Tesla Univ., Belgrade, Serbia)

This investigation is aimed at scaling behavior of a transition region from the damaged to the fragmented phase in impact-induced breakup of a slender projectile. The input data are provided by molecular dynamics simulations of the ballistic Taylor test performed with a simple generic model to explore an extended low-energy range. Flat-ended, monocrystalline, nanoscale projectiles, with a fixed aspect ratio but ten different diameters, impact a rigid target under the right angle. With gradually increasing striking velocity, a substantial projectile disintegration eventually takes place and is identified with the damage-fragmentation phase transition. The atomistic simulations enable a detailed insight into the neighborhood of the damagefragmentation transition and the fragmentation onset at the critical point. The transition onset is determined to be dependent upon the striking velocity. A finite size scaling analysis of the average fragment mass is carried out to determine critical exponents and dependence of the critical striking velocity upon the slender projectile' s diameter.

Fluid Mechanics

Solid particles velocity distribution in pneumatic transport of granular materials in channels with a noncircular cross section taking into account secondary flow (Saša M.Milanović, et al., Univ. of Niš, Fac. of Mech. Eng., Niš).

In this paper the authors examine a turbulent two-phase air-solid particle flow in straight horizontal channels with a non-circular cross-section. Two-phase flows are characterized by a specific complex of flow phenomena that result from the interactions between the gas and the solid phase. During a turbulent flow in the cross-section of a channel, secondary flows also appear, and their influence cannot be neglected.

Also, a numerical simulation of a two-phase developed turbulent flow is presented. The stress model of turbulence is corrected by taking into account the influence of the induction of secondary flows of the second kind in the gas phase. A full Reynolds stress model is used to model the turbulence, with all the components of turbulent stresses determined from their eigen equations. The paper also presents changes in turbulent stresses and particle velocities.

Multitemperature ZND detonation model (S.Simić, *et al.*, Univ. of Novi Sad, Fac. of Tech. Sciences, Novi Sad)

The study is concerned with modeling aspects of ZND detonation within the context of multi-temperature gaseous mixtures. Using the simple model of reversible reaction, the model is developed which takes into account the influence of different temperatures of reactants and products on the process. A hierarchy of models is analyzed and it is shown that multi-temperature model admits oscillatory solutions, not observed in the single-temperature case.

Numerical analysis of detonation waves in multitemperature ZND model (Damir Madjarević, et al., Univ. of Novi Sad, Fac. of Tech. Sciences, Novi Sad)

The study is concerned with numerical analysis of multi-temperature ZND detonation wave. The model takes into account the influence of different temperatures of reactants and products on the process. It is shown that detonation profiles could be monotonous, but also oscillatory, in contrast to the standard single-temperature model. Parametric analysis of the profiles is provided.

Mechanics of Solid Bodies

Non-local axially loaded rod placed on viscoelastic and pasternak type foundation: dynamic stability analysis (D.Zorica, et al., Fac. of Tech. Sci., Univ. of Novi Sad)

The problem of determining the dynamic stability boundary (critical value of the axial force) of an axially loaded nonlocal rod of Eringen's type is considered. The rod is positioned on a viscoelastic foundation of the Pasternak type. Constitutive equations containing fractional derivatives of real and complex order are used to model the viscoelasticity of the foundation. The influence of various model parameters on the value of a critical axial load is examined.

Combined sub-harmonic resonances of nanobeam on fractional visco-pasternak type foundation (M.Cajić, et al. Math. Ins. SASA, Belgrade)

In this work, the authors observe combined parametric and external sub-harmonic resonances of order one-third of a geometrically nonlinear nonlocal nanobeam model resting on a fractional visco-Pasternak type foundation. Euler-Bernoulli beam theory, nonlinear strain-displacement relation and nonlocal elasticity constitutive equation are employed to the obtained fractional order governing equation for the transverse vibration of a system. Under the assumption of a small fractional damping, we used the perturbation multiple-scales method to obtain an approximated analytical solution for the frequency-amplitude response for variable axial and transverse external loads. Several numerical examples are given to show the effects of different parameters on the frequency-amplitude response.

Free vibration analysis of curved Bernoulli-Euler beam using isogeometric approach (M.Jočković, et al., Univ. of Belgrade, Fac. of Civil Eng., Belgrade)

Isogeometric analysis (IGA) is based on a concept that uses the same base functions for representing both the model geometry and the solution space. The most common base functions used in the IGA are NURBS (Non-Uniform Rational B-Splines) functions for their capability to analytically represent various geometries. In this paper, the IGA is applied in the free vibration analysis of rotation-free plane curved Bernoulli-Euler beam. Geometry of the undeformed and deformed beam is defined using convective coordinates and cross section basis vectors. Results of free vibration analysis for beam with arbitrary curvature are compared with the results obtained from the conventional finite element method (FEM) software. The significant advantages of the IGA approach over the FEM are shown and discussed.

Influence of Pasternak viscoelastic layer on Timoshenko beams stochastic stability (I.Pavlović, et al., Univ. of Niš, Fac. of Mech. Eng., Niš)

The moment Lyapunov exponents of a Timoshenko beam supported by a generalized Pasternak-type viscoelastic foundation subjected to white noise process are investigated. Bounds of the almost sure asymptotic stability of a beam as a function of viscous damping coefficient, shear correction factor, and parameters of Pasternak foundation are obtained. Analytically obtained results from the previous authors work are firstly checked and confirmed with numerically obtained results for the moment Lyapunov exponent using Monte Carlo simulation method. This method is further used for a numerical determination of the moment Lyapunov exponents for different system parameters.

Buckling of circular graphene sheets in an elastic medium (Ratko Maretić, et al. Univ. of Novi Sad, Fac. of Tech. Sciences, Novi Sad)

In the present work an attempt is made to study the stability of a circular graphene solid nanoplate under the uniform in-plane compression load where the plate is placed in an elastic medium which is modeled as a Winkler foundation. The rim of the plate is clamped. Using the theory of non-local elasticity, the exact analytical solution corresponding to the axisymmetric and asymmetric forms of stability loss is obtained. A detailed analysis of the characteristic equation is performed and the lowest roots of the characteristic equation are determined. In particular, the dependence of the critical load values on the foundation stiffness, nonlocal parameter and the number of nodal lines is investigated. It has been shown that, in some cases, the loss of stability may occur in an axisymmetric form having a single nodal line. In other cases, the stability loss may also occur in forms that posses more than one nodal circles.

Implicit stress integration of the elastic-plastic strain hardening model based on Mohr-Coulomb (D. Rakić, et al. Univ. of Kragujevac, Fac. of Eng., Kragujevac)

The paper presents an implicit stress integration of the elastic-plastic strain hardening constitutive model with non-associative yield condition based on the Mohr-Coulomb model using incremental plasticity theory. Yield surface of the presented constitutive model is defined using material parameters whose interpretation and estimation is presented in the paper. Governing parameter method was used for solving of non-linear equation system. Implicit integration procedure of model constitutive relations is presented in details as well as the algorithm for its FEM implementation. Developed algorithm was implemented in the general-purpose finite element program PAK designed for static and dynamic, linear and non-linear analysis of the structures. Verification of the implemented algorithm is performed using test example.

FEM analysis of concrete gravity dam by damage plasticity constitutive model (V.Lj.Dunić,e t al. Univ. of Kragujevac, Fac. of Eng., Kragujevac)

In this paper, the damage plasticity constitutive model is chosen and implemented and the verification is done for uniaxial and multiaxial examples from the literature. Furthermore, the concrete gravity dam was experimentally investigated and also was numerically analyzed in literature, but using the Cohesive Crack Model or Extended Fictitious Crack Model (EFCM). In this work, the same FEM model is analyzed by damage plasticity constitutive model implemented into the FEM software PAK and the obtained results are presented and observations of the results are given.

Determination of natural frequencies of a planar serial flexure-hinge mechanism using a new pseudo-rigid-body model (PRBM)method (S.Šalinić, A.Nikolić, Fac. of Mech. and Civil Eng., Univ. of the Kragujevac, Kraljevo)

This paper presents an approach to the free vibration analysis of the planar serial flexure-hinge compliant mechanisms basing on a PRBM with 3-DOFs joints (rigid links interconnected by flexure hinges). Two lateral and one rotational springs with corresponding stiffnesses are placed in each joint in the PRBM. The circular hinge type of flexure hinges is considered. Theoretical considerations are accompanied by a numerical example where a RRR compliant micro-motion stage is analyzed. The influence of the spring stiffnesses determined based on various flexure hinge compliance equations available in the literature on the vibration frequencies of the compliant mechanism is studied. Also, the comparison of an accuracy in the determination of vibration frequencies of the compliant mechanism between the proposed PRBM and the classical PRBM (with one-DOF revolute joints) is given.

Non-linear principal resonance of an orthotropic and magnetoelastic rectangular plate oscillating on fractional viscoelastic layer (N.Nešić, et al., Math. Ins. SASA, Belgrade)

In this paper, the authors derived governing equation for the vibration of a thin orthotropic plate resting on the fractional viscoelastic layer and under the combined actions of a magnetic field and transverse harmonic load. The von Karman plate theory of large deflection and the influence of magnetic Lorenz force induced by the eddy current are introduced into the model. By applying the Bubnov-Galerkin method, the nonlinear governing equation is transformed into a non-linear fractional order differential equation. The amplitude-frequency equations are further derived by the means of the multiple scales method where numerical examples show the influence of different physical parameters on the system behavior.

MHD flow and heat transfer in the porous medium under the influence of an externally applied magnetic field and induced magnetic field (J.D.Petrović, et al., Univ. of Niš, Fac. of Mech. Eng., Niš)

This paper analyzes the MHD flow and heat transfer in the porous channel whose walls are horizontal. The upper wall moves with constant velocity, while the lower wall is stationary and both walls have been kept on constant but different temperature. Induced magnetic field in the channel is parallel to the channel walls and its direction coincides with the direction of the moving upper wall. The general equations that describe the discussed problem (momentum, magnetic induction and energy equation) are reduced to ordinary differential equations and solutions with the appropriate boundary conditions obtained. Effects of the Hartmann number, Reynolds magnetic number, suction parameter, G parameter and porosity parameter have been presented graphically to show influences on dimensionless velocity, induced magnetic field and dimensionless temperature.

E4 and MITC4+ shell finite element performance analysis (M.M.Rafailović, *et al.* Univ. of Kragujevac, Fac. of Eng., Kragujevac)

This paper presents a correction of the 4-node MITC (Mixed Interpolation of Tensorial Components) quadrilateral shell finite element, i.e. MITC4 element. Correction refers to the improvement of membrane behavior, where the components of membrane strain in mid-surface of the shell are assumed using the concept of MITC method. The purpose is to reduce a membrane locking that happens when the MITC4 shell elements are geometrically distorted in curved geometries, while the element retains good membrane behavior. Numerical results obtained with E4 shell finite element, which is implemented in PAK software package, are presented and compared with those obtained with MITC4+ element. This numerical example shows the main problems of E4 element in case of very thin shells and curved geometries, which should be significantly reduced by using the above mentioned modified element.

Comparative buckling analysis and determination of the effective length factors using two numerical procedures (S.Ćorić, Univ. of Belgrade, Fac. of Civil Eng., Belgrade)

This paper deals with stability analysis of the frame structures with accuracy assessment of different solutions for the effective length calculation. Numerical analysis was firstly performed by FEM, using the computer program ALIN. Stiffness matrices were derived using the trigonometric shape functions related to the exact solution of differential equation of bending of beam according to the second order theory. Algorithm is based on the calculation of the global stability analysis of the frame structures. Some kind of iterative buckling analysis is also analyzed, that uses a modified geometric stiffness matrix.The numerical example multi-story plane frame with two different configurations of loadings is analyzed. It was shown that there is a fundamental difference between the two analyzed approaches in the case when the loads are applied to each column at each story in the frame. That difference in the determination of the effective length factor is related to the behavior of the upper (less loaded) columns.

Elastoplastic analysis of frame structures subjected to cyclic loading (Z.Perović, D.Šumarac, Univ. of Belgrade, Fac. of Civil Eng., Belgrade)

In this paper, the authors analyzed three dimensional frame structures, subjected to cyclic loading in plastic domain. Model of the material, based on the Preisach model of hysteresis is used. The aim of this paper is to determine an influence of various parameters of both cross section and beam element formulation on the results of elastoplastic analysis. Results obtained with the Euler-Bernoulli assumption for beam bending are compared with the results obtained with the Timoshenko beam theory. Although the method of concentrated plasticity is used, an increased number of 2-node frame element can approximate effects of distributed plasticity method. Since the formulation of the section forces is based on the division of cross section on fiber elements, a number of integration points was also varied in order to determine a convergent solution. Some aspects of convergence and numerical performance of analysis are presented as well.

Eigen sensitivity and structural optimization with an accent on the repeated frequencies (N.Trišović, et al., Univ. of Belgrade Fac. of Mech. Eng., Belgrade)

Sensitivity analysis is the study of changes in system response with respect to design parameters. It is being used in a variety of engineering disciplines ranging from the automatic control theory to the analysis of large-scale physiological systems. Some of the areas where sensitivity analysis has been applied include: development of insensitive control systems, use in gradient-based mathematical programming methods and approximation of the system response to a change in the system parameter, an assessment of design changes on the system performance. The application of sensitivity analysis is limited to construction of segments for which necessary mathematical relations can be determined. If this is not possible, sensitivity analysis is only partially applicable. The Eigen value sensitivity analysis is useful when resonant frequencies need to be restricted. Different methods for analyzing structural eigen sensitivity are considered. An example is given to illustrate an optimization problem for a system with repeated frequencies.

Control and Robotics

Effect of piezoelectric fiber-reinforced composite (PFRC actuator orientation on controllability of antisymmetric composite plates for active vibration control (N.D.Zorić, et al., Univ. of Belgrade, Fac. of Mech. Eng. Belgrade)

In order to increase the performance of an active vibration control, piezoelectric fibers are stacked into a single layer composite, making (PFRC) actuator and sensor. These actuators and sensors are used for an active vibration control of thin-walled structures, placing them at the surface of the structure. Since that, control performances depend on sizes, positions and orientations of the PFRC actuators and sensors. The aim of this paper is to investigate the effect of the PFRC actuator orientation and position (top or bottom) on controllability of cross-ply and angle-ply antisymmetric composite plates for an active vibration control. Depending on the layers' orientation, composite laminates possess coupling behavior and since antisymmetric laminates possess bending-stretching coupling behavior, the effect of this behavior on controllability will be also discussed.

On approximate analytical solutions of equations of motion: Toda oscillators and an optimal orbital transfer (J.Kovačević, et al., Univ. of Novi Sad Fac. of Tech. Sci., Novi Sad)

Four nonlinear problems were solved by the use of a method comprising the Laplace transform and method of successive approximations. The Cauchy problems describing motions of a simple pendulum, the Toda oscillators without and with damping, as well as the nonlinear two-point boundary problem describing the optimal orbital transfer were tackled.

Velocity control of a mechanical system using the second-order decomposition principle (M.Živanović, EdePro, Belgrade)

In this research paper stabilization of the nominal velocity of a mechanical system is obtained by corresponding modification of the differential equation of switching surface in the second-order-decomposition-principle control of the nominal motion of a mechanical system. Particular form of the switching surface can provide stabilization of the nominal velocity in the second-order sliding mode. Comparison of velocity controllers has been made and the second-order-decomposition-principle nominal velocity stabilization is illustrated by the corresponding simulation of motion of a 3DOF manipulator.

Dynamic modelling and control design of seven degrees of freedom robotic arm (P.Mandić, et al., Univ. of Belgrade, Fac. of Mech. Eng., Belgrade)

In this paper kinematic and dynamic model or robot manipulator with 7 degrees of freedom is given. Lagrange's equations of the second kind in the covariant form are obtained by applying the Rodriguez method, instead of regular Newton-Euler or Lagrange method. By implementing inverse dynamics control, a linear and decoupled system is obtained, after which a classical *PID* controller is introduced. In order to verify mathematical model is well derived, along with its control system design, numerical simulation of a given robot is presented, wherein trajectory tracking problem is investigated.

Control system design of spatial disorientation trainer (Jelena Vidaković, et al. Lola Ins., Belgrade)

The spatial disorientation trainer (SDT) is a dynamic flight simulator used to enhance the ability of pilots of modern combat aircraft to deal with dangerous effects of spatial disorientation and it can be modeled as 4DOF robot manipulator. In this paper, control system design of SDT based on a dynamic model is presented. Two control strategies are compared: 1) computed torque method with feedforward compensation of nonlinearities and cross-coupling effects in the dynamic model; 2) single joint (decentralized) PD position controller. PD controller is designed for the actuator model which includes inertia reflected on rotor shafts (effective inertia) where position feedback design considers structural natural frequencies of the manipulator. Effective inertias of SDT for commanded motions are obtained from the robot inverse dynamic model which is developed using recursive Newton-Euler equations. Simulation of position tracking for commanded motion is performed in Matlab Simulink.

Multiobjective optimization for dynamic balancing of four-bar mechanism (Marina Bošković, et al., Univ. of Kragujevac, Fac. of Mech. and Civil Eng., Kraljevo,)

This paper presents an optimization technique for dynamic balancing of four-bar mechanism (FBM) in order to minimize shaking force and shaking moment. The balancing problem is solved as a multi-objective optimization problem and thus avoids the use of weighting factors. Kinematic and dynamic parameters of FBM are taken as design variables. The eight objective functions, that contain joint reaction forces, input torque, shaking force and shaking moment, are simultaneously minimized. A new algorithm, named sub-population firefly algorithm is used for solving the optimization problem under the defined constraints. The standard FA algorithm was improved in two ways. The first improvement is related to avoidance of local minimum, and the second improvement provides satisfaction of constraints in each iteration step. By applying the proposed algorithm, a certain decrease at the shaking force and shaking moment is achieved and the effectiveness of the improved algorithm is discussed.

Analysis and optimization of underactuated finger for cmsyslab robotic hand (M.D.Lukić, et al., Univ. of Belgrade, Fac. of Mech. Eng., Belgrade)

In this paper the mathematical analysis of 3-DOF underactuated robotic finger with linkage driven mechanism is presented. The optimization procedure is described for obtaining optimal parameters of four bar mechanism. As a result, the adaptability of the finger is improved and the grasping forces maximized within the working area limits.

Calculation of the acceleration force components and roll and pitch link angles of the CFS and SDT (V.Kvrgić, et al., Lola Ins., Belgrade)

A centrifuge flight simulator (CFS) for pilot training is designed as a three-degree-of-freedom 3DOF manipulator with rotational axes. In this paper, through rotations about these axes, acceleration forces that act on aircraft pilots are simulated. The spatial disorientation trainer (SDT) examines a pilot's ability to recognize unusual orientations, to adapt to unusual positions and to persuade the pilot to believe in the aircraft instruments for orientation and not in his own senses. The SDT is designed as a (4DOF) manipulator with rotational axes. Through rotations about these axes, different orientations can be achieved; different acceleration forces acting on the pilot can also be simulated. In this paper, the acceleration forces and angular velocities that act on the simulator pilot in the CMS and SDT are calculated along with the roll and pitch angles of the gondola for these forces.

Reciprocally convex approach to finite-time stability of systems with time-varying delays (S.Stojanović, et al., Univ. of Niš, Fac.of Tech., Leskovac)

In this paper, the problem of finite-time stability for a class of linear systems with time-varying delay is studied. By using Lyapunov-Krasovskii-like functional with an exponential function and applying a reciprocally convex approach, a finite-time stability criterion is proposed in terms of linear matrix inequalities. The advantage of the proposed method is verified by a numerical example.

Delay decomposition approach to delay dependent stability for linear discrete-time systems with time-varying delay (S.Stojanović, et al., Univ. of Niš, Fac.of Tech., Leskovac)

In the second paper the authors studied delay-dependent stability of linear discrete-time systems with time-varying delay. By decomposing the delay interval into two no equidistant subintervals by tuning parameter α, choosing different Lyapunov matrices in the decomposed intervals and estimating the upper bound of some cross terms more exactly, some new delay-dependent stability criteria are established in terms of linear matrix inequality. The numerical examples show that the obtained results are less conservative than some existing ones in the literature.

Interdisciplinary Areas

Thermal and magnetic effects on the forced vibration of an elastically connected nonlocal orthotropic double-nanoplate system (M.Stamenković Atanasov, et al, Math. Ins. SASA, Belgrade)

The paper investigates the problem of the nonlocal forced transversal vibration of an orthotropic double nanoplate system under thermal and magnetic effects. Both nanoplates are rectangular, simply supported and coupled by a Winkler elastic medium and authors use the Eringen's nonlocal continuum theory. Based on the nonlocal constitutive relation and Kirchhoff-Love plate theory, the system of two coupled non-homogeneous partial differential equations of motion is derived, where the effects of the Lorentz magnetic force are obtained via a Maxwell relation. Analytical methods are employed to consider the dynamic responses of the orthotropic double nanoplate system for uniformly distributed harmonic surface load. Also, closed-form solutions of the response amplitudes for forced vibration are derived. The nonlocal parameter, thermal parameter, magnetic fields and exciting load are discussed in detail.

Flow and heat transfer of two immiscible micropolar fluids in the presence of uniform magnetic field (M.M. Kocić, et al., Univ. of Niš, Fac. of Mech.Eng., Niš)

In this paper, the steady flow and heat transfer of two incompressible electrically conducting micropolar fluids through a parallel plate channel are investigated. The upper and lower plates have been kept at the two constant different temperatures and the plates are electrically insulated. Applied magnetic field is perpendicular to the flow, while the Reynolds magnetic number is significantly lower than one. The general equations under the adopted assumptions are reduced to ordinary differential equations and three closed-form solutions are obtained. The velocity, micro-rotation and temperature fields in the function of Hartmann number, Reynolds number, the coupling parameter and the spin-gradient viscosity parameter are graphically shown and discussed.

Computational 2d analyses of several jet vane types aimed for the rocket engine thrust vector control (I.A.Kostić, et al., Univ. of Belgrade, Fac of Mech. Eng., Belgrade)

This paper is confined to the computational 2D analyses of two types of TVC devices, positioned at the domain of exit section of the supersonic nozzle, all with nominal Mach number 2.6 at the nozzle exit. Six jet tab configurations for which experimental data from supersonic wind tunnel were available, have been used for the development and validation of the meshing and the computational model. The model has proven to be reliable and stable in the sense of convergence, and able to give good agreements with the experimental data both in the sense of qualitative and quantitative comparisons. The same control volume setup has then been applied for the analyses of four selected jet vane configurations, initially with a constant chord length, for which no experimental data were available. All computations have reached a stable convergence, and provided very useful information about their aerodynamic efficiency. For the most efficient jet vane type, additional computations involving variations in the chord length and investigations of the appropriate hinge moments, have proven the capability of the established CFD model to provide very important guidelines in the initial stages of the TVC design and development.

Analytical modeling of ballistic perforation in plug formation mode (P.Elek, et al., Univ. of Belgrade, Fac. of Mech. Eng., Belgrade)

The paper considers ballistic perforation of ductile metal plates by rigid projectiles in plug formation regime. Analytical modeling of the penetration process is based on the application of momentum and energy conservation laws for the penetrator/plug system. After outlining of the well-known Recht-Ipson (RI) model, the new analytical model has been formulated taking into account the two most important resistance forces- the plug compression and shear, so one can obtain the ballistic curve. The important parameters in the relation are the ballistic limit velocity and the relative mass of the plug where for low values of the relative plug mass, the ballistic curves of the proposed model and the RI model are very close to each other, but for higher values of this parameter the results of two models significantly deviates. Comparison with the available experimental data indicates a good agreement between measured velocities and model predictions.

As a summary of a three-day work, the Congress chair, prof M. Lazarević was pleased to conclude that the 6th Congress of SSM fulfilled the expectations of the organizers. He expressed his gratitude to all the authors and participants from abroad, as well as from Serbia, for their contribution and efforts which made this Congress possible and successful, and invited all the participants to the next Congress of SSM (7th) that will be organized in 2019.

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6. Međunarodni kongres Srpskog društva za mehaniku: prikaz

Ovaj rad prikazuje najvažnije informacije o 6. kongresu Srpskog društva za mehaniku, koji je održan na Tari od 19. do 21. juna 2017. Kongres je organizovan od strane Srpskog društva za mehaniku. Dat je kratak prikaz najznačajnijih radova predstavljenih na ovom kongresu, a koji se bave teorijskom i primenjenom mehanikom.

Ključne reči: **mehanika, teorijska mehanika, primenjena mehanika, mehanika fluida, kinematika, dinamika, robotika, biomehanika, međunarodni naučni skup, Srbija.**

Международный конгресс сербского общества по механике: обзор

В этом документе представлена самая важная информация о 6-м Конгрессе Сербского общества механики, который проходил на горе Тара с 19 по 21 июня 2017 года. Конгресс был организован Сербским обществом механики. Здесь даётся краткий обзор наиболее важных работ, представленных на этом Конгрессе, посвящённых теоретической и прикладной механике.

Ключевые слова: **механика, теоретическая механика, прикладная механика, механика жидкости, кинематика, динамика, робототехника, биомеханика, международная научная встреча, Сербия.**

Le sixième congrès international de la Société serbe pour la mécanique: compte-rendu

Cet article présente les plus importantes informations sur le sixième congrès de la Société serbe pour la mécanique qui a eu lieu à Tara du 19 au 21 juin 2017. Le congrès a été organisé par la Société serbe pour la mécanique. On a donné un bref compte-rendu concernant les travaux les plus signifiants présentés au cours de ce congrès qui s’occupent de la mécanique théorique et de la mécanique appliquée.

Mots clés: **mécanique, mathématique théorique, mathématique appliquée, mécanique des fluides, cinématique, dynamique, robotique, mécanique bio, réunion scientifique internationale, Serbie.**