

PREFACE

We hereby present to you a special issue of the thematic proceedings under the title *Dynamics of hybrid systems of complex structures* which consists of twelve chapters with a number of scientific results of numerous researchers from the ON164001 Project team.

I. The basic data of the Project ON174001 *“Dynamics of hybrid systems with complex structures; Mechanics of materials”*

The period from January 1, 2011 to December 30, 2019, was the project cycle period – the longest project cycle period in the last half of the century. The Ministry of Education, Science and Technological Development of the Republic of Serbia financed, among others, the Project ON174001 “Dynamics of hybrid systems of complex structures; Mechanics of Material”. This project was headed by Katica (Stevanović) Hedrih, and the project activities and the realization of the research program were coordinated at the Mathematical Institute of the Serbian Academy of Sciences and Arts.

A total of 46 researchers were accepted into the project team in the first year; 27 researchers were hired, out of which 7 members were junior researchers - magisters of science and doctoral students from Serbia, as well as 19 foreign scientists (for whom the Ministry agreed to be involved in the research team, but did not fund salaries and DMT). Initially, among the researchers of the team from Serbia, there were 20 doctors of science and the largest number in the highest university and scientific titles.

There were 13 university and scientific institutions from Serbia that appeared as the institutional participants and implementers of the ON174001 Project. Both were signatories to the annual contracts and reports on the successful implementation of the research program on the ON174001 Project (a list of these project members and implementers is given in a separate appendix).

During the project cycle, 10 additional junior doctoral researchers were accepted and hired for a project team. A number of researchers were due to retire during the process, but they remained members of the research team and contributed to the success of the project.

The total number of researcher months per year averaged 217 researcher months.

During the project cycle, another 13 junior researchers received and defended their doctorates.

In December 2019, the project cycle of 7 junior researchers – doctoral students, who were subsequently included in the project team in the final years, was completed. They passed all the exams in their doctoral studies and were in the phase of applying for doctoral dissertations.

The project was successfully realized in the last project cycle lasting 9 years, which was initially planned for 5 years and additional 4 years were obtained. The success of the project was based on a well-designed research program, based on the continuation of research from 5 to 9 years.

II. The Project ON174001 “*Dynamics of hybrid systems with complex structures; Mechanics of materials*” produced original scientific results in the following research themes:

1. Elements of mathematical phenomenology and applications (in Mechanics, in nonlinear dynamics in general, in the integration of scientific knowledge in reducing the number of models of dynamical systems);
2. Analytical mechanics of discrete fractional order systems; Derived a series of theorems;
3. Nonlinear and rare phenomena in the dynamics of hybrid systems with coupled structures of rigid and deformable bodies; Transfer of energy through a system and subsystems; Synchronization of subsystems.
4. Models of biodynamical oscillators; Phenomenon of transfer of signals, information and energy through their complex structures; Oscillations of DNA helix chains and discrete continuum models of *Zona Pelucida*;
5. Mechanics of discrete continuum models; Dynamics of coupled structures of deformable bodies and discrete continuum layers with different constitutive relations: Linear elastic, nonlinear elastic, visco-elastic, hereditary and fractional order properties;
6. Phenomenon of dynamics of systems with friction and vibro-impact system; Theory of collision of rolling bodies; Dynamics of billiards;
7. Mechanics of damage and fracture;
8. Control of systems with delay and theorems of stability;
9. Continuation of doctoral research in accordance with scientifically based themes by young PhD students;
10. Thirteen PhD Students, younger than 30 years of age, were included in the project team and its scientific research; All of them were participants of the two-year seminar.

Other topics considered in the framework of the project are: nonlinear transformation, rheonomic system, nonholonomic constraints, mass moment vectors, gyro-rotor dynamics, approximation, amplitude-frequency characteristic, stability, synchronization, theory of collision, vibro-impact system, dynamics of billiards, energy analysis, non-local theory and applications, biomechanical oscillators and control motion. The project collaborators participated in the conferences ENOC 2011 and 2014, IUTAM ICTAM 2012, ESMC 2012, Mini-symposium of Nonlinear Dynamics 2012, 2014, 2015, etc. A member of the project was awarded EuroMech Young scientist prize Roma 2011.

Home page of the Project activities:

http://www.mi.sanu.ac.rs/novi_sajt/research/projects/174001a.php

III. *Main additional results of the ON164001 Project are:*

1* Provided financial and scientific support for a number of scientific courses and fundamental ideas for research by introducing junior trainee researchers to scientific work, resulting in 11 doctoral dissertations and two master's theses which

were successfully defended: ON174001 - Dynamics of hybrid systems with complex structures. Mechanics of materials. (Period 2011-2019), supported by the Ministry of Science Republic of Serbia;

Researchers from the Project team ON174001 defended PhD dissertations on the basis of the scientific research results of the Project ON174001:

dr Ljiljana Veljović (2011)
dr Julijana Simonović (2012)
dr Srdjan Jović (2011)
dr Andjelka Hedrih (2016)
dr Danilo Karličić (2016)
dr Ljubinko Kevac (2017)
dr Radoslav Radulović (2017)
dr Milan Cajić (2017)
dr Marija Mikić (2018)
dr Goran Simeunović (2011)

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2* Uniting researchers from the Republic of Serbia and 13 university and scientific centers in a single team doing research on 10 topics in the field of mechanics and applications;

3* Publishing a large number of papers in journals both in domestic and international journals visible on KoBSON, SCOPUS and other professional databases;

4* Participation of junior researchers in prestigious European and world congresses of mechanics, nonlinear dynamics, solid state mechanics and Serbian congresses of mechanics; in the scope of these activities, they made significant contacts with researchers from other countries; some of the researchers participated in postdoctoral training in Great Britain and Poland.

5* Organization of two international symposia on nonlinear dynamics;

6 * Organization of nine one-day mini-symposia on project research topics; A large number of lectures were held at scientific seminars in MI SASA; Organization of a series of Mini-symposia within the Serbian Congresses of Mechanics; in the scope of the last Serbian Congress of Mechanics, the researchers from the project were the organizers of the three mini-symposia that constituted almost 50% of the total number of congress presentations.

7* Three postdoctoral trainings were achieved, and another postdoctoral training was obtained with a scholarship from Marie Skłodowska Curie.

8* The project ON174001 "Dynamics of hybrid systems of complex structures: Mechanics of materials" employed 13 researchers. There are 8 members who are still working at MI SASA, 2 members are employed at the Faculty of Mechanical Engineering in Niš and the Faculty of Technical Sciences in Kosovska Mitrovica, one member was employed at the Innovation center of the Faculty of Electrotechnical Engineering in Belgrade. One of them is in the Innovation Center of the Faculty of

the Faculty of Mechanical Engineering in Belgrade. The following project researchers were employed in MI SASA:

dr Katarina Maksimović (part)

dr Milan Cajić

Đorđe Jovanović

dr Danilo Karličić

dr Ivana Atanasovska

dr Anđelka Hedrih

Stepa Paunović

dr Slobodanka Boljanović

Branislav Milenković

Marija Stamenković (now at the Faculty of Mechanical Engineering, University of Niš)

Nikola Neš (now at the Faculty of Technical Sciences in Kosovska Mitrovica, University of Priština)

Aleksandar Atanasov (now in Corridors of Serbia)

dr Ljubinko Kevac was employed at the Innovation Centre of Electrotechnical Faculty at the University of Belgrade on the basis of Project In 174001.

dr Goran Simeunović was employed at the Innovation Centre of Mechanical Faculty at the University of Belgrade on the basis of Project In 174001.

9* Procurement of computer equipment for project researchers;

10 * Acquisition of ANSYS computer software for the needs of researchers;

11* As a project activity, there was a newly established seminar: Mechanics of machines and mechanisms-models and mathematical methods, which continues in MI SASA;

12* A number of researchers achieved qualitative and quantitative scientific results needed for their advancement in scientific and university titles, starting from full-time researchers to full professors, i.e., from research associates to scientific advisors;

13* Researchers from the ON174001 project formed at least two proposals for new projects that are to be coordinated by MI SASA if approved, gathering researchers from other university and scientific institutions;

14* A special issue of Elsevier's International Journal on Nonlinear Mechanics was published, with the project leader as an invited leading guest editor and dedicated to the Elements of Mathematical Phenomenology and Phenomenological Mapping of Mihailo Petrović, the founder of the Serbian school of mathematics. Half of the papers from that issue are the papers written by the researchers from the ON174001 Project and the rest of contributors are various authors from abroad.

The project leader participated as one of ten co-authors in the preparation and publication of a special issue of Rudarski glasnik, with the integral content dedicated to the 175th anniversary of the birth of academician Ljubomir Klerić, founder of the Serbian School of Mechanics and Mechanical Engineering.

15* A special issue of the Scientific Review of the Scientific Society of Serbia was published.

16* A special issue of the TAM magazine dedicated to Anton Bilimović and one issue with selected works from the International Symposium Nonlinear Dynamics were published.

17* A number of national monographs were published. Among the researchers, Professor Dragutin Debeljković stands out; with his associates, he published a large number of monographs with applied elements in the scientific field in which he conducted research.

18* The project manager held two-year lecture courses for junior researchers and doctoral students in preparation for research and pointed out ideas for further research.

IV. Viewing the contents of this thematic publication

In 2017, the Board for Non-Periodic Publications of the Mathematical Institute of the Serbian Academy of Sciences and Arts (SASA) with the President, Academician Vladan Djordjević, sent me, as the Project Leader of Project ON174001 "Dynamics of hybrid systems of complex structures; Mechanics of Materials" (2011-2019), an invite to present the scientific results of the research achieved on this project; I was asked to be a guest editor of a special issue from the category of non-periodical publications of SASA.

An invitation was sent to all researchers from Serbia from the project team for the submission of review papers with presentations of their own verified scientific results or a group of researchers with whom they cooperated. Twelve researchers responded and sent eight manuscripts-review papers, which were rated positively by the reviewers.

Additionally, four invitations were sent to scientists in the field of nonlinear dynamics, from abroad, from Italy, Brazil, Ukraine, England (now from India), who also participated in the international scientific activities of the ON174001 Project. They responded and sent four manuscripts-review papers. All four manuscripts were rated positively by the reviewers; out of these manuscripts, two are one-author papers, one is a two-author paper and one is a multi-author paper.

All 12 manuscripts-review papers were included in 12 chapters of this special thematic issue called *DYNAMICS OF HYBRID SYSTEMS OF COMPLEX STRUCTURES* of non-periodic thematic publications MI SASA.

The contents of these review papers through 12 chapters presented the main, although not all scientific results of the ON174001 Project, but together with the information from the appendix, they provided the information on significant scientific results which were realized and published, as well as the international scientific activity of the ON174001 project.

The first chapter is a review of the work of Giuseppe Rega, a prominent scientist in the field of Nonlinear Dynamics, under the title: *Nonlinear Dynamics in Mechanics: A Journey through Personal Research Results*. He pointed out in the introduction to his manuscript his long-term collaboration with the scientists and junior researchers from Serbia, in Niš, Novi Sad and Belgrade. The reviewer wrote for this paper: "Of

course, I recommend this excellent review paper". The reviewer rated the manuscript with excellent marks in all parameters.

In Chapter 2, under the title: *Multi-Parametric Analysis of Complex Hybrid Systems Dynamics under External Excitation*, Julijana Simonović, presents the scientific results in the field of nonlinear dynamics, verified through a series of single and two-author published papers.

Chapter 3 presents the scientific results and contributions of the theory of body collisions in rolling, through a review by Katica R. (Stevanović) Hedrih, under the title: *The Latest Theory of Body Collisions in Rolling and the Dynamics of Vibro-Impact Systems through Scientific Projects over Three Decades*. In the introductory part of this review, the results of a group of researchers in the field of application of a research methodology for investigating nonlinear dynamics of vibro-impact systems, through three project cycles, on three projects which she managed, are given. The main part of this review paper presents the latest authentic results of the author in the field of collision dynamics and the methodology of studying the nonlinear dynamics of vibro-impact systems with rolling bodies in successive collisions.

The fourth chapter contains a review paper of the prominent, on an international scale, scientific group of authors from Brazil, with José Manoel Balthazar as the first and leading author. The groups of the following authors: José Manoel Balthazar, Angelo Marcelo Tasset, Rodrigo Tumolin Rocha, Jorge Luis Palacios Felix, Marcus Varanis, Clivaldo de Oliveira, Mauricio Aparecido Ribeiro, Atila Madureira Bueno and Rafael Henrique Avanço submitted an invited review paper under the title: *A Short Review on a Hybrid Vibrating Systems with Limited Power Supply (RNIS)*.

The fifth and the sixth chapter contain two review papers in the field of fracture and damage mechanics, written by the three leading researchers in this field from Serbia. In the fifth chapter, there is a review paper by Slobodanka Boljanović, under the title: *Failure Performance Modeling of Cyclically Loaded Plates with Edge Stress Raisers*, in which she presented her original scientific contributions from these fields, based on her published articles. Katarina Maksimović and Stevan Maksimović in their review paper under the title: *Structural Analysis and Optimization of Layered Composite Structures: Numerical and Experimental Investigations*, presented co-authored results, which they verified with a series of published papers.

Chapter 7 reviews the work of Lidia V. Kurpa and Tatyana V. Shmatko, under the title: *Application of the R-functions Method for Vibration and Buckling Analysis of Functionally Graded Plates and Shallow Shells with Complex Planform. Literature Review from 2014 to 2020*. To describe the content of this paper, here are a few sentences from the review: "This paper is a comprehensive review study of the previous original authors results in the field of application of the R-functions method in vibration and buckling problems of functionally graded plates and shallow shells with complex geometry. The authors gave a clear introduction into the R-functions method and provided several examples of its application in linear and nonlinear vibration/buckling problems of functionally graded plates and shallow shells. The corresponding literature is cited. The validation study is presented to demonstrate the accuracy and reliability of the results obtained by the R-functions method with the results from other methods found in the literature. Moreover, the authors have

portrayed their findings with a number of numerical examples and results. Finally, the results reveal all the advantages of the R-functions method in construction of admissible functions for energy functional and presentation of the solution in an analytical form, which is especially important for the solution of nonlinear problems. Therefore, the reviewer recommends this paper for publication in its present form."

Chapter 8 contains a review paper under the title: *Dynamics of a Spinning Shaft with Non-Constant Rotating Speed that Lead to Theorems in Mechanics*, by Fotios Georgiades. Recent developments in nonlinear dynamic analysis of mechanical systems are discussed. The nonlinear dynamic analysis of a spinning shaft with non-constant rotating speed, as a specific type of hybrid system, in various ways is done.

The review paper by Ljubinko B. Kevac and Mirjana M. Filipović *Development of Cable-Suspended Parallel Robot, CPR System, and its Sub-Systems* is also in Chapter 9, and belongs to the field of nonlinear robot dynamics. It is based on the published series of papers of these two authors in prestigious international journals.

Chapter 10 contains a review paper by prominent authors Sreten B. Stojanović, Miloš M. Stevanović and Dragutin Lj. Debeljković. This review paper is: *Robust Finite-Time Stability of Continuous and Discrete-Time Systems with Interval Time-varying Delay and Nonlinear Perturbations*. The results presented in this review are in the field of System Control and Stability.

Marija Stamenković Atanasov, a junior researcher and doctoral student from the ON174001 Project, submitted a paper under the title: *Brief Review of the Published Papers During the Participation in the Project "Dynamics of Hybrid Systems with Complex Structures. Mechanics of Materials" - OI 174001*. This paper presents Chapter 11 of this special issue of the thematic non-periodical publication MI SASA.

The final chapter, the 12th chapter in this publication, is on the topic of Biomechanics, and represents a separate topic from the research program on the ON174001 Project program. Within the framework of this chapter is a review paper by the author Andjelka N. Hedrih, under the title: *Biological Oscillators*. This review paper presents a monograph paper on biological oscillators and is based on the results of the author from the doctoral dissertation and a series of published papers in journals and at international conferences on different models and types of biological oscillators.

Guest Editor Katica R. (Stevanović) Hedrih