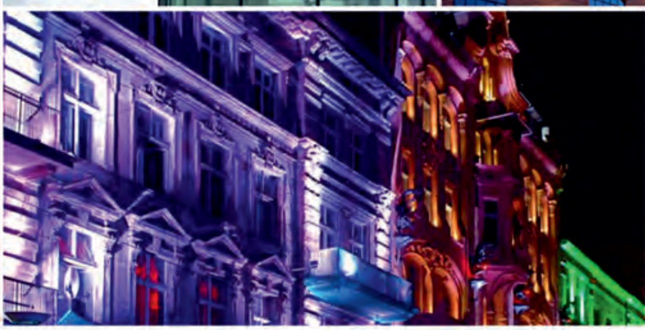
15th INTERNATIONAL CONFERENCE

DYNAMICAL SYSTEMS THEORY AND APPLICATIONS

ŁÓDŹ, DECEMBER 2-5, 2019

ABSTRACTS



EDITORS
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M. KAŹMIERCZAK
J. MROZOWSKI
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DSTA 2019

15th Conference
on
DYNAMICAL SYSTEMS
Theory and Applications
DSTA 2019

ABSTRACTS

EDITORS
J. Awrejcewicz, M. Kaźmierczak, J. Mrozowski, P. Olejnik
Łódź, December 2-5, 2019
POLAND

ORGANIZING COMMITTEE

Lodz University of Technology, Faculty of Mechanical Engineering
Department of Automation, Biomechanics and Mechatronics
1/15 Stefanowski Str., 90-924 Łódź, Poland
Phone: +48 42 631-22-25, Fax: +48 42 631-24-89
http://abm.p.lodz.pl

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Wydawnictwo Politechniki Łódzkiej
ul. Wólczańska 223, 90-924 Łódź
tel. 42 631 20 87, fax. 42 631 25 38
e-mail: wydawnictwo@lib.p.lodz.pl

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tel./fax (042) 633 02 52
marta@arsa.net.pl
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SCIENTIFIC COMMITTEE

PREFACE

This is the fifteen time when the conference “Dynamical Systems – Theory and Applications” gathers a numerous group of outstanding scientists and engineers, who deal with widely understood problems of theoretical and applied dynamics.

Organization of the conference would not have been possible without a great effort of the staff of the Department of Automation, Biomechanics and Mechatronics. The patronage over the conference has been taken by the Committee of Mechanics of the Polish Academy of Sciences and the Ministry of Science and Higher Education.

It is a great pleasure that our invitation has been accepted by so many people, including good colleagues and friends as well as a large group of researchers and scientists, who decided to participate in the conference for the first time. With proud and satisfaction we welcome nearly **255** persons from **47** countries all over the world. They decided to share the results of their research and many years experiences in the discipline of dynamical systems by submitting many very interesting papers.

This booklet contains a collection of **338** abstracts, which have gained the acceptance of referees and have been qualified for publication in the conference edited books. Included abstracts belong to the following topics:

- asymptotic methods in nonlinear dynamics,
- bifurcation and chaos in dynamical systems,
- optimization problems in applied sciences
- control in dynamical systems,
- dynamics in life sciences and bioengineering,
- engineering systems and differential equations,
- non-smooth systems
- mathematical approaches to dynamical systems
- original numerical methods of vibration analysis,
- stability of dynamical systems,
- vibrations of lumped and continuous systems,
- experimental/industrial studies,
- mechatronics.

Our previous experience shows that an extensive thematic scope comprising dynamical systems stimulates a wide exchange of opinions among researchers dealing with different branches of dynamics. We think that vivid discussions will influence positively the creativity and will result in effective solutions of many problems of dynamical systems in mechanics and physics, both in terms of theory and applications.

Every two years we extend scope and recognition of the conference. This time, we have opened **12** special sessions gathering **149** presentations.

We do hope that DSTA 2019 will contribute to the same extent as all the previous conferences to establishing new and tightening the already existing relations and scientific and technological co-operation between both Polish and foreign institutions.

On behalf of both Scientific and Organizing Committees

Chairman

Professor Jan Awrejcewicz

LIST OF ABSTRACTS

SPECIAL SESSION 2

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SPECIAL SESSION 8

KEYNOTE LECTURES

paper id: VIB217 (keynote speech)

Continuum & statistical aspects of gradient theory

Elias C. Aifantis

Abstract: Gradient theory for elasticity, plasticity and diffusion processes has been advanced by the author and co-workers over the last two decades. The key ingredient was the enhancement of classical theories with internal lengths and internal times. This enhancement enabled the capturing of shear band width and thickness, as well as the interpretation of deterministic size effects. However, intermittent plasticity and stochastic effects cannot be modeled. This is done by further enhancement of gradient theory with statistical aspects. An effective way to achieve this is by resorting to Tsallis q-statistics and non-extensive entropy thermodynamics. Typical examples from micropillar experiments are considered. Acknowledgements: The support of Hellenic Foundation for Research and Innovation (HFRI) MIS 5005134: "Nano-chemomechanics in Deformation and Fracture: Theory and Applications in LiBs and SGS" and MIS 5045454: "Material Instabilities, Size Effects, and Morphogenesis: Nanomaterials and Brain" is acknowledged. The participation of I. Tsagrakis, I. Konstantopoulos, A. Sidiropoulos, G. Petsos, O. Kapetanou and A. Tsolakis in these projects is also acknowledged. Reference: E.C. Aifantis, Internal length gradient (ILG) material mechanics across scales & disciplines, Adv. Appl. Mech. 49, pp. 1-110, 2016.

1) Elias C. Aifantis, Professor: Aristotle University of Thessaloniki, 54124, Greece (GR), mom@mom.gen.auth.gr.

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December 2-5, 2019. Lodz, POLAND.

paper id: OPT308 (keynote speech)

Synchronization of complex interaction networks of reaction-diffusion systems. Application in neuroscience

M. Aziz Alaoui

Abstract: Neuroscience consists of the study of the nervous system and especially the brain. The neuron is an electrically excitable cell processing and transmitting information by electrical and chemical signaling, the latter via synapses, specialized connections with other cells. A.L. Hodgkin and A. Huxley proposed the first neuron model to explain the ionic mechanisms underlying the initiation and propagation of action potentials in the squid giant axon. Here, we are interested in the asymptotic behavior of complex networks of reaction-diffusion (PDE) systems of such neuron models. We show the existence of the global attractor and the identical synchronization for the network. We determine analytically, for a given network topology, the onset of such a synchronization. We then present numerical simulations and heuristic laws giving the minimum coupling strength necessary to obtain the synchronization, with respect to the number of nodes and the network topology.

[1] M. Aziz Alaoui, Professor: University of Le Havre Normandie, 25 rue Philippe Lebon BP 1123 76063 Le Havre, France (FR), aziz.alaoui@univ-lehavre.fr.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: ASY225 (keynote speech)

New trends for the motion of a rigid body and dynamical systems

Tarek Amer

Abstract: New advancements in terrestrial and cosmic technology require consideration of non-classical problems in dynamics. One of the important problems is the rotational motion of a rigid body about one of its fixed point whether is symmetric, about one of its principal axes, or asymmetric. In the present work, we consider the motion of a gyrostat under the influence of a gyrostatic moment vector and perturbing moments. It is assumed that, the center of mass is displaced slightly from the dynamic symmetry axis. The governing equations of motion are solved using one of the perturbation methods. The attained solutions are represented graphically to reveal the well effect of the applied moments and its impact on the stability of the body. The reinforce of the importance of this work is focused on the many applications in different fields such as aviation, submarines and so on.

[1)] Tarek Amer, Professor: Faculty of Science, Tanta University, Mathematics Department, Faculty of Science, Tanta University, Tanta 31527, Egypt (EG), tarek.saleh@science.tanta.edu.eg.

15th INTERNATIONAL CONFERENCE
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December 2-5, 2019. Lodz, POLAND.

paper id: ASY307 (keynote speech)

Data-driven nonlinear dynamics

Bala Balachandran

Abstract: With the availability of extensive data from simulations and laboratory and field experiments, data-driven dynamics is playing an important role in understanding the behavior of nonlinear systems. To illustrate this role, two examples are provided in this talk. The first example is related to extreme waves and the second example is related to chaotic dynamics. Freak waves or rogue waves are waves that can appear out of nowhere in oceans as well as other systems. These waves are characterized by extremely large wave amplitudes and extremely high-energy concentrations. As a representative case, time histories recorded for the Draupner wave event are considered, and based on this data and the use of the Inverse Scattering Transform, it is shown how the imminence of extreme wave formation can be picked up from the data. In the second example, time histories obtained from simulations of different prototype nonlinear systems (e.g., Lorenz'63 and Lorenz'96 systems) are considered and how this data can be used with a neural machine to forecast chaotic dynamics. Some thoughts on future directions will be presented to close the talk.

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1) Bala Balachandran, Ph.D.: Department of Mechanical Engineering, University of Maryland, College Park, MD 20742-3035, United States (US), balab@umd.edu.

15th INTERNATIONAL CONFERENCE
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December 2-5, 2019. Lodz, POLAND.

paper id: OPT286 (keynote speech)

Optimum first failure load design of one/two-core sandwich plates under blast loads, and their ultimate loads

Romesh C. Batra

Abstract: For sandwich plates with facesheets made of unidirectional fiber-reinforced composite having either glass, or carbon or aramid fibers and balsa wood core loaded by a blast pressure, we find optimal geometries and materials for maximizing the first failure load. We assume that the areal density is fixed and use the Nest-Site Selection optimization algorithm, a third-order shear and normal deformable plate theory, a one-step stress recovery scheme, and the Tsai-Wu failure criterion. We also delineate the effect on the first failure load of inertia forces and uncertainties in values of various parameters, and find the ultimate load by progressively degrading elasticities of failed elements. We find that the optimal single-core sandwich designs are symmetric about the mid-surface with thick facesheets and the optimal two-core sandwich designs have a thin middle facesheet, and thick top and bottom facesheets. The first failure load of the optimal clamped single-core (two-core) design is approximately 20% (30%) more than that of the corresponding simply-supported plate. We find that the first failure occurs in a facesheet (core) due to the in-plane transverse axial stress (transverse shear stress) exceeding its critical value. The collapse load of a clamped (simply-supported) sandwich structure is approximately 15%-30% (0%-17%) higher than the first failure load.

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[1] Romesh C. Batra, Professor: Virginia Polytechnic Institute and State University, Department of Biomedical Engineering and Mechanics, M/C 0219, Blacksburg, VA 24061, United States (US), rbatra@vt.edu.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: BIF285 (keynote speech)

Analytical periodic motions to chaos in nonlinear dynamical systems

Albert Luo

Abstract: Analytical solutions of period-m flows and chaos in nonlinear dynamical systems are presented through the generalized harmonic balance method. The mechanism for a period-m flows jumping to another period-n motion in numerical computation is found. The period-doubling bifurcation via Poincare mappings of dynamical systems is one of Hopf bifurcations of periodic flows. The stable and unstable period-m motions can be obtained analytically. In addition, the stable and unstable chaos can be achieved analytically. The methodology presented in this paper is independent of small parameters. The nonlinear damping, periodically forced, Duffing oscillator was investigated as an example to demonstrate the analytical solutions of periodic motions and chaos.

[1] Albert Luo, Ph.D.: Southern Illinois Unviersity Edwardsville, Department of Mechanical and Industrial Engineering, Southern Illinois University Edwardsville, Edwardsville, IL62026, United States (US), aluo@siue.edu.

15th INTERNATIONAL CONFERENCE
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paper id: MAT250 (keynote speech)

Nonlinear normal vibration modes and associated problems

Yuri V. Mikhlin

Abstract: Nonlinear normal modes (NNMs) are periodic motions of specific type. In the normal mode a finite- DOF system vibrates like a single-DOF conservative one. The non-localized and localized NNMs, bifurcations of NNMs and global dynamics near NNMs are analyzed in different papers. The Kauderer-Rosenberg concept of NNMs is based on determination of trajectories in configuration space. In general, these trajectories are curvilinear and can be constructed by use of power series. Shaw and Pierre developed alternative concept of NNMs for nonlinear dissipative systems which is based on computation of invariant manifolds in phase space. Generalization of the NNMs concepts to forced, self-exited and parametric vibrations, and to continuous system dynamics is made. NNMs have been used to solve numerous applied problems. In particular, NNMs are applied to analyze free and forced dynamics of rotors, mechanical systems having nonlinear absorbers, elastic systems such as beams, cylindrical shells, arches, shallow shells with complex base et al. Some unexpected kinds of NNMs can be found. Thus, NNMs existing only for finite values of the system amplitude (or energy) and vanishing when the amplitude tends to zero, are determined. NNMs of forced chaotic vibrations exist in elastic systems that have lost stability under external compressive force. In dissipative systems under resonance conditions the transient nonlinear normal modes existing only for some levels of energy, are found. These modes attract other motions near values of time, corresponding to the mentioned energy levels.

[1)] Yuri V. Mikhlin, Professor: National Technical University , Dept. of Appl. Mathematics, NTU, Ukraine (UA), Yuri_Mikhlin@mail.ru.

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December 2-5, 2019. Lodz, POLAND.

paper id: BIF287 (keynote speech)

Unpredictability in physical systems: Basin entropy and Wada basins

Miguel A.F. Sanjuan

Abstract: In nonlinear dynamics, basins of attraction are defined as the set of points that, taken as initial conditions, lead the system to a specific attractor. This notion appears in a broad range of applications where multistability is present, which is a common situation in neuroscience, economy, astronomy, ecology, and other disciplines. Nonlinear systems often give rise to fractal boundaries in phase space, hindering predictability. When a single boundary separates three or more different basins of attraction, we call them Wada basins. Usually, Wada basins have been considered even more unpredictable than fractal basins. However, this particular unpredictability has not been fully unveiled until the introduction of the concept of basin entropy. The basin entropy provides a quantitative measure of how unpredictable a basin is. With the help of several paradigmatic dynamical systems, we illustrate how to identify the ingredients that hinder the prediction of the final state. The basin entropy together with two new tests of the Wada property have been applied to some physical systems such as experiments of chaotic scattering of cold atoms, models of shadows of binary black holes, and classical and relativistic chaotic scattering associated to the Hénon-Heiles Hamiltonian system in astrophysics.

[1] Miguel A.F. Sanjuan, Professor: Universidad Rey Juan Carlos, Tulipan s/n, 28933 Mostoles, Madrid, Spain (ES), miguel.sanjuan@urjc.es.

SPECIAL SESSION 1

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December 2-5, 2019. Lodz, POLAND.
paper id: NON50

Nested closed invariant curves in the 2D piecewise linear normal form

Viktor Avrutin, Zhanybai Zhusubaliyev

Abstract: In the present work we explain a possible mechanism leading to the appearance of several attracting closed invariant curves nested into each other in the piecewise-linear 2D normal form. We demonstrate that this kind of multistability may be related to the well-known period adding bifurcation structure. Recently, a similar phenomenon has been reported for a piecewise smooth map modeling the behavior of a power electronic DC-DC converter. In the reported case, two period adding structures overlap in the parameter space, causing two attracting closed invariant curves to coexist and their basins of attraction to be separated from each other by a repelling closed invariant curve. Now, we demonstrate that this type of multistability exists in a more general class of models and explain how it results from a specific deformation of a single period adding bifurcation structure. Here, the appearance of nested attracting closed invariant curves is caused by a combination of two effects: on one hand, the period adding structure is already deformed in such a way that the periodicity regions forming this structure overlap, and on the other hand, the closed invariant curves existing in some of these periodicity regions are still not destroyed. We also demonstrate that in this case the basins of attraction of the nested attracting invariant curves may be separated not only by repelling closed invariant curves, but also by chaotic saddles.

[1] Viktor Avrutin, Ph.D.: University of Stuttgart, IST, Pfaffenwaldring 9, 70569 Stuttgart, Germany (DE), avrutin.viktor@gmail.com , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Zhanybai Zhusubaliyev, Professor: Southwest State University, 50 Years of October Str. 94, 305040, Kursk,, Russia (RU), zhanybai@hotmail.com .

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: MAT291

Dynamics of sensing element of micro- and nanoelectromechanical sensors as anisotropic size-dependent plate

Marina Barulina, Alexey Golikov, Sofia Galkina

Abstract: Equations of motion of a sensing element of micro- and nanoelectromechanical sensors as an anisotropic size-dependent plate were obtained based on the modified couple-stress theory. The sensing element was considered as rectangular console plate under the distributed force at the bottom of the sensing element. The dynamic version of the principle of virtual displacements and the third-order theory of laminated composite plates and shells were used for obtaining the differential equations of motion and natural boundary conditions.

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[1] Marina Barulina, Ph.D.: Institute of Precision Mechanics and Control, Russian Academy of Sciences, 410028, Saratov, ul. Rabochaya, 24, IPTMU RAS, Russia (RU), marina@barulina.ru, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Alexey Golikov, Ph.D.: Institute of Precision Mechanics and Control, Russian Academy of Sciences, 410028, Saratov, ul. Rabochaya, 24, IPTMU RAS, Russia (RU), algolikov@yandex.ru.

[3] Sofia Galkina, M.Sc. (Ph.D. student): Institute of Precision Mechanics and Control, Russian Academy of Sciences, 410028, Saratov, ul. Rabochaya, 24, IPTMU RAS, Russia (RU), leokox@yandex.ru.

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December 2-5, 2019. Lodz, POLAND.

paper id: BIF206

Asymmetry induced complex dynamics of coupled laser systems

Anastasios Bountis, Yannis Kominis, Joniald Shena, Vassilios Kovaniis

Abstract: Coupled semiconductor lasers are systems possessing complex dynamics that are interesting for numerous applications in photonics. In this paper, we first review our results on the existence and stability of asymmetric phase locked states of a single dimer, consisting of two coupled semiconductor lasers with carrier density dynamics. We show that stable phase locked states of arbitrary asymmetry exist whose field amplitude ratio and phase difference can be dynamically controlled by appropriate current injection. Moreover, we obtain stable limit cycles with asymmetric characteristics, emerging through Hopf bifurcations from the phase locked states. Also, we emphasize the importance of Exceptional Points, and we show that asymmetry enables their existence in extended regions of the parameter space. The dynamics of the asymmetric dimers under periodic modulation of the pumping current is also investigated and the appearance of anti-resonances and sharp-resonances with very high frequencies are demonstrated. Finally, we describe our recent findings on optically coupled arrays of coupled dimers and explore their interesting and versatile nonlinear dynamics. In particular, we couple in an appropriate way a large number of dimers and show that, depending on their degree of asymmetry, they exhibit organized high amplitude oscillations, or oscillate very close to phase locked states, suggesting that such photonic networks may prove useful in a variety of beam forming and beam shaping applications.

[1] Anastasios Bountis, Professor: Department of Mathematics, Nazarbayev University, Kabanbay batyr 53, 010000 Nur-Sultan, Kazakhstan (KZ), tassosbountis@gmail.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Yannis Kominis, Associate Professor: School of Applied Mathematics and Physical Sciences, National Technical University of Athens, Greece (GR), gkomin@central.ntua.gr.

[3] Joniald Shena, Ph.D.: National University of Science and Technology MISiS, Leninsky prosp. 4, Moscow, 119049, Russia (RU), jshena@physics.uoc.gr.

[4] Vassilios Kovaniis, Ph.D.: Professor, Department of Electrical and Computer Engineering, Virginia Tech, Arlington VA, United States (US), vassilios.kovanis@gmail.com.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: ASY229

The interaction of two point vortices with sources in an unsteady 2D shear flow and the transition to chaos

Xavier Carton, Konstantin Koshel, Jean Reinaud, Charly De Marez

Abstract: Recent work has shown that a proper description of the ocean mesoscale turbulence requires oceanatmosphere coupling. In this work, we take this coupling into account by using the fully coupled wind stress curl acting on an axisymmetric vortex. We show that this generates a source/sink flow in an isolated circular vortex. To assess the consequences of this flow on vortex interaction, we first consider two such vortices, with zero spatial extent (point vortices) and associated with a source or a sink. We calculate the trajectories of this vortex pair. We add an external shear flow, typical of oceanic conditions. We calculate the fixed points and stability of this system. Then we assume that the external shear flow is time varying (with a small periodic component). Using a perturbation expansion, we calculate the nonlinear response of the vortex pair to this fluctuating flow. We analyse how this quasi-periodic response can bifurcate towards chaotic evolution when the external oscillating flow becomes more intense. We analyse the chaotic trajectories thus created.

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[1] Xavier Carton, Professor: LOPS, IUEM, UBO, LOPS IUEM UBo rue Duomnt d'Urville 29280 Plouzane, France (FR), xcarton@univ-brest.fr, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Konstantin Koshel, Professor: POI DVO RAS, POI DVO RAS, Vladivostok, Russia (RU), kvkoshel@poi.dvo.ru.

[3] Jean Reinaud, Associate Professor: Vortex Group - Mathematical Institute - University of Saint Andrews, University of Saint Andrews, Scotland, England (GB), jnr1@st-andrews.ac.uk.

[4] Charly De Marez, M.Sc. (Ph.D. student): LOPS, IUEM, UBO, LOPS, IUEM, UBO, Rue Dumont d'Urville, 29280 Plouzane, France (FR), charly.demarez@univ-brest.fr.

Kuramoto Oscillators under local unidirectional coupling: the phenomenon of bunching and anti-bunching

Lock Yue Chew

Abstract: Inspired by our recent work that relates bus bunching as a phenomenon of synchronisation of phase oscillators [Scientific Reports 9, 6887 (2019)], we construct a model of Kuramoto oscillators that follows an analogous interaction mechanism of local unidirectional coupling. We uncovered the critical transitions of the Kuramoto oscillators to the state of complete phase-locking (bunched state) or partial phase-locking (partially bunched states) from the state where the oscillators are completely unbunched. By adding various configurations of kicking force to the system as a form of control, we investigate the transformation of the stable bunched state of the Kuramoto oscillators to a state where the oscillators remain staggered (anti-bunched) with respect to each other.

[1)] Lock Yue Chew, Associate Professor: Nanyang Technological University, 21 Nanyang Link, SPMS-PAP-04-04, Singapore (SG), lockyue@ntu.edu.sg, the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

paper id: BIF252

An experimental investigation on noisy intermittency

Ezequiel Del Rio, Sergio Elaskar

Abstract: Intermittency is a route to chaos when transitions between laminar and chaotic dynamics occur. The main attribute of intermittency is the reinjection mechanism, described by the reinjection probability density (RPD), that maps trajectories of the system from the chaotic region into the laminar one. Results on chaotic intermittency depend on the RPD, that was takes as a constant [1]. Recently, a generalized no uniform RPD has been observed in a wide class of 1D maps, hence the intermittency theory has been generalized, including the classical one as a particular case [2]. Noise has a impact on the intermittency phenomena and the generalized RPD introduces a novel scenario because it is affected by the noise. An analytical approach was introduced to estimate the noisy RPD [3]. In this work, by using the Poincare map, we apply our noisy theory of 1D maps to an experimental continuous system. We found that noisy data provides a description of both, noisy and an ideal noiseless system. We found that the response to the noise of the experimental Poincare map is different than the obtained by numerical simulations. Work supported by the Spanish Ministry of Science and Innovation (ESP2013-41078-R). References. [1] Schuste, H. & Just, W., 2005: Deterministic Chaos. An Introduction (WILEY-VCH Verlag GmbH & Co. KGaA). [2] Elaskar, S. & del Rio E., 2016: New Advances on Chaotic Intermittency and Applications (Springer). [3] del Rio, E., Sanjuán, M.A.F. & Sergio Elaskar, 2012: Commun. Nonlinear Sci. Numer. Simulat. 17 3587-3596.

[1] Ezequiel Del Rio, Associate Professor: Dpto. Fisia Aplicada, ETSI Aeronáutica y del Espacio. Universidad Politécnica de Madrid, Plaza Cardenal Cisneros, 28040 Madrid, Spain (ES), ezequiel.delrio@upm.es, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Sergio Elaskar, Professor: epartamento de Aeronáutica, FCEFyN, Instituto de Estudios Avanzados en Ingeniería y Tecnología CONICET. Universidad Nacional de Córdoba, Av.Velez Sarsfield 1611. Cordoba,, Argentina (AR), sergio.elaskar@gmail.com.

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Dynamical Systems — Theory and Applications

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paper id: MAT9

Exact non-linear scan patterns of laser scanners with rotational Risley prisms: mathematical analysis, simulations, and experiments

Virgil-Florin Duma

Abstract: Rotational Risley prisms are one of the fastest two-dimensional (2D) laser scanning systems. Their drawback is the strong non-linearity of the scan patterns they produce, in contrast to the most common raster scanning generated with 2D dual axis galvanometer scanners (GSs) or with Micro-Electro-Mechanical Systems (MEMS) with oscillatory mirrors. The aim of this paper is to present the graphical method (that, to our knowledge, we have introduced) in order to determine, using commercially-available mechanical design programs, the exact scan patterns of pairs of rotational Risley prisms. These patterns are compared both with the common raster scanning and with the most recent spiral scanning — which are both slow, as they use 2D GSs or MEMS. A multi-parameter analysis is developed for this purpose — considering all the four possible configurations of Risley prisms scanners. Both the angular and the linear deviations through the prisms are deduced and their non-linear functions are studied. Various parameters of the prisms and of the assembly are considered: the prisms angles, their rotational speeds, as well as the distances between the prisms and from the system to the scanned plane. Experimental validations complete the mathematical analysis and the simulations.

[1)] Virgil-Florin Duma, Professor: Aurel Vlaicu University of Arad, Str. Elena Dragoi nr. 2, Romania (RO), dumavirgil@yahoo.co.uk , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: LIF11

Stability of discrete fractional systems under random perturbations and lifespan distribution of living species

Mark Edelman

Abstract: Various features of the development of individual living species, including individual humans, are programmed. Is death also programmed, and if yes, how is it implemented and what can be the underlying mechanism providing the inevitability of death? The hypothesis presented in this paper is based on the similarity of the human evolution to the evolution of simple discrete nonlinear fractional (with power-law memory) systems. Caputo fractional/fractional difference logistic map is a simple discrete system with power-/asymptotically power-law memory and quadratic nonlinearity. In the area of parameters where the fixed point is unstable, its evolution starts as the evolution of a system with a stable fixed point but then this fixed point becomes unstable, suddenly breaks, and turns into a period two point. Considered under various types of random perturbations, the time spans of the evolution as a fixed point before the break (lifespans) obey the Gompertz-Makeham law, which is the observed distribution of the lifespans of live species, including humans. The underlying reason for modeling the evolution of humans by fractional systems are the observed power law in human memory and the viscoelastic nature of organ tissues of living species. Models with power-law memory may explain the observed decrease at very large ages of the rate of increase of the force of mortality and they imply limited lifespans.

[1] Mark Edelman, Professor: Yeshiva University, Courant Institute, BCC CUNY, 6629 Broadway Apt. 4D, Bronx, NY 10471, United States (US), edelman@cims.nyu.edu, the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

paper id: BIF30

Impact of topology on directed network dynamics

Alexander Goltsev

Abstract: Many social, technological, and biological systems with asymmetric interactions display a variety of collective phenomena, such as opinion formation and synchronization. This has motivated much research on the dynamical impact of local and mesoscopic structure in directed networks. However, the constraints imposed by the global organization of directed networks remain largely undiscussed. Here, we control the global organization of directed Erd˝os–Rényi networks, and study its impact on the emergence of synchronization and ferromagnetic ordering, using Kuramoto and Ising dynamics. In doing so, we demonstrate that source nodes – peripheral nodes without incoming links – can disrupt or entirely suppress the emergence of collective states in directed networks. This effect is imposed by the bow-tie organization of directed networks, where a large connected core does not uniquely ensure the emergence of collective states, as it does for undirected networks

[1)] Alexander Goltsev, Professor: Department of Physics, University of Aveiro,, Department of Physics, University of Aveiro, Campus Universitario de Santiago, 3810-193 Aveiro, Portugal (PT), goltsev@ua.pt, the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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paper id: BIF126

Generation of hidden multiscroll attractors based on piecewise linear systems

Rodolfo de Jesús Escalante Gonzalez, Eric Campos Cantón

Abstract: In this work, we present an approach to generate a hidden multiscroll attractor by defining a vector field on R^3 with an even number of equilibria. The vector field is defined by affine linear systems such that each equilibrium point is a saddle point. So the space is partitioned in hyperbolic set. We start by generating a self-exited multiscroll attractor based on heteroclinic orbits. Interesting phenomena appear when the equilibria are separated by pairs, firstly, the system presents only one basin of attration which is divided accordingly with the separation of the equilibria, and the coexistece of different self-exited doble-scroll attractors arise. At a certain separation of equilibria a hidden multiscroll attractors emerges. In this process of separation of equilibria, the resulting basin of attraction presents a widening.

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[1] Rodolfo de Jesús Escalante Gonzalez, M.Sc. (Ph.D. student): Instituto Potosino de Investigación Científica y Tecnológica, Camino a la presa San Jose 2055, Mexico (MX), rodolfo.escalante@ipicyt.edu.mx.

[2] Eric Campos Cantón, Professor: Instituto Potosino de Investigación Científica y Tecnológica, Camino a la presa San Jose 2055, Mexico (MX), eric.campos@ipicyt.edu.mx, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Evolution of a wave function in a mixed phase space: chaos-assisted tunneling

David Guéry-Odelin

Abstract: In the presence of a complex classical dynamics associated with a mixed phase space, a quantum wave function can tunnel between two stable islands through a chaotic sea, an effect that has no classical counterpart. We report here new results on this topics realized on a quantum modulated pendulum involving a Bose Einstein condensate placed in a deep and strongly modulated optical lattice. In contrast with the pioneering works of M. Raizen and W. Phillips published in 2001, we investigate a mixed phase space having two classical dynamically stable islands symmetric in position space. The diffraction pattern of our BEC initially placed at different positions in phase space enables us to reconstruct the classical phase space including its bifurcations. Besides this cartography of the phase space, we observe the quantum tunneling between the two stable islands and its strong variations depending on the system parameters. The detailed analysis of the tunneling curve also reveals the two types of tunneling: regular tunneling and chaos assisted tunneling for which the intermediate states that mediates the transport towards the other islands can be identified.

[1] David Guéry-Odelin, Professor: University Paul Sabatier, 118 Route de Narbonne, 31000 Toulouse, France (FR), david.gueryodelin@gmail.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Final state sensitivity of intermingled basins

Takehiko Horita

Abstract: Final sensitivity of intermingled basins in a analytically tractable system is considered. Under a certain scaling assumption, a modified version of the external capacity dimension is introduced, which is connected with the uncertainty exponent of the basins. The dimension plays a similar role as the capacity dimension of the basin boundary in the case of basins with fractal basin boundaries. The scaling assumption is confirmed on the basis of a multifractal analysis by introducing local singularity exponent of the basins and its spectrum. It is shown that the left endpoint value of the singularity spectrum determines the uncertainty exponent of the basins.

[1)] Takehiko Horita, Professor: Osaka Prefecture University, 1-1 Gakuencho, Sakai, 599-8531, Japan (JP), horita@ms.osakafu-u.ac.jp , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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From dissipation-induced instability to the dynamics of engines

Alejandro Jenkins

Abstract: In the 1930s, Philippe Le Corbeiller proposed connecting the mathematical theory of Lyapunov stability with the thermodynamics of engines (understood as devices capable of generating and maintaining a cyclic motion at the expense of an external disequilibrium without any corresponding periodicity). Unfortunately, this had little impact in the scientific community and was not developed very far by Le Corbeiller himself. I will argue that Le Corbeiller's program is still a promising way forward in the theory of non-equilibrium thermodynamics, which until now has, for the most part, failed to capture the detailed dynamics of work extraction by engines. In classical physics, such work extraction requires an active, non-conservative force, something that has been studied almost exclusively in the context of mechanical instabilities. I will treat three separate problems: the generation of waves on the surface of the water by the action of the wind, the hunting oscillation of a train, and the tidal acceleration of the Moon. I will show how the dialogue between dynamical systems theory and thermodynamics simplifies the solutions to these problems while revealing surprising commonalities among them. Finally, I will also argue that a similar approach can throw light on the thermodynamics of non-conservative chaotic systems, including Chua's circuit and the Lorenzian waterwheel.

[1)] Alejandro Jenkins, Professor: Universidad de Costa Rica, 11501-2060, San José, Costa Rica (CR), alejandro.jenkins@ucr.ac.cr , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Quantum-gravity in a dynamical system perspective

Sijo K. Joseph

Abstract: General Theory of Relativity and Quantum theory gives two different description of the same mother nature in the big and small scale respectively. Mathematical languages of these two theories are entirely different, one is geometric while the other one is probabilistic. This curious feature makes the merging of these theories (quantum-gravity) considerably difficult. In this manuscript, we explore quantum-gravity in a dynamical system perspective. For example, in the standard quantum theory, the wave equation is a linear partial differential equation while in General Theory of relativity, the field equations are highly nonlinear. A classical dynamical system can show very rich phase-space structures which is absent in a linear partial differential equation. In order to incorporate gravitational corrections one can think about the nonlinear extensions of quantum theory. In this manuscript such an attempt to quantum gravity is explored. Dissipative and forcing corrections are found in the newly formulated quantum equation and it's physical interpretations are given.

[1] Sijo K. Joseph, Ph.D.: Tel-Aviv University, Tel-Aviv, Israel (IL), sijothankam@gmail.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Maximal stick duration for an electromechanical system

Roberta Lima, Rubens Sampaio

Abstract: Electromechanical systems are an interesting type of coupled systems. The mutual influence between electromagnetic and mechanical subsystems characterizes coupling. Each subsystem affects the behavior of the other. This works analyzes the dynamics of an electromechanical system considered the existence of Coulomb dry-friction in the mechanical subsystem. The friction induces two qualitatively different and alternate modes of motion of the mechanical subsystem, the stick- and slip-modes, with a non-smooth transition between them. Stick happens when the sum of all forces acting over the mechanical subsystem is zero during a non zero time interval. In the electromagnetic subsystem there is only slip. The objective of this paper is to characterize the dynamics of the coupled system considering the the stick- and slip modes of the mechanical subsystem. The focus is to determine how the coupling between the two subsystems is affected by the stick- and slip oscillations of one subsystem. One the variables of great interest in the analysis is the maximal stick duration, witch depends on the electrical and mechanical parameters.

[1] Roberta Lima, Associate Professor: PUC-Rio, R. Marquês de São Vicente, 225 - Gávea, Brazil (BR), roberta_10_lima@hotmail.com.

[2] Rubens Sampaio, Professor: PUC-Rio, R. Marquês de São Vicente, 225 - Gávea, Brazil (BR), rsampaio@puc-rio.br, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Locating unknown steady states: When machine learning meet time series dataset

Wei Lin

Abstract: With tremendous development of data collections, processing, and mining, data-driven and model-free methods and algorithms are highly expected in various communities of science, engineering, and even social science. Those complex data, experimentally collected along with the time evolution, are usually supposed to be produced by the hidden complex dynamical systems, whose explicit models are often unknown partially or even completely. In order to depict the skeleton of such complex data and make accurate prediction without any explicit models, advanced technologies of machine learning have been invited and applied successfully. In this talk, we propose an integrated framework connecting the machine learning technique with the adaptive delayed feedback control, and demonstrate the effectiveness of the proposed framework in locating and controlling the unobservable and unstable steady states based merely on the collected data of chaotic time series produced by complex systems. It is anticipated that our works including the machine learning techniques are able to meet the requirements arising in the research of complex systems, and also that the theory of complex dynamical systems can inversely contribute to illustrating and complementing the principles of machine learning techniques.

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1) Wei Lin, Professor: Fudan University, 220 Handan Road, Shanghai 200433, China (CN), wlin@fudan.edu.cn, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Nonlinear dynamics of microbeam resonators under periodical and pulse opto-thermal excitations

Aleksei Lukin, Ivan Popov, Lev Shtukin, Olga Privalova, Dmitry Indeitsev

Abstract: The principle of laser thermo-optical exposure to a deformable medium is increasingly used in the tasks of non-destructive testing of equipment and structures, determining the physicomechanical properties of materials, studying the geometric and physical parameters of objects and structures at the nano- and microscale level, in biomedicine, as well as in the industry of nano and microsystems. One of the important directions of development and research in this area is laser thermo-optical generation of oscillations of moving elements of microelectromechanical systems for various purposes (sensors, signal processing systems).This work is devoted to the construction and study of mathematical models of the dynamics of a micromechanical beam resonator under pulsed and periodic localized thermo-optical action. The considered model of the resonator is based on the laser thermo-optical principle of generating bending oscillations of a beam-like movable element and the electrostatic principle of detecting the output signal. Nonlinear resonator dynamics under opto-thermal excitations is investigated using asymptotic methods of nonlinear mechanics, finite difference and finite element methods with account for the coupling of longitudinal and transverse motions.

[1)] Aleksei Lukin, Ph.D.: Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), lukinalexei@yandex.ru, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2)] Ivan Popov, M.Sc. (Ph.D. student): Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), vanwork@yandex.ru.

[3)] Lev Shtukin, Ph.D.: Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), lvtvsh4749@gmail.com.

[4)] Olga Privalova, Ph.D.: Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), o.privalova@mail.ru.

[5)] Dmitry Indeitsev, Professor: Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), dmitry.indeitsev@gmail.com.

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Topologies that favor synchronization in energy transmission networks

Elbert Macau

Abstract: Energy transmission networks (power grids) are a typical example of the study of a system that presents a collective behavior of interconnected dynamical units. Local instabilities in these networks can result in cascade failures and even in blackouts. Power grids can be described my means of complex networks of oscillators, where transmission lines are described by the edges and generators or consumers of energy are represented by nodes. The oscillator model often used in literature to describe the behavior of the generators/consumers is the second order Kuramoto model. In this work, an evolutionary optimization technique is used to generate network topologies that present a relatively small number of edges and favors frequency synchronization as the dynamics of the nodes are given by a second order Kuramoto oscillator. These topologies would be of great interest when building power grids duo to the costs involved in the construction of transmission lines.

[1] Elbert Macau, Professor: National Institute for Space Research - INPE, 12243-260, Brazil (BR), elbert.macau@gmail.com, the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Dynamics of a network of map-based neurons in problems of reservoir computing

Oleg Maslennikov, Mechislav Pugavko, Vladimir Nekorkin

Abstract: Reservoir computing is a framework of computational neuroscience and machine learning where it is assumed that information processing occurs in a special high-dimensional network called a reservoir. In this work we consider a reservoir system which contains a network of neuron-like map-based elements. The system task is to generate a certain type of oscillations at the readout. We uncover what type of dynamic behaviors emerge at a microscopic level of individual reservoir nodes at different stages of training.

[1] Oleg Maslennikov, Ph.D.: Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanov Str., 603950 Nizhny Novgorod, Russia (RU), oleg.maov@gmail.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Mechislav Pugavko, B.A. (M.Sc. student): Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanov Str., 603950 Nizhny Novgorod, Russia (RU), slavapugavko2@gmail.com.

[3] Vladimir Nekorkin, Professor: Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanov Str., 603022 Nizhny Novgorod, Russia (RU), vnekorkin@appl.sci-nnov.ru.

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Probabilistic paths dynamics over weighted complex networks

Pablo Medina, Alejandro Valdivia

Abstract: Probabilistic interactions among temporal events provide a framework for a theoretical model to describe phenomena in multiple applied instances of different natural and social sciences. For example, sequences of seismic events, symbols sequences, events in armed conflicts, internet, and the brain dynamics may be modeled considering ensembles of networks of a set of nodes connected by specific probabilities represented by weighted links. Interestingly, literature reports that networks that represent these systems present characteristics of complex networks like small-world networks and scale-free networks, which shades light of the correlation presented among them. However, to the best of our knowledge, there is no evidence in the literature that relates the topology of these networks with the transition rates that fully describe these interactions. The sequences of weights of these links seem to form probability paths, which constitutes an interesting tool to describe the dynamical flux of information. In this work, we present a mathematical model to describe the probability paths in an ensemble of networks. We contrast the results of our approach with results obtained from simulations of dynamical events on complex networks. We study networks whose topology is described by Erdos-Renyi, Watts-Strogatz, and Barabasi-Albert models and its weights are distributed as power-laws. We applied our results to characterize different symbol sequences like western languages and sequences of seismic events.

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[1] Pablo Medina, Ph.D.: Departamento de Fisica, Facultad de Ciencias, Universidad de Chile, Las Palmeras 3425, Santiago, Chile, Chile (CL), avidjoulem@gmail.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Alejandro Valdivia, Professor: Departamento de Fisica, Facultad de Ciencias, Universidad de Chile, Las Palmeras 3425, Santiago, Chile, Chile (CL), alejandro.valdivia@gmail.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Structural stability of interaction networks against negative external fields

José Fernando Mendes

Abstract: I this talk I will show how can we explore structural stability of weighted and unweighted networks of positively interacting agents against a negative external field. Show that the agents support the activity of each other to confront the negative field, which suppresses the activity of agents and can lead to a collapse of the whole network. The competition between the interactions and the field shape the structure of stable states of the system. In unweighted networks (uniform interactions) the stable states have the structure of k-cores of the interaction network. The interplay between the topology and the distribution of weights (heterogeneous interactions) impacts strongly the structural stability against a negative field, especially in the case of fat-tailed distributions of weights. We show that apart critical slowing down there is also a critical change in the system structure that precedes the network collapse. The change can serve as early warning of the critical transition. In order to characterize changes of network structure we develop a method based on statistical analysis of the k-core organization and so-called 'corona' clusters belonging to the k-cores.

[1)] José Fernando Mendes, Professor: University of Aveiro, Campus Santiago, 3810-193 Aveiro, Portugal (PT), jfmendes@ua.pt, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Cloning of chimera states in a multiplex network of relaxation oscilators

Vladimir Nekorkin

Abstract: A new phenomenon of the chimera states cloning in a two-layer multiplex network with short-term couplings has been discovered and studied. For certain values of strength and time of multiplex interaction, in the initially disordered layer, a state of chimera is formed with the same characteristics (the same average frequency and amplitude distributions in coherent and incoherent parts, as well as an identical phase distribution in coherent part), as in the chimera which was set in the other layer. The mechanism of the chimera states cloning is examined. It is shown that the cloning arises from the competition of oscillations in pairs of oscillators from different layers.

1) Vladimir Nekorkin, Professor: Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Ulyanov Str., 46, Russia (RU), vnekorkin@appl.sci-nnov.ru , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Rank distributions, nonlinear dynamics, and number theory

Alberto Robledo, Carlos Velarde

Abstract: We address the wide spectrum physics of ranked data originating from many different sources that include those obeying the laws of Zipf and Benford but incorporate other types of behaviors. The formalism distinguishes between data sorted out by magnitude or by frequency and can be expressed in two equivalent ways, one stochastic and the other deterministic. We show that rank distributions fall into distinct universality classes each with links to number theory sets such as factorial, natural, prime and Fibonacci numbers. We reproduce these sets of numbers, exactly or increasingly accurately, as specific trajectories of iterated maps. Subsequently we obtain their reciprocals, or algebraic inverses, also as trajectories of associated nonlinear maps and calculate their sums or series. All cases are contained in the renormalization group fixed-point map for the tangent bifurcation each for a specific value of the nonlinearity z. The value z=2 is crucial in different ways as it is a borderline power. For z>2 the series of reciprocals converges, while for z≤2 diverges. At z=2 logarithmic corrections arise in correspondence with prime number known bounds. Also, z=2 signals the vanishing of the contraction dimension Z=2-z, the minimal value that an attractor can exert on ensembles of trajectories. Furthermore, z=2 corresponds to the classical case of Zipf law. Rescaled reciprocals of number sets link to rank distributions, while rescaled number sets provide probability densities that have extensive generalized entropies as measured by maximum rank values.

[1] Alberto Robledo, Ph.D.: Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Apartado Postal 20-364, 01000, Ciudad de Mexico, Mexico (MX), robledo@fisica.unam.mx, the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Carlos Velarde, Ph.D.: Instituto de Investigaciones en Matematicas Aplicadas y en Sistemas, Universidad Nacional Autonoma de Mexico, Apartado Postsal 20-364, 01000, Mexico City, Mexico (MX), velarde@unam.mx.

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Experimental analysis of dynamic susceptibility of selected elements of the railway braking system

Wojciech Sawczuk, Grzegorz Marek Szymański

Abstract: The research results presented in this article relate to the analysis of dynamic properties of selected elements of the railway braking system. In the article for elements of a complete caliper from a railway passenger car with a disc brake system, an impulse test was carried out to estimate the frequency of resonance vibrations of these elements. The obtained natural frequencies from the tested elements were grouped taking into account their mutual location. The authors pointed out that some elements of the braking system have a common natural frequency, which can affect the vibrations of the disc brake system during braking.

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1) Wojciech Sawczuk, Ph.D.: Poznan University of Technology, Poznan, Piotrowo 3 street 60-965, Poland (PL), wojciech.sawczuk@put.poznan.pl, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

2) Grzegorz Marek Szymański, Associate Professor: Poznan University of Technology, Pozna, Piotrowo 3 street, 60-965, Poland (PL), grzegorz.m.szymanski@put.poznan.pl.

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Nordmark map and the problem of large-amplitude chaos in an impact oscillator

David Simpson, Viktor Avrutin, Soumitro Banerjee

Abstract: It has long been known that impacting mechanical systems exhibit sudden onset of large amplitude chaotic oscillation close to grazing. In 1991, Nordmark offered a plausible explanation by showing that the discrete-time map obtained for such systems is piecewise smooth, with a square root term in the right hand side. It was understood that this 'square root singularity' causes the abrupt onset of chaos at grazing. However, bifurcation diagram of the Nordmark map exhibits a gradual increase in the size of the chaotic attractor following grazing, though experimental investigations exhibited an abrupt onset of a large-amplitude chaotic oscillation that lasted for a short range of the parameter. This was called a narrow band of chaos. Evidently, this characteristic of the chaotic orbit is not adequately captured by the Nordmark map. In this paper we probe this question by numerically computing the Poincare map of the system and by analytically computing the corresponding Nordmark map. We find that the two maps differ significantly away from the grazing point. Parts of the attractor lie in regions of phase space where the two maps differ substantially. That is why the classical Nordmark map does not provide a good model to probe this phenomenon.

[1] David Simpson, Ph.D.: Massey University, Institute of Fundamental Sciences, Massey University, New Zealand, New Zealand (NZ), d.j.w.simpson@massey.ac.nz .

[2] Viktor Avrutin, Ph.D.: University of Stuttgart, Institute for Systems Theory and Automatic Control, University of Stuttgart, Germany, Germany (DE), avrutin.viktor@gmail.com .

[3] Soumitro Banerjee, Professor: Indian Institute of Science Education & Research, Kolkata, IISER Kolkata, Mohanpur campus, West Bengal 741246, India (IN), soumitro@iiserkol.ac.in , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Local control of an array of globally coupled oscillators

Arūnas Tamaševičius, Elena Adomaitienė, Skaidra Bumelienė

Abstract: Two control methods for stabilization of the steady states in an array of the globally coupled FitzHugh-Nagumo oscillators by means of the local feedback are described. The first technique is based on the proportional feedback with a constant adjustable reference. The second technique is an adaptive one, employing the first order stable filter. The possibility to control an array locally, that is via a single randomly chosen (or accidentally accessed) oscillator has been demonstrated. Mathematical analysis, numerical simulations, and hardware experiments with an electrical circuit imitating dynamics of the mathematical model have been performed.

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[1] Arūnas Tamaševičius, Ph.D.: Center for Physical Sciences and Technology, LT-10257 Vilnius, Lithuania (LT), tamasev@pfi.lt , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Elena Adomaitienė, Ph.D.: Center for Physical Sciences and Technology, LT-10257, Vilnius, Lithuania (LT), elena.tamaseviciute@ftmc.lt .

[3] Skaidra Bumelienė, Ph.D.: Center for Physical Sciences and Technology, LT-10257, Lithuania (LT), skaidra@pfi.lt .

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Deciphering the Transport in complex systems

Juan A. Valdivia, Jose Rogan, Pablo Medina, Miguel Kiwi, Felipe Torres

Abstract: In the past few years have studied the topological structure of static and evolving complex networks. In more recent times, researchers have become interested in analyzing the network as a dynamical system on which there is a dynamical quantity that varies in time, or where packets are transported across the network. We discuss examples of transport over complex networks that can involve the generation of spontaneous magnetization or nontrivial topological phase transitions in magnetic systems; the propagation of electric or spin currents, quantum information, photons; the evolution of stress dissipation in active geophysical regions; transport of vehicles in cities or packets in communication networks, etc. We also present recent simulation and analytical results on the transport of a classical quantity in a generalization of the “Ehrenfest urn” over complex networks. Concepts of interest include the characterization of the asymptotic dynamical equilibrium state, the distribution of time scales, the approach to the dynamical equilibrium state, and the fluctuations distribution at equilibrium, etc. These concepts are analyzed for a number of nontrivial complex networks, such as the so-called scale-free and small-world networks. These results provide intuition about the transport and nontrivial dynamics that occur in the systems discussed above.

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1) Juan A. Valdivia, Professor: Universidad de Chile, Las Palmeras 3425 Nunoa, Santiago, Chile (CL), alejo@macul.ciencias.uchile.cl, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

2) Jose Rogan, Professor: Universidad de Chile, Las Palmeras 3425 Nunoa, Santiago, Chile (CL), jrogan@macul.ciencias.uchile.cl.

3) Pablo Medina, Ph.D.: Universidad de Chile, Las Palmeras 3425 Nunoa, Santiago, Chile (CL), avidjoulem@gmail.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

4) Miguel Kiwi, Professor: Universidad de Chile, Las Palmeras 3425 Nunoa, Santiago, Chile (CL), m.kiwi.t@gmail.com.

5) Felipe Torres, Ph.D.: Universidad de Chile, Las Palmeras 3425 Nunoa, Santiago, Chile (CL), felestorres@gmail.com.

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Order-parameter analysis of collective dynamics in networks of oscillators

Zhigang Zheng

Abstract: Collective behaviors of networks of oscillators have attracted much attention in recent years. The synchronization among populations of oscillators represent a typical collective behavior. In the present talk, we give a retrospect of recent developments of synchronizations in networks of oscillators from the microscopic level to the macroscopic level. In the microscopic level, synchronization among oscillators can be well exhibited in terms of the synchronization tree, where the process from partial synchrony to global synchrony is accompanied by the reduction of phase-space dimension. This supports a macroscopic approach of collective synchronization in terms of order-parameter dynamics. The dynamics of high-dimensional space can be reduced to a low-dimensional subspace in terms of the order-parameter approach. The order-parameter equation enables us to grasp the essential low-dimensional dynamical mechanism of the synchronization for complex networks. Different solutions of the order-parameter equation correspond to diverse collective states, and different bifurcations reveal various transitions among these collective states.

[1)] Zhigang Zheng, Professor: Huaqiao University, 361021, China (CN), zgzheng@hqu.edu.cn, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: NON123

Border-collisions in a periodically forced self-oscillatory piecewise smooth system with a high number of switching manifolds

Zhanybai Zhusubaliyev, Viktor Avrutin

Abstract: We report a number of new dynamic phenomena arising in a piecewise smooth system, whose motion involves two oscillatory components: a low frequency periodic external force and high frequency self-oscillations. Ultimately, this system can be modeled by a map with an extremely high number of switching manifolds. It is well-known that when a self-oscillatory system is subjected to an external periodic forcing, the total motion can be seen as occurring on a closed invariant curve and, in the absence of resonances (synchronization or entrainment), the motion is said to be quasiperiodic. The problem that we are interested in is associated with the role that border-collision bifurcations play in synchronization of the two modes and in transitions to chaos.

[1] Zhanybai Zhusubaliyev, Professor: Southwest State University, 50 Years of October Str. 94, 305040, Kursk, Russia (RU), zhanybai@hotmail.com , the author presented this contribution at the conference in the special session: "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Viktor Avrutin, Ph.D.: University of Stuttgart, Pfaffenwaldring 9, 70569 Stuttgart, Germany (DE), Viktor Avrutin <avrutin.viktor@gmail.com> .

SPECIAL SESSION 2

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paper id: MAT103

The dynamics analysis of a spatial linkage with flexible links and imperfect revolute joints

Krzysztof Augustynek, Andrzej Urbaś

Abstract: The algorithm for generating the dynamics equations of the two-dof spatial linkage is considered in the paper. The presented linkage is composed of the five rigid or flexible links which form a serial closed-loop kinematic chain. It is assumed that revolute joints can be imperfect. The dynamics equations are derived using the Lagrange equations of the second kind. The joint coordinates together with homogeneous transformation matrices are applied to generate the equations of motion. The presented algorithm gives the opportunity to generalize it for any linkages with a tree closed-loop kinematic structure. The flexible links are modelled by means of the Rigid Finite Element method in the sense of classic approach. Author's spatial model of the revolute joint with a radial and axial clearance is proposed to take into account clearance effects. In this model a revolute joint is discretized by means of the contact elements located on the cylindrical and frontal surfaces of the journal and bearing. Such approach allows us to detect automatically collisions in many points of the contacting surfaces. The normal contact force is calculated using the Nikravesh-Lankarani formula which is an extension of the classic Hertz model because it additionally takes into account the energy dissipation. The LuGre friction model is applied to model friction phenomenon in joints. In numerical simulations, an interaction between the links' flexibility and clearance in joint during the motion of the linkage is analysed.

[1] Krzysztof Augustynek, Ph.D.: University of Bielsko-Biala, ul. Willowa 2 43-309 Bielsko-Biała, Poland (PL), kaugustynek@ath.bielsko.pl , the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2] Andrzej Urbaś, Ph.D.: University of Bielsko-Biala, ul. Willowa 2 43-309 Bielsko-Biała, Poland (PL), aurbas@ath.bielsko.pl .

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paper id: MAT2

Application of the Lie symmetries in the moving frames theory to solve nonholonomic constraints problems

Claudio Basquerotto, Adrián Ruiz, Edison Righetto, Samuel da Silva

Abstract: The main goal of this work is to use the Lie symmetries in the moving frames theory to solve a mechanical problem with nonholonomic constraint. The extraction of Lie symmetries in motion equations can be used to reduce the order and to obtain conservation quantities. Additionally, the classification of motion equations, i.e., to apply a transformation to obtain an already known solution of a mapped equation, can be effectuated with a Cartan's moving frame theory. In order to illustrate the approach a nonholonomic constrained mechanical system is solved to obtain a general closed-solution in explicit form. A full detailed analysis is discussed to explain the Lie symmetries and the correspondent moving frame obtained.

[1] Claudio Basquerotto, Associate Professor: Universidade Federal do Sul e Sudeste do Pará - Unifesspa, Folha 17, Quadra 04, Lote Especial, s/n.º - Nova Marabá, PA, 68505-080, Brazil (BR), cbasquerotto@unifesspa.edu.br, the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2] Adrián Ruiz, Ph.D.: Universidad de Cádiz - UCA, Department of Mathematics, Universidad de Cádiz - UCA, Department of Mathematics, 11510, Puerto Real, España, Spain (ES), adrian.ruiz@uca.es.

[3] Edison Righetto, Associate Professor: Universidade Estadual Paulista - UNESP, Faculdade de Engenharia de Ilha Solteira, Departamento de Matemática, Avenida Brasil, 56, Centro, CEP 15385-000, Ilha Solteira, São Paulo, Brasil, Brazil (BR), edisonrighetto72@gmail.com.

[4] Samuel da Silva, Associate Professor: Universidade Estadual Paulista - UNESP, Faculdade de Engenharia de Ilha Solteira, Departamento de Engenharia Mecânica, Avenida Brasil, 56, Centro, CEP 15385-000, Ilha Solteira, São Paulo, Brasil, Brazil (BR), samuel.silva13@unesp.br.

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Optomechatronic disk choppers with generalized window profiles: Ascertainment and multi-parameter analysis of non-linear transmission functions

Virgil-Florin Duma

Abstract: Choppers are one of the most utilized devices in laser systems, almost as common as lenses, prisms, and filters. The most common configuration of optical choppers uses rotational disks with windows with linear margins (the classical chopper). We have developed and patented a novel configuration of disks, with windows with non-linear (e.g. semi-circular or elliptical) margins, in order to introduce supplemental parameters in the transmission functions of such devices. The non-linear profile of the laser impulses produced by such choppers can thus be designed, obtaining for example approximately triangular impulses (in contrast to classical chopper disks). We have proposed for such devices the name of eclipse choppers, due to the way they obscure the section of laser beam (in the plane of the disk), similarly to a planetary eclipse. In the present paper, we also introduce another configuration of disk choppers, that have linear margins (like classical choppers), but tilted with regard to the disk radius. This is a chopper with generalized window profile. A supplemental angular parameter — corresponding to the tilt of the linear margin of the window — is thus introduced. A multi-parameter analysis of these novel choppers is made, with regard to (positive and negative values of) such angles, but also with regard to the other geometric and kinematic parameters of the device. A comparison is finally completed between the possible non-linear profiles of the laser impulses produced by such generalized window profiles and those produced by classical, as well as by eclipse choppers.

[1] Virgil-Florin Duma, Professor: Aurel Vlaicu University of Arad, Str. Elena Dragoi nr. 2, Romania (RO), dumavirgil@yahoo.co.uk , the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

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paper id: CON349

Nonlinear modelling and control of self-balancing human transporter

Saransh Jain, Sarthak Jain, Mohit Makkar

Abstract: Various modelling and control strategies have been developing in quest for efficiently managing non-linear systems, which is majorly done by incorporating maximum possible aspects of behavior of a system into mathematical equations and then introduce control schemes to direct the influence of all the variables of such equations in a desired manner. Though some of these developed control schemes are still struggling to produce satisfying results when it comes to controlling non-linear systems, Proportional-Integral-Derivative (PID) and Linear-Quadratic- Regulator (LQR) are the two very efficient control schemes known for their stability properties and optimal control when applied to non-linear systems. Self Balancing Human Transporter (SBHT) is one such non-linear system which is widely used and needs to be effectively controlled to maintain uniform speed and dynamic stability. It is very crucial to work on both, the dynamics and efficient control of two wheel SBHT. This article will show the design and analysis of more advanced and recently developed algorithms of the above mentioned control schemes being applied on the new, more precise, fully functional and non linear simulation model of two wheel SBHT. Comparison study between the two has also been done on various parameters.

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[1] Saransh Jain, B.A. (M.Sc. student): The LNMIIT Jaipur, The LNMIIT, Jaipur,, India (IN), saransh.j1997@gmail.com, the author presented this contribution at the conference in the special session "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2] Sarthak Jain, B.A. (M.Sc. student): The LNMIIT Jaipur, The LNMIIT, Jaipur,, India (IN), sarthakjain098@gmail.com.

[3] Mohit Makkar, Ph.D.: The LNMIIT Jaipur, The LNMIIT, Jaipur,, India (IN), mohit.makkar@lnmiit.ac.in.

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Dynamical Systems — Theory and Applications

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Consideration about H-type rotor with the Magnus effect

Mateusz Jakubowski

Abstract: One significant disadvantage of vertical axis wind turbines (VAWT) is a fluctuation of the pitch angle during rotor rotation. A H-type rotor, which is a lift-type rotor, consists of straight airfoil blades producing a shaft torque by means of a lift force. The lift force depends on the pitch angle. While the rotor is rotating, the pitch nonlinearly changes twice at one spin of the rotor from zero to the highest value. Between these levels, the pitch angle reaches a certain value. Which means the available maximum value of the lift force is not achievable for current aerodynamic conditions. The pitch angle is between relative velocity of the blade and linear velocity. In this work the authors consider a H-type rotor which uses the Magnus effect to generate lift force: straight blades are replaced by Magnus rotors. The lift force produced by the rotation of cylinders is independent on the pitch angle. Thus, the cylinders may create similar lift force in all angular position of the rotor. The pitch angle with high value is ideal because of bigger tangential component of the force (torque). Classic airfoils generate lift force until stall phenomenon occurs (i.e. 14 degrees). Rotating cylinders can operate with 45 degrees pitch and more. It has to be noted that value of the lift force may be higher than airfoil. However, large drag force could also appear. The goal is to find a specific aerodynamic condition and proper geometry of the rotor to increase turbine efficiency. The authors propose mathematical formulation of the problem and some preliminary results in this work.

[1] Mateusz Jakubowski, M.Sc. (Ph.D. student): Institute of Applied Mechanics, Poznan University of Technology, 60-965 Poznań, Poland (PL), mateusz.ja.jakubowski@doctorate.put.poznan.pl, the author presented this contribution at the conference in the special session "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

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paper id: CON37

Quaternion based free-floating space manipulator dynamics modeling using the dynamically equivalent manipulator approach

Elżbieta Jarzębowska, Marcin Kłak

Abstract: The paper presents a dynamics modeling method dedicated to free-floating spacecraft, e.g. manipulators, based on a modified Dynamically Equivalent Manipulator (DEM) method. DEM enables dynamics modeling of space manipulators (SM) via their suitable substitution by ground fixed manipulator models. The resulting SM dynamics is equivalent to the ground one. This provides attractive modeling and control design tools. It enables carrying tests and experiments for SM in earth labs multiple times what contributes to mission cost and failure reductions. Originally, DEM is developed in Euler angles. The paper contribution is the modification of DEM to present SM dynamics in quaternions. The Euler angles description is not suitable for dynamics and control of SM and other spacecraft, e.g. for large reorientation and attitude description. Quaternions do not share Euler angles' drawbacks and they are computationally more efficient. However, their implementation reveals challenges due to nonlinear relations for SM angular velocities and a constraint equation they add to SM dynamics. The motivation for DEM modification is to make dynamics models suitable for description of arbitrary SM maneuvers and missions like debris removal, servicing, space mining and on-orbit docking and assemblies. It may also support SM attitude controller designs. Derivation of Lagrange based dynamics in quaternions can be found in some works but it is limited to ground fixed manipulators with position constraints only. The development of DEM in quaternions is illustrated by an example of SM attitude dynamics.

[1] Elżbieta Jarzębowska, Associate Professor: Warsaw University of Technology, 00-665 Warsaw, Nowowiejska 24 st, Poland (PL), elajarz@meil.pw.edu.pl.

[2] Marcin Kłak, M.Sc. (Ph.D. student): Warsaw University of Technology, 00-665 Warsaw, Nowowiejska 24 st, Poland (PL), marcin.klak@gmail.com, the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

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paper id: NUM36

Dynamics and vibration analysis of a spatial linkage model with flexible links and joint friction subjected to position and velocity motion constraints

Elżbieta Jarzębowska, Andrzej Urbaś, Krzysztof Augustynek

Abstract: In the paper a spatial linkage (SL), i.e. a serial closed-loop kinematic chain composed of rigid and flexible links subjected to work regime velocity programmed constraints (VPC) is analysed. The key component of the SL dynamics derivation is an automated computational procedure for constrained dynamics generation. It serves systems subjected to holonomic and first order nonholonomic constraints and proved its effectiveness to rigid or flexible open chain models. The contribution of our research is twofold. Firstly, it extends the procedure on SL models composed of flexible links with closed-loop kinematics, for which a spanning tree can have a serial or tree structure. Secondly, it analyzes dynamics and vibration of the SL motion with VPC that come from work regime or requirements on it. The procedure for constrained dynamics generation provides reference dynamics, which solutions satisfy all constraints on the SL. The basic distinction between this procedure and others, usually Lagrange based, is that final equations are in the reduced state form, i.e. constraint reaction force are eliminated during derivation. This is the essential advantage of the presented procedure. It provides the smallest set of dynamics equations, which may serve for motion planning. Analysis of desired motion and vibrations caused by adding VPC, enable designing proper velocity ranges for the SL in work regimes and assessing kinematic parameters needed to follow these motions. The theoretical development of automated generation of constrained dynamics is illustrated by an example of the SL model.

[1] Elżbieta Jarzębowska, Associate Professor: Warsaw University of Technology, 00-665 Warsaw, Nowowiejska 24 st, Poland (PL), elajarz@meil.pw.edu.pl, the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2] Andrzej Urbaś, Ph.D.: University of Bielsko-Biala, 43-309 Bielsko-Biala, Willowa 2, Poland (PL), aurbas@ath.bielsko.pl.

[3] Krzysztof Augustynek, Ph.D.: University of Bielsko-Biala, 43-309 Bielsko-Biala, Willowa 2, Poland (PL), kaugustynek@ath.bielsko.pl.

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paper id: BIF66

Dynamic and control applied to a non-ideal portal frame structure to energy harvesting

Remei H. Junior, Wagner B. Lenz, Rodrigo T. Rocha, Mauricio A. Ribeiro, Angelo Marcelo Tusset, Jose M. Balthazar, Elzbieta Jarzebowska

Abstract: In this work, we present a method for energy harvesting from a simple portal frame structure excited by a non-ideal energy source, that is of limited power supply, with a chaotic behavior. The energy harvesting is computed by using of a nonlinear piezoelectric material. The dynamical response of the system is examined, when the vibration energy transfer (saturation phenomenon) takes place between the symmetric (vertical) mode and the horizontal (sway) mode. The chaotic system behavior is studied numerically, by its time history and phase portraits, and the results are validated by the existence of a positive maximal Lyapunov exponent. A passive controller was designed by means of a nonlinear substructure with properties of a nonlinear energy sink. The numerical results show the displacement of the structure and the maximum power harvested by the device with and without the passive nonlinear energy sink. The obtained numerical results demonstrate the vibration levels of the structure and the maximum power harvested by the device with and without the passive nonlinear energy sink.

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[1] Remei H. Junior, M.Sc.: UTFPR, Av. Monteiro Lobato, S/N, Ponta Grossa - PR, Brazil (BR), a.m.tusset@gmail.com.

[2] Wagner B. Lenz, M.Sc.: UTFPR, Av. Monteiro Lobato, S/N, Ponta Grossa - PR, Brazil (BR), wagner.barth5@gmail.com.

[3] Rodrigo T. Rocha, Ph.D.: UTFPR, Av. Monteiro Lobato, S/N, Ponta Grossa - PR, Brazil (BR), digao.rocha@gmail.com.

[4] Mauricio A. Ribeiro, Ph.D.: UTFPR, Av. Monteiro Lobato, S/N, Ponta Grossa - PR, Brazil (BR), mau.ap.ribeiro@gmail.com.

[5] Angelo Marcelo Tusset, Associate Professor: UTFPR, Av. Monteiro Lobato, S/N, Ponta Grossa - PR, Brazil (BR), a.m.tusset@gmail.com, the author presented this contribution at the conference in the special session "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[6] Jose M. Balthazar, Professor: UTFPR, Av. Monteiro Lobato, S/N, Ponta Grossa - PR, Brazil (BR), jmbaltha@gmail.com.

[7] Elzbieta Jarzebowska, Associate Professor: Warsaw University of Technology, 00-665 Warsaw, Poland (PL), elajarz@meil.pw.edu.pl.

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paper id: VIB32

The dynamics and control of a high-rise vertical transportation system with a hydraulic damper-actuator system

Stefan Kaczmarczyk

Abstract: Tall structures often sway with large amplitude and low frequency due to resonance conditions induced by wind loads and long-period seismic excitations. These sources of excitation affect the performance of vertical transportation systems (VTS) deployed in these structures. The fundamental natural frequencies of tall buildings fall within the frequency range of the wind and seismic excitations and the sway motions form the excitation mechanism which acts upon the VTS. Particularly affected are long slender structural components such as the suspension ropes, compensating cables and travelling cables. Complex nonlinear resonance interactions arise in the system when the frequency of the excitation is tuned to the natural frequencies of those elements. To mitigate the effects of resonance interactions the masses and geometry of the VTS can be adjusted to shift the resonance regions and to avoid excessive dynamic responses. However, in most cases the structural constraints and design limitations do not leave much space for the possible changes to be effective. The methods to mitigate the effects of dynamic interactions in a high-rise VTS involve the application of hydraulic tie-down devices attached at the compensation sheave assembly. The aim of this study is to develop a numerical simulation model to predict and analyse the resonance behaviour of the system equipped with a nonlinear damper. The performance and characteristics of the hydraulic 'tie-down' / damping device can then be optimized and adjusted to minimize the effects of adverse dynamic responses of the system.

[1] Stefan Kaczmarczyk, Professor: University of Northampton, The University of Northampton, University Drive, Northampton NN1 5PH, England (GB), stefan.kaczmarczyk@northampton.ac.uk, the author presented this contribution at the conference in the special session "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

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paper id: CON113

Slosh analysis on a full car model with SDRE control and hydraulic damper

Wagner Barth Lenz, Mauricio A. Ribeiro, Angelo M. Tusset, Elżbieta Jarzębowska, Jose Manoel Balthazar

Abstract: Slosh has been one of the main concerns for transportation vehicles, specifically with partially filled tanks. The liquid movement due to changes of vehicle velocity magnitude and direction as well as external excitations can be the source of damage and stability problems in trucks and passenger vehicles. Due to size and the intrinsic movement, the natural frequency of sloshing is similar to the human input frequency. Thus, managing and controlling the vehicle-tank system dynamics is required to maintain the desired safety standards. In this paper a numerical study of a full vehicle-tank model is conducted by investigating motion of a linear pendulum model without baffles. A numerical analyses of the full vehicle-tank dynamics model, biffurcation diagram and 0-1 test, is performed and a controller based upon the State-Dependent Riccati Equation method to control the pressure on the chamber of the damper is considered the dissipation on the restriction valve dynamics . The preliminary results demonstrate s that the pendulum model adequately maps the fluid behavior in the tank. Nevertheless, due to low dissipation of slosh motion, around the natural frequency the displacement increases significantly and the vehicle motion can cause damage and loss of control. In this case, the passive control is unable to significantly reduce the slosh. Nevertheless, it significantly reduce the pendulum motion and avoids the overturn and improving the driviblility and safety

[1] Wagner Barth Lenz, M.Sc.: Federal University of Technology – Paraná, 84016-210, Brazil (BR), wagner.barth5@gmail.com.

[2] Mauricio A. Ribeiro, Ph.D.: Federal University of Technology – Paraná, 84016-210, Brazil (BR), mau.ap.ribeiro@gmail.com.

[3] Angelo M. Tusset, Ph.D.: Federal University of Technology – Paraná, 84016-210, Brazil (BR), a.m.tusset@gmail.com.

[4] Elżbieta Jarzębowska, Associate Professor: Warsaw University of Technology, Poland, 00-661, Poland (PL), elajarz@meil.pw.edu.pl.

[5] Jose Manoel Balthazar, Professor: Federal University of Technology – Paraná, 84016-210, Brazil (BR), jmbaltha@gmail.com, the author presented this contribution at the conference in the special session "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

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paper id: CON336

Finite element analysis of magneto-rheological fluid embedded on journal bearings

Airton Nabarrete, Gustavo de Freitas Fonseca

Abstract: In this work, the influence of magneto-rheological fluid embedded on journal bearings in the dynamic behavior of rotors is considered. The modified Reynolds equations for Bingham viscoplastic materials are used for determination of the nonlinear hydrodynamic forces. Flexible rotors are modeled by the finite element method. The proper weight of the structure, unbalance and bearing hydrodynamic forces are included in the equation of motion as external excitations. Non-linear hydrodynamic forces calculation depends on the relative position between the shaft and the journal bearing. For this reason, the system response is determined by the modified Newmark method, which contemplates the determination of the equilibrium at any time step by the incorporation of the Newton-Raphson method. The whole model was developed in the MATLAB® programming environment. The results of the case studies are presented as orbital graphs, displacements versus time and frequency responses.

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[1] Airton Nabarrete, Professor: Instituto Tecnologico de Aeronautica - Divisao de Engenharia Aeronautica, Praca Marechal Eduardo Gomes 50, Vila das Acacias, 12228-900, Sao Jose dos Campos, SP, Brazil (BR), nabarret@ita.br, the author presented this contribution at the conference in the special session "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2] Gustavo de Freitas Fonseca, M.Sc. (Ph.D. student): Instituto Tecnologico de Aeronautica - Divisao de Engenharia Aeronautica, Praca Marechal Eduardo Gomes 50, Vila das Acacias, 12228-900, Sao Jose dos Campos, SP, Brazil (BR), gustavofonsecaufmg@gmail.com.

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paper id: CON22

Nonlinear control of an inverted pendulum actuated by two reaction wheels

Joao Francisco Silva Trentin, Samuel da Silva, Jean Marcos de Souza Ribeiro, Hanspeter Schaub

Abstract: Reactions wheels have been extensively used to control and stabilize a wide range of applications. This paper studies the performance of the use of two reaction wheels for controlling an inverted pendulum. The model for this pendulum configuration and a nonlinear controller designed using Lyapunov theory are presented. Moreover, the controller has an attractive feature of choosing how each reaction wheel may be actuated. Therefore, the difference of actuating of the pendulum is evaluated online using two reaction wheels or using one at a time. A full detailed analysis of the simulated results is discussed to explain the differences in the use of the actuators.

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1) Joao Francisco Silva Trentin, M.Sc. (Ph.D. student): São Paulo State University - UNESP, Avenida Brasil Sul 56, Ilha Solteira, São Paulo. Postal code: 15385-000., Brazil (BR), joao.trentin@unesp.br, the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

2) Samuel da Silva, Associate Professor: São Paulo State University - UNESP, Avenida Brasil Sul 56, Ilha Solteira, São Paulo. Postal code: 15385-000., Brazil (BR), samuel.silva13@unesp.br.

3) Jean Marcos de Souza Ribeiro, Associate Professor: São Paulo State University - UNESP, Avenida Brasil Sul 56, Ilha Solteira, São Paulo. Postal code: 15385-000., Brazil (BR), jean.ribeiro@unesp.br.

4) Hanspeter Schaub, Professor: University of Colorado Boulder, Boulder, Colorado. Postal code: 80309-0431, United States (US), hanspeter.schaub@colorado.edu.

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paper id: MAT165

Parameters estimation by harmonic probing of hysteresis models of bolted jointed

Rafael Teloli, Samuel da Silva, Gaël Chevallier

Abstract: Assembled structures are essential due to the full range of real structures which posse joint interfaces, such as gas turbines, automotive vehicles, aerospace structures, and civil applications. However, the friction effects in the joint interface are challenging to predict and depend, for instance, on the interaction which occurs on the contact surface, the presence of hysteresis effect, and so on. Hence, a practical strategy is to manipulate it with simple experimental cases to adequately explain the influence of the joint, and then, to enlarge these methodologies for industrial cases. In this context, this paper proposes a nonlinear modal analysis of an assembled structure, through the framework of the harmonic balance method and a smoothing procedure in the hysteretic restoring force. The procedure adopted here breaks it into smooth polynomial intervals. An experimental setup composed of two beams, as substructures, made of aluminum and connected with a bolted joint is utilized to demonstrate the strategy. The bolted structure examined presents full hysteretic damping induced by stick-slip characteristics depending on the excitation amplitude level. A Bouc-Wen model was adequated to describe the measured hysteresis loops and utilized to identify and to fit the parameters by optimization. Consequently, the updated numerical model is compared with experimental data. The harmonic balance method, applied along with the smoothing procedure, shows to be a straightforward, simple, and attractive alternative for handling this type of problem.

[1] Rafael Teloli, M.Sc. (Ph.D. student): UNIVERSIDADE ESTADUAL PAULISTA - FACULDADE DE ENGENHARIA DE ILHA SOLTEIRA, Avenida Brasil, 56, Ilha Solteira - SP, Brazil (BR), rafael.teloli@unesp.br, the author presented this contribution at the conference in the special session "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2] Samuel da Silva, Associate Professor: UNESP - Faculdade de Engenharia de Ilha Solteira, Avenida Brasil, 56, Ilha Solteira - SP, Brazil (BR), samuel.silva13@unesp.br.

[3] Gaël Chevallier, Professor: Université de Franche-Comté, FEMTO-ST, 15B Avenue des Montboucons, France (FR), gael.chevallier@univ-fcomte.fr.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: MAT101

Evaluation of the crane's actuators strength based on the results obtained from dynamics model

Andrzej Urbaś, Krzysztof Augustynek

Abstract: The strength analysis of the crane's actuators is presented in the paper. The analysis is performed using the loads obtained from the dynamics analysis. The mathematical model of the flexible supported crane is formulated using the Lagrange equations of the second kind. The main structure of the crane is built of the five bodies forming an open-loop kinematic chain. The actuators form the closed-loop kinematics chains. The crane performs an assumed motion aimed at transferring a load in the form of lumped mass of various values. The mathematical model takes into account the jib's flexibility, which is discretized by means of the Rigid Finite Element Method (RFEM). The formalism of the joint coordinates and homogeneous transformation matrices are used to describe the crane's kinematics. The equations of motion are supplemented by the constraint equations formulated for the cut-joints. The Lagrange multipliers corresponding to reaction forces at the cut-joints, are used to the actuators' quasi-statics analysis. The Finite Element Method (FEM) is used to model the actuators' flexibility. The numerical calculations present the influence of the jib's flexibility and load's mass on the maximum stresses and strains of the actuators at a given crane's working moment.

[1)] Andrzej Urbaś, Ph.D.: University of Bielsko-Biala, 43-309, Poland (PL), aurbas@ath.bielsko.pl , the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2)] Krzysztof Augustynek, Ph.D.: University of Bielsko-Biala, 43-309, Poland (PL), kaugustynek@ath.bielsko.pl .

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Dynamical Systems — Theory and Applications

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paper id: CON176

Application of trajectories in extended phase space for identification of external excitement

Viktorija Volkova

Abstract: External excitation plays a dominant role in forming periodic oscillation modes, as it sustains the free oscillations in the system at the frequencies that are equal to or a fractional or multiple value of the frequency of the external excitation. The effect of the polyharmonic external excitation causes the emergence or onset of novel properties in the system. Thus, the linear mechanical system may have an infinite number of the resonance frequency ranges corresponding to harmonics of the external excitation. The phenomenon of dynamic smoothing is also an evidence of the polyharmonic nature of the external excitation. Dynamic smoothing manifests itself by the decreased effect of the positional friction forces as it is displayed in the graphs of transient processes in the mechanical systems. Therefore, some assumptions, for instance, those concerning the monoharmonic nature of changes in the external excitation, which are commonly used in studying the real mechanical systems, are not always correct. The application of phase trajectories and its mappings on plane “acceleration – displacement” is suggested by author to nonparametric identification of external excitement forms systems models. The efficiency of the given method had estimated by it’s comparison with a known method of non-parametric identification.

[1)] Viktorija Volkova, Professor: Department of construction, geotechnics and geomechanics, Dnipro University of Technology, Televizionnaya str.12, ap.48, Dnipro, UA49005, Ukraine (UA), drvev09@gmail.com , the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

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paper id: CON29

Effect of the rotor support elements lubricated by magnetic fluids on chaotic and regular vibration of rotors during rubbing

Jaroslav Zapomel, Petr Ferfecki, Jan Kozánek

Abstract: To achieve a compromise between the vibration attenuation and minimization of the forces transmitted to the stationary part a new rotor support element has been designed. It consists of a squeeze film bearing lubricated by magnetically sensitive oil and of a hydrodynamic bearing inserted in it. The damping is controlled by changing the magnetic field passing through the layer of magnetic fluid. This paper deals with influence of the proposed support element on character of the rotor vibration during the rotor rubbing. The rotor consists of a flexible shaft and of one rigid disc placed in a hole in the stationary part. The pressure distribution in the oil films is governed by the Reynolds equations, classical and the one adapted to magnetic fluids. The dry friction is considered during the collisions. The rotor vibration is described by a set of nonlinear differential equations of the first and second order. The goal of the study was to investigate effect of the magnetic field on regularity of the rotor vibration. The results of the computational simulations show that in cases when the collisions occurred (i) character of the induced vibration depends on speed of the rotor rotation (the chaotic, quasiperiodic and periodic vibration was observed) and (ii) application of the magnetic field can change irregular oscillation into regular one. The performed study contributed to learning more on the effect of magnetically controlable fluids lubricating the rotor bearings on the rotor vibration character in dependence on speed of the rotor rotation.

[1] Jaroslav Zapomel, Professor: VSB - Technical University of Ostrava, VSB – Technical University of Ostrava, 17. listopadu 2172/15 708 00 Ostrava-Poruba, Czech Republic (CZ), jaroslav.zapomel@vsb.cz, the author presented this contribution at the conference in the special session: "Nonlinear behavior, performance, and control designs for complex structures in Civil, Aeronautical, Aerospace and Ocean Engineering" organized by J.M. Balthazar, E. Jarzębowska and A.M. Tusset.

[2] Petr Ferfecki, Ph.D.: VŠB = Technical Universitz of Ostrava, 70800, Czech Republic (CZ), petr.ferfecki@vsb.cz.

[3] Jan Kozánek, Ph.D.: Institute of Thermomechanics of the CAS, v.v.i., 18200, Czech Republic (CZ), kozanek@it.cas.cz.

SPECIAL SESSION 3

15th INTERNATIONAL CONFERENCE

Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: VIB31

Gradient and fractional elasticity models in statics and dynamics

Elias C. Aifantis

Abstract: Nonlocal gradient elasticity has been shown to eliminate elastic singularities and interpret size effects in classical static problems. In dynamics the situation is more complex and a current assessment is provided. A key issue is the need of both internal lengths and internal times to be introduced. Some examples on vibrations are presented. Fractional counterparts of these models are also discussed.

References: [1] E.C. Aifantis, Internal length gradient (ILG) material mechanics across scales &disciplines, Adv. Appl. Mech. 49, pp. 1-110, 2016.

1) Elias C. Aifantis, Professor: Aristotle University of Thessaloniki, 54124, Greece (GR), mom@mom.gen.auth.gr, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: CON24

Response sensitivity of damper-connected adjacent structural systems subjected to fully non-stationary random excitations

Tiziana Alderucci, Federica Genovese, Giuseppe Muscolino

Abstract: In the last decades, due to the growing population, civil engineers faced with the problem of the design of adjacent buildings in limited areas; this could lead to mutual pounding if those structures are subjected to dynamic excitation such as ground motion accelerations. Among the possible solutions to this problem, the connection with vibration control devices, such as dampers, could be an innovative way. The sensitivity analysis represent a powerful tool in the optimization procedure, especially when the design of vibration control devices is required; in fact it is possible to determine the alterations of the structural response with the reference structural parameters changes. In this paper a method for the evaluation of the sensitivity of the response of two adjacent buildings connected through fluid dampers is presented; the sensitivity of the structural response statistics is obtained through very simple frequency domain integrals. The proposed approach requires the evaluation of explicit closed form solutions of the derivatives of time-frequency response vector functions with respect to the parameters that define the modified structural model. To do so it is necessary to write governing motion equations in state-variables. A numerical application shows the effectiveness of the proposed approach thanks to the comparison with Monte Carlo Simulation

[1] Tiziana Alderucci, Ph.D.: Department of Engineering, University of Messina, C.da Di Dio - Villaggio S. Agata - 98166 Messina, Italy (IT), talderucci@unime.it.

[2] Federica Genovese, M.Sc. (Ph.D. student): Department of Engineering, University of Messina, C.da Di Dio - Villaggio S. Agata - 98166 Messina, Italy (IT), fedgenovese@unime.it.

[3] Giuseppe Muscolino, Professor: Department of Engineering, University of Messina, C.da Di Dio - Villaggio S. Agata - 98166 Messina, Italy (IT), gmuscolino@unime.it, the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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Dynamical Systems — Theory and Applications

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paper id: VIB177

Vibration mitigation of coupled bending-torsion beams via tuned mass dampers

Andrea Burlon

Abstract: Tuned mass dampers are well established devices for vibration mitigation of structures. These devices are tuned in order to move the main resonance frequencies of a structure away from troubling frequencies of external excitations. Several studies in literature can be found regarding the dynamics of structures coupled with tuned mass dampers. Attention is focused on those works involving beams as primary structures. All of them have always considered beams with symmetric cross section, and no works have dealt with beams with asymmetric one. The latter beams, of great interest since employed in several engineering applications, show coupled bending torsional phenomena due to the asymmetry of the cross section. In this study, an exact and computationally efficient technique is proposed to address the dynamics of beams with mono symmetric cross section coupled with tuned mass dampers. The proposed technique is based on the elementary coupled bending torsion theory and makes use of the theory of generalised function to handle the actions exchanged between the beam and the tuned mass dampers. The proposed technique allows to investigate the effectiveness and vibration reduction capabilities of tuned mass dampers for the beams under study.

[1)] Andrea Burlon, Ph.D.: Mediterranea University of Reggio Calabria, Via Graziella-Feo di Vito 89124 Reggio Calabria, Italy (IT), a.burlon91@gmail.com , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: MAT163

Fractional nonlinear viscoelastic rubbers for base isolated systems

Andrea Burlon, Mario Di Paola, Giuseppe Failla

Abstract: Base isolation is often used to prevent structural damage from earthquake shaking and, among different isolation devices, friction-pendulum and viscoelastic-rubber devices are certainly most common. For structural dynamic analyses, an accurate modelling of the base isolation device is obviously crucial and, specifically, a rigorous description of the actual constitutive law is of outmost importance for viscoelastic rubbers. The paper will address this issue starting from the observation that the rubber creep law is indeed a power law in time, with a coefficient depending non-linearly on the stress. This implies that the stress-strain constitutive law is inherently non-linear and, as a result, the Boltzmann superposition principle does not apply. To overcome this limitation, the paper will propose a non-linear variable transformation to a new space where the classical linear stress-strain relation, involving standard fractional operators, is obtained. Dynamic analyses of a single-degree-of-freedom structural system, base-isolated by a viscoelastic-rubber device, will be presented in both frequency and time domains by using artificial earthquake time histories. The purpose is to show how the amount of dissipated energy and reduction in the maximum response amplitude change whereas the proposed, accurate model is used for the viscoelastic-rubber device.

[1] Andrea Burlon, Ph.D.: Mediterranea University of Reggio Calabria, Via Graziella-Feo di Vito 89124 Reggio Calabria, Italy (IT), a.burlon91@gmail.com , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Mario Di Paola, Professor: University of Palermo, Viale delle Scienze 90128, Italy (IT), mario.dipaola@unipa.it .

[3] Giuseppe Failla, Associate Professor: Mediterranea University of Reggio Calabria, Via Graziella-Feo di Vito 89124 Reggio Calabria, Italy (IT), giuseppe.failla@unirc.it .

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paper id: MAT205

Perturbation analysis of a MDOF system equipped a tuned mass damper

Vincent Denoël

Abstract: Tuned mass dampers (TMD) are commonly used to tame undesired vibrations. Several criteria exist to determine, with some sort of optimality, the parameters of the device in order to reach the desired performance. These criteria are typically expressed in one of the various closed form expressions developed over the past decades and resulting from the analysis of a primary system equipped with a TMD. However several cases of practical interest require taking into consideration the interaction of multiple structural modes of the mutual influence of several dampers. An explicit analytical treatment of a dynamical system with more that 2 DOFs is possible but results in excessively long (and therefore unpractical) equations. In this paper, we invoke the smallness of the added mass(es), with respect to the modal masses in the several (primary) modes of vibration and develop a perturbation method to determine the response of the coupled system. These development result in neat, short and applicable expressions for the natural frequencies of a multi-DOF structure with one or several TMDs, as well as their responses to narrow- and broad-band excitations. The paper will provide the main steps of the analytical derivation, the important resulting formula and a validation and application of the concepts to a realistic problem.

1) Vincent Denoël, Professor: University of Liège, Allée de la Découverte 9, 4000 Liège, Belgium (BE), v.denoel@uliege.be, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: CON99

A novel procedure for dynamic identification from ambient vibration data

Alberto Di Matteo, Mario Di Paola, Iain Peter Dunn, Chiara Masnata, Antonina Pirrotta

Abstract: Dynamic identification based on ambient vibration data, also known as Operational Modal Analysis (OMA), is a class of procedure which pertain with the identification of the modal properties of systems based on vibration data collected when the systems are under their operating conditions. In this manner, no initial excitation or measured artificial excitation is required. These procedures for testing and/or monitoring systems, are particularly attractive for civil engineers concerned with the safety of complex structures. However, since the external force is not recorded, the identification methods need to be particularly sophisticated and based on stochastic mechanics. In this context, this contribution will introduce an innovative ambient identification method based on the application of the Hilbert Transform, to obtain the analytical representation of the system response in terms of the correlation function. In particular, it is worth stressing that the analytical signal is a complex representation of a time domain signal: the real part is the time domain signal itself, while the imaginary part is its Hilbert transform. In this regard, numerical examples, as well as real experimental data, will be used assessing the reliability and accuracy of the proposed approach over other conventional procedure.

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[1] Alberto Di Matteo, Ph.D.: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), alberto.dimatteo@unipa.it .

[2] Mario Di Paola, Professor: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), mario.dipaola@unipa.it .

[3] Iain Peter Dunn, M.Sc. (Ph.D. student): University of Palermo, viale delle Scienze Ed. 8, Italy (IT), iainpeter.dunn@unipa.it .

[4] Chiara Masnata, M.Sc. (Ph.D. student): University of Palermo, viale delle Scienze Ed. 8, Italy (IT), chiara.masnata@unipa.it .

[5] Antonina Pirrotta, Professor: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), antonina.pirrotta@unipa.it , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: NUM100

Path integral approach and Kolmogorov-Feller equation for nonlinear systems under parametric Poisson white noise

Alberto Di Matteo, Mario Di Paola, Antonina Pirrotta

Abstract: In this study the response evaluation in terms of probability density function (PDF) of nonlinear systems under parametric Poissonian white noise is examined. Specifically, the extension of the Path Integral method to this kind of systems is addressed. Notably, these systems exhibit a jump at each impulse occurrence, whose amplitude can be determined analytically assuming two general classes of nonlinear multiplicative functions. Relying on the obtained closed form relations liking the impulses amplitude distribution and the corresponding jump response of the system, the Path Integral method is extended to deal with systems excited by parametric Poisson white noise. On this base, a more amenable version of the pertinent Kolmogorv-Feller equation, that rules the evolution of the response PDF of the system, is also determined.

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[1] Alberto Di Matteo, Ph.D.: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), alberto.dimatteo@unipa.it .

[2] Mario Di Paola, Professor: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), mario.dipaola@unipa.it , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[3] Antonina Pirrotta, Professor: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), antonina.pirrotta@unipa.it .

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Control base isolation structure (BIS) with a novel passive tuned mass damper inerter (TMDI) device

Salah Djerouni, Mouncef Eddine Charrouf, Mahdi Abdeddaim, Nassim Djedoui, Abdelhafid Ounis

Abstract: The recent earthquakes history shows that the conception of resistant, safe and economical structures is daily challenges for structural engineers among the newest vibration control devices figures the inerter which is a device capable of developing a large fictive mass using rotational inertia in this research work a classical tuned mass damper TMD is compared with an inerter based mass damper TMDI which consists of tuned mass damper which a hybrid mass ,real and fictive .the two devices are used to control the vibration of a base isolated structure BIS submitted to earthquake excitations .for this purpose , a ten storey structure is equipped with a TMD and TMDI alternatively and a time history analysis is performed under different earthquake records .the obtained results shows a good performance of the structure equipped with a TMD in terms of base and top displacement as well as the inter storey drift and base shear force .

[1)] Salah Djerouni, M.Sc. (Ph.D. student): civil engineering, 07004, Algeria (DZ), s.djerouni@univ-biskra.dz, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2)] Mouncef Eddine Charrouf, M.Sc. (Ph.D. student): civil engineering, 07004, Algeria (DZ), s.djerouni@univ-biskra.dz, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[3)] Mahdi Abdeddaim, Ph.D.: civil engineering, 07004, Algeria (DZ), s.djerouni@univ-biskra.dz, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[4)] Nassim Djedoui, Ph.D.: civil engineering, 07004, Algeria (DZ), s.djerouni@univ-biskra.dz, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[5)] Abdelhafid Ounis, Associate Professor: civil engineering, 07004, Algeria (DZ), ounisafi@gmail.com.

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Novel concepts of resonators for beam structures

Giuseppe Failla, Gioacchino Alotta

Abstract: Beam structures equipped with resonators are common in structural and mechanical engineering applications. In general, they are represented as a continuous-discrete system where a continuous 1D Euler or Timoshenko beam is coupled with discrete mass-spring subsystems modelling single-degree-of-freedom (SDOF) or multi-degree-of-freedom (MDOF) resonators. Typical resonators are activated by beam deflection and vibrate transversely to the beam axis. The paper aims to introduce novel concepts of MDOF resonators, featuring multiple degrees of freedom in transverse as well as lateral directions relative to the beam axis, to be activated by beam deflection at the attachment point. It will be shown that the novel MDOF resonators can be reverted to equivalent external constraints, with reaction depending only on the beam deflection at the attachment point through a suitable frequency-dependent stiffness. On this basis, the coupled motion equations of the continuous-discrete system will be solved using the motion equation of the beam only, obtaining frequency and time responses under arbitrary loads by a generalized function approach: the frequency response will be derived by direct integration of the motion equation of the beam, while modal frequency and impulse responses will be built by complex modal superposition. Frequency response and modal responses will be calculated in exact analytical form, for any number of resonators. The paper will investigate the dynamics of beams equipped with the novel MDOF resonators and show the advantages of the proposed analytical framework.

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[1] Giuseppe Failla, Associate Professor: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), giuseppe.failla@unirc.it, the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Gioacchino Alotta, Ph.D.: University of Palermo, Viale delle Scienze, 90100 Palermo, Italy (IT), gioacchino.alotta@unipa.it.

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paper id: CON105

Response spectrum analysis of mid-story seismically isolated building structures

Federica Genovese, Giuseppe Muscolino

Abstract: Among the increasing practical applications, the mid-story isolation system (MSIS), in which the isolation devices are typically installed at the top of the first story of a building, has recently gaining popularity because it can satisfy both architectural concerns of aesthetics and functionality. The dynamic behaviour of a mid-story isolated structure and a base isolated structure (BIS) may not be identical since the seismic responses of a mid-story isolated building may be significantly affected by the flexibility of the substructure. Indeed, in this case the structural system must be considered as composed by three substructures: the superstructure, above the MSIS, assumed as a multi-storey building; the substructure below the MSIS composed only by columns; the MSIS itself. Moreover, the three subsystems, usually assumed as classically damped, have different damping ratios, which have to be taken into account in adequate manner in response spectrum analysis (RSA). It follows that to be effective in practice, the RSA for these systems should embed the following features: i) reduced computational effort, avoiding the calculation of complex-valued eigenproperties; ii) accurate representation of the damping, properly taking into account the concentration of energy dissipation at the three structural subsystems. These requirements are inherent in the damping-adjusted combination rule that, in this paper, is detailed for the seismic analysis and design of mid-story isolated buildings. The new proposed approach for MSIS is numerically validated by Monte-Carlo simulation.

[1] Federica Genovese, M.Sc. (Ph.D. student): Department of Engineering, University of Messina, C.da Di Dio - Villaggio S. Agata - 98166 Messina, Italy (IT), fedgenovese@unime.it.

[2] Giuseppe Muscolino, Professor: Department of Engineering, University of Messina, C.da Di Dio - Villaggio S. Agata - 98166 Messina, Italy (IT), gmuscolino@unime.it, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: VIB114

On the use of tuned mass dampers for vibration mitigation in offshore wind turbines

Mina Ghassempour, Giuseppe Failla, Felice Arena, Giovanni Malara

Abstract: Vibration mitigation in horizontal-axis offshore wind turbines is of crucial importance to prevent fatigue damage of the structural components. Among others, many studies have examined tuned mass dampers (TMDs) in order to reduce tower-top oscillations under combined wind-wave loadings. In this context, the paper investigates the dynamic response of a 5MW offshore wind turbine resting on a tripod in intermediate water depth (50 m), when an omnidirectional TMD is installed inside the nacelle. Fully-coupled, non-linear aero-hydro-servo-elastic dynamic analyses are implemented in GH-BLADED, a software package certified by Germanischer-Llyod for analysis and certification of offshore wind turbines. A wide range of potential tuning frequencies, mass and damping ratios are explored, in both operational and parked rotor conditions at a typical offshore site. The main conclusion of the study is that the tuning frequency to attain optimal reduction of structural vibrations shall be changed depending on the wind velocity in operational conditions, while is equal to the natural frequency of the first support-structure modes when the rotor is parked. This result is attributable to inherent non-linearity of rotor dynamics and demonstrates that a conventional design of the TMD based on the natural frequencies of the support-structure modes may not be suitable for offshore wind turbines.

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[1] Mina Ghassempour, M.Sc. (Ph.D. student): University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), mina.ghassempour@unirc.it , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Giuseppe Failla, Associate Professor: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), giuseppe.failla@unirc.it .

[3] Felice Arena, Professor: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), arena@unirc.it .

[4] Giovanni Malara, Ph.D.: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), giovanni.malara@unirc.it .

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: ENG78

Theoretical and experimental investigations of a magnetic levitation system for energy recovery

Krzysztof Kecik

Abstract: The paper analysis of a magnetic levitation system consists of two identical magnets rigidly mounted to the tube's end. Between them a third magnet is free to levitate (pseudo-levitate) due to the proper polarity. The behaviour of the harvester is significantly complicated by the strong electromechanical coupling among the components. The Harmonic Balance Method is used to approximately describe the response of the base excited oscillator with a cubic nonlinearity. The analytical results are verified by a path following method and experiment. Acknowledgments: The project/research was financed in the framework of the project Lublin University of Technology-Regional Excellence Initiative, funded by the Polish Ministry of Science and Higher Education (contract no. 030/RID/2018/19).

[1)] Krzysztof Kecik, Associate Professor: Lublin University of Technology, Nadbystrzycka 38d, 20-618 Lublin, Poland (PL), k.kecik@pollub.pl, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: STA77

Improving functionality of absorber/harvester system by a smart adaptive suspension

Krzysztof Kecik, Rafal Rusinek

Abstract: In this work, a vibration absorber/harvester is designed and the interaction between its vibration absorption ability and harvesting capability is investigated. The special designed pendulum is mounted to the oscillator leads to the autoparametric system. In order to increase the effectiveness, the adaptive smart suspension consisting of the magnetorheological damper and shape memory spring is applied. The smart elements can improve or worsen effecivness of vibration mitigation as well as energy harvesting. However, the unstable zones can be easy reduced by a MR damper. Acknowledgments: The project/research was financed in the framework of the project Lublin University of Technology-Regional Excellence Initiative, funded by the Polish Ministry of Science and Higher Education (contract no. 030/RID/2018/19).

[1] Krzysztof Kecik, Associate Professor: Lublin University of Technology, Nadbystrzycka 38d, 20-618 Lublin, Poland (PL), k.kecik@pollub.pl, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Rafal Rusinek, Associate Professor: Lublin University of Technology, Nadbystrzycka 38d, 20-618 Lublin, Poland (PL), r.rusinek@pollub.pl.

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paper id: CON59

Innovative tuned resonant devices for offshore floating wind turbines

Valentina Laface, Carlo Ruzzo, Giuseppe Failla, Felice Arena

Abstract: Serviceability of offshore floating wind turbines strongly depends on adequate mitigation of the support motion and, although a few strategies have been proposed in this respect, many challenges are still to be addressed for a consistent reduction of support oscillations under combined wind-wave loadings. The purpose of the paper is to introduce innovative tuned resonant devices for floating wind turbines, consisting of multi-degree-of-freedom (MDOF) mass-spring subsystems with multiple internal resonances tunable to various potential frequencies. This concept is suggested by experimental/numerical evidence that the frequency response of floating supports for wind turbines exhibits distinct peaks, corresponding to structural motion as well as to the main frequency contents of wind and waves. The study will focus on the OC3-Hywind spar as reference floating wind turbine. Different potential MDOF tuned resonant devices will be investigated, with translational degrees of freedom activated by rigid body motions of the spar. Numerical results will be obtained from a simplified non-linear numerical model under variable input conditions, including different wind velocities, periodic and irregular waves. Non-linearity will be associated with fluid-structure interaction, while the rotor-nacelle-assembly will be reverted to a lumped mass loaded by a thrust force in operational and parked rotor conditions. The simplified numerical model will provide preliminary yet valuable insight into the performances of the proposed MDOF tuned resonant devices.

[1)] Valentina Laface, Ph.D.: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), valentina.laface@unirc.it, the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2)] Carlo Ruzzo, Ph.D.: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), carlo.ruzzo@unirc.it.

[3)] Giuseppe Failla, Associate Professor: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), giuseppe.failla@unirc.it.

[4)] Felice Arena, Professor: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), arena@unirc.it.

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Dynamical Systems — Theory and Applications

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paper id: CON283

Parametric optimization of TLCD-Main Structure Coupled System subject to seismic excitations

Juliano Ferreira Martins, Marcus Vinicius Girão De Morais, Suzana Moreira Ávila

Abstract: The vibration levels in slender structures, such as walkways, bridges, high towers, and wind turbines, are receiving more importance with span increase. On preserving the structure lifespan, it is necessary to study additional mechanical devices capable of reducing the vibrational level of the main structure. These absorbers are essential for structural health. Tuned Liquid Column Damper (TLCD) is a kind of passive absorber composed by a U-shaped tube filled with liquid, commonly, water. In the last thirty years, this device has been researched by several researchers as an alternative to vibration reduction. TLCD is a non-linear mechanical system due to turbulent head-loss in oscillatory conditions. To avoid solving nonlinear simultaneous equations, solutions such as statistical linearization and parameter optimization have been proposed in previous works. Yalla and Kareem derived a closed-form solution for the optimized TLCD damping ratio and head loss coefficient for white noise. Alkmin et al present optimal parameters of mass and aspect ratio to control the main structure subjected to several kinds of wind random excitations. The equipment is also an object of study for seismic excitations. This study performs a parametric optimization using response maps to obtain TLCD optimum parameters to arbitrary seismic excitations. First, optimum parameters of TLCD coupled to the main structure using response maps were compared to the analytical solution. Finally, the same procedure was reproduced to obtain optimal parameter for seismic excitations.

[1] Juliano Ferreira Martins, B.A. (M.Sc. student): University of Brasilia, Av Pq Aguas Claras lt3824, ap 606. Brasilia - DF, 71930000, Brazil (BR), juliano.martins@hotmail.com, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Marcus Vinicius Girão De Morais, Associate Professor: University of Brasilia, Universidade de Brasília - Campus Darcy Ribeiro Departamento de Engenharia Mecânica - Bloco G Sala 1-10/08, Brazil (BR), mumorais@gmail.com.

[3] Suzana Moreira Ávila, Associate Professor: Univeristy of Brasilia, Universidade de Brasilia, Campus Gama, Brazil (BR), suzana.avila@gmail.com.

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Design of a medium-scale test for the assessment of a resonant seismic barrier within the ReWarD Project

Antonio Palermo, Farhad Zeighami, Athanasios Vratsikidis, Zhibao Cheng, Dimitris Pitilakis, Alessandro Marzani

Abstract: The growing interest about meta-structures from the civil engineer community has led to the development of novel low frequency isolation systems for ground borne vibrations and seismic waves. Among those, the resonant Metabarrier, i.e., an array of meter-size resonators embedded in the ground around the structure, or a cluster of structures, to be protected, has been recently proposed. The metabarrier is designed to attenuate the surface ground motion induced by Rayleigh waves, with the potential ability to retrofit and shield existing vulnerable structures including historical buildings and cultural heritage sites. Additionally, it can be tuned to operate at specific frequencies ranges, for instance at the resonant frequencies of the structure. While the metabarrier conceptual design has been validated numerically and at small-scale laboratory tests, its engineering implementation still needs an on-field validation. Here we present the design of an experimental campaign, currently under development at the Euroseistest facility (\url{http://euroseisdb.civil.auth.gr}) within the framework of the ReWarD project (\url{https://site.unibo.it/reward/en}), meant at testing the performance of a medium-scale metabarrier. The barrier is designed according to the stratigraphy of the site exploiting dispersion curves and time history analysis developed within a Finite Element framework. The experimental test, designed according to such numerical indications, are expected to confirm a significant attenuation of the ground motion in the presence of the metabarrier.

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[1] Antonio Palermo, Ph.D.: University of Bologna, Viale del Risorgimento 2, Italy (IT), antonio.palermo6@unibo.it.

[2] Farhad Zeighami, M.Sc. (Ph.D. student): University of Bologna, Viale del Risorgimento 2, Italy (IT), farhad.zeighami3@unibo.it.

[3] Athanasios Vratsikidis, M.Sc. (Ph.D. student): Aristotle University of Thessaloniki, 424 GR-54124 Thessaloniki, Greece (GR), avratsik@civil.auth.gr.

[4] Zhibao Cheng, Ph.D.: Beijing Jiaotong University, Beijing, China, 100044, China (CN), chengzb@bjtu.edu.cn.

[5] Dimitris Pitilakis, Associate Professor: Aristotle University of Thessaloniki, 424 GR-54124 Thessaloniki, Greece (GR), dpitilakis@civil.auth.gr.

[6] Alessandro Marzani, Ph.D.: University of Bologna, Viale del Risorgimento 2, Italy (IT), alessandro.marzani@unibo.it, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: CON98

Optimal design of Tuned Mass Damper Inerter for base isolated structures

Antonina Pirrotta, Alberto Di Matteo, Chiara Masnata

Abstract: In this study the use of the Tuned Mass Damper Inerter (TMDI) to control the response of base isolated structures under stochastic horizontal base acceleration is examined. The TMDI, recently introduced as a generalization of the classical Tuned Mass Damper, allows to achieve enhanced performance compared to the other passive vibration control devices. Thus, it represents an ideal alternative for reducing displacements of base isolated structures. To this aim, a straightforward numerical approach is proposed for the optimal design of this device considering a white noise base excitation. Further, optimal TMDI parameters are derived in closed-form minimizing the displacement variance of the corresponding undamped base isolated system. A thorough numerical analysis is performed and related results, in terms of optimal parameters and control performance, are compared with pertinent data obtained by a more computationally demanding iterative optimization procedure. Results pertaining to both white noise and colored noise base excitations, as well as real recorded ground motions, assess the efficiency of the TMDI and the accuracy of the proposed optimal design procedure.

[1] Antonina Pirrotta, Professor: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), antonina.pirrotta@unipa.it , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Alberto Di Matteo, Ph.D.: University of Palermo, viale delle Scienze Ed. 8, Italy (IT), alberto.dimatteo@unipa.it .

[3] Chiara Masnata, M.Sc. (Ph.D. student): University of Palermo, viale delle Scienze Ed. 8, Italy (IT), chiara.masnata@unipa.it .

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paper id: VIB49

Bayesian assessment of viscoelastic damping models

Fernando Rochinha, Reniene Santos, Daniel Castello

Abstract: Advanced damping materials, due to their ability to dissipate mechanical energy, have been increasingly employed to mitigate damage in engineering devices operating in harsh environments. This damage is produced by induced vibrations that might be attenuated by passive or active structural control. The conception, design and real-time operation of such sort of strategy heavily relies upon modeling and computational simulation. In the present work, the initial objective is to construct reliable constitutive models that are based on internal variables for viscoelasticity in small deformations. These variables were added with the intention of representing the deformation of irreversible systems, such as viscoelasticity. Although the internal variables models are not being extensively used, they have gained a lot of attention because of their accuracy in modeling the damping of the material and in its ability to deal with frequency and temperature dependence in the time domain. we employ a Bayesian approach to carry out an analysis about the ability to reproduce the observable inelastic behavior when internal variables are used in the modeling. This analysis focus on the use of different constitutive models with special emphasis in small number of internal variables. Here, our strategy relies on confronting the results from a higher fidelity model with those obtained with a lower one. The degree of accuracy is assumed to be dictated by the number of internal variables in the hierarchical family of models

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[1] Fernando Rochinha, Professor: Universidade Federal do Rio de Janeiro, Eng. Mecanica. Centro de Tecnologia. Cidade Universitaria. G-201. Ilha do Fundao. rio de Janeiro. RJ, Brazil (BR), faro@mecanica.coppe.ufrj.br, the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Reniene Santos, M.Sc. (Ph.D. student): Universidade Federal do Rio de Janeiro, Eng. Mecanica. Centro de Tecnologia. Cidade Universitaria. G-201. Ilha do Fundao. rio de Janeiro. RJ, Brazil (BR), renienemus@hotmail.com.

[3] Daniel Castello, Associate Professor: Universidade Federal do Rio de Janeiro, Eng. Mecanica. Centro de Tecnologia. Cidade Universitaria. G-201. Ilha do Fundao. rio de Janeiro. RJ, Brazil (BR), dnl.castello@gmail.com.

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Effect of uncertainty in dynamic response of multi-cracked beams

Roberta Santoro, Giuseppe Failla

Abstract: This study deals with beams under dynamic loads, in presence of multiple cracks with uncertain parameters. The crack is modelled as a linearly-elastic rotational spring and, following a non-probabilistic approach, both stiffness and position of the spring are taken as uncertain-but-bounded parameters. The key idea is a preliminary monotonicity test, which evaluates sensitivity functions of the beam response to the separate variation of every uncertain parameter (i.e. stiffness and position of each crack) within the pertinent interval. Then, two alternative procedures calculate lower and upper bounds of the response. If the response is monotonic w.r.t. all the uncertain parameters, the bounds of the response are calculated selecting, for every parameter, either the lower bound or the upper bound depending on the sign of the sensitivity function associated with the parameter. In contrast, if the response is non-monotonic w.r.t. even one parameter only, the bounds of the response are evaluated via optimization and anti-optimization procedures. The method applies for every response variable (deflection, rotation, stress resultants) and the implementation takes advantage of analytical forms obtained, in this study, for all response variables and related sensitivity functions. Numerical results are presented for a multi-cracked beam equipped with tuned mass dampers to assess the effect of the uncertainty on the frequency response.

[1] Roberta Santoro, Associate Professor: University of Messina, C.da Di Dio, (S. Agata) 98166 Messina, Italy (IT), roberta.santoro@unime.it , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[2] Giuseppe Failla, Associate Professor: University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy (IT), giuseppe.failla@unirc.it , the author presented this contribution at the conference in the special session: "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

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paper id: VIB339

The use of the dynamic vibration absorber for energy harvesting

Leo Acho Zuppa, Jan Awrejcewicz, Nataliya Losyeva, Volodymyr Puzyrov, Nina Savchenko

Abstract: Vibration energy is abundantly present in many natural and artificial systems and can be assembled by various mechanisms, mainly using piezoelectric and electromagnetic means. In the present article, the electromechanical system with two degrees of freedom is considered. To the main mass, whose vibrations are to be reduced, an additional element (dynamical vibration absorber or DVA) is attached. The DVA consists of a spring, damping and piezoelectric elements for energy harvesting. The goal is to reduce the vibration of the main structure and at the same time collect energy from the vibration of the connected vibration absorber. Two configurations are studied: with linear and nonlinear coupling. For the first one the condition is obtained in closed form for the optimal dimensionless frequency ratio. For the second case the method of averaging is applied which allows to analyze the influence of nonlinear component on system's dynamics.

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[1] Leo Acho Zuppa, Professor: Universitat Politecnica de Catalunya, EDIFICI TR5 DESPATX 357 C. COLOM, 11 08222 TERRASSA SPAIN, Spain (ES), leonardo.acho@upc.edu.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, 1/15 Stefanowski Str., 90-924 Łódź, Poland, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[3] Nataliya Losyeva, Professor: Vasyl Stus Donetsk National University, 600-richia 21, Vinnitsia, Ucraine, Ukraine (UA), natalie.loseva@gmail.com.

[4] Volodymyr Puzyrov, Professor: Vasyl Stus Donetsk National University, 600-richia 21, Vinnitsia, Ucraine, Ukraine (UA), v.puzyryov@donnu.edu.ua, the author presented this contribution at the conference in the special session "Innovative strategies for vibration control and mitigation" organized by G. Failla and R. Santoro.

[5] Nina Savchenko, Associate Professor: Zhukovsky National Aerospace University ”KhAI”, 17, Chkalova str., Kharkiv, Ukraine, Ukraine (UA), nina_savchenko@hotmail.com.

SPECIAL SESSION 4

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paper id: BIF260

Distribution of lifetimes for transient bursting states in coupled noisy excitable systems

Nurtay Albanbay, Bekbolat Medetov, Michael Zaks

Abstract: In ensembles of coupled oscillators, intrinsic fluctuations often enable notrivial dynamics in seemingly simple situations. We investigate this effect on the example of two coupled FitzHugh-Nagumo oscillators subjected to external noise. At the considered parameter values, the unique global attractor of the deterministic system is its state of rest. Additive white noise of low or moderate intensity leads to the onset of transient bursting regime: series of intermittent bursts (patches of spikes), followed by the abrupt decay to the state of rest. Depending on the noise strength and the initial conditions, the number of bursts before the ultimate decay displays strong variations. Our numerical studies have disclosed that in the sufficiently large ensembles of realizations, the statistics of lifetimes for the transient bursting states follows the exponential distribution. The distribution slope (i.e. the mean duration of the bursting regime) depends on the noise intensity, being small for very weak noise and asymptotically diverging when the noise becomes stronger. Observations on the statistics of transient bursting regimes have been qualitatively and quantitatively confirmed by our experiments with the coupled analog electronic circuits, modeling the FitzHugh-Nagumo dynamics. We relate the exponential character of the distribution to the probability that the trajectory of the system, under the action of noise, escapes the local basin of attraction of the state of rest.

[1] Nurtay Albanbay, M.Sc. (Ph.D. student): Kazakh National Research Technical University named after K.I.Satpayev, 22a Satpaev str., 050013, Almaty, The Republic of Kazakhstan, Kazakhstan (KZ), nurtay.a90@gmail.com, the author presented this contribution at the conference in the special session "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

[2] Bekbolat Medetov, Ph.D.: al-farabi kazakh national university, al-Farabi Kazakh National university. 71 al-Farabi Ave., Almaty, Republic of Kazakhstan, 050040 Tel. 8 (727) 377-33-33, 8 (727) 377-33-30, Kazakhstan (KZ), bm02@mail.ru.

[3] Michael Zaks, Professor: Humboldt University of Berlin, Newton str.15 D-12489 Berlin, Germany, Germany (DE), zaks@physik.hu-berlin.de.

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paper id: STA87

Numerical and analytical investigation of chatter suppression by parametric excitation

Fadi Dohnal, Wolfgang Hörtnagel

Abstract: A concept for increasing process stability during milling is presented utilizing the time-periodic modulation of the tool support. A simple time-delayed system describing the effect of regenerative chatter is enhanced by a time-periodic variation of the support. Such a system leads to entirely new dynamics. Numerical results of stability charts are discussed in terms of spindle speed and cut depth and show classic chatter lobes that are modified by the parametric excitation. This kind of parametric excitation is more general than the one occurring for varying spindle speed because its frequency is independent of the cutting frequency of the tool and therefore independent of the spindle speed and number of teeth. First analytical approximations on the stability of the modified lobes are benchmarked against numerical predictions. This study is a preparation for experimental tests.

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1) Fadi Dohnal, Professor: UMIT, Linker Iselweg 21, 9900 Lienz, Austria (AT), fadi.dohnal@umit.at.

2) Wolfgang Hörtnagel, M.Sc. (Ph.D. student): UMIT, Linker Iselweg 21, 9900 Lienz, Austria (AT), wolfgang.hoertnagel@umit.at, the author presented this contribution at the conference in the special session "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

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December 2-5, 2019. Lodz, POLAND.

paper id: VIB104

Analysis of parametric vibration of a roller coaster flexible wheel

Piotr Gierlak, Andrzej Burghardt, Krzysztof Kurc, Dariusz Szybicki

Abstract: The article concerns the analysis of parametric vibrations of a flexible roller coaster wheel. The analysis was carried out in the context of designing a new wheel, whose role was to ensure the reduction of vibrations of the roller coaster trucks. For this purpose, the possibility of radial deformation of the wheel is ensured by introducing susceptibility in the area between the hub and the outer surface. Such solution, with the appropriate choice of parameters, made it possible to reduce vibrations in the wheel-track system. The susceptible structure results in periodically variable stiffness of the wheel during rolling. The aim of the analysis was to determine selected parameters of the susceptible part of the wheel in such a way that the resonance vibrations would not be excited by parametric vibrations. The results of the parametric vibration analysis combined with the wheel resonance characteristics allowed for the formulation of indications for the design of the new wheel.

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[1] Piotr Gierlak, Ph.D.: Rzeszow University of Technology, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland (PL), pgierlak@prz.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

[2] Andrzej Burghardt, Associate Professor: Rzeszow University of Technology, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland (PL), andrzejb@prz.edu.pl .

[3] Krzysztof Kurc, Ph.D.: Rzeszow University of Technology, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland (PL), kkurc@prz.edu.pl .

[4] Dariusz Szybicki, Ph.D.: Rzeszow University of Technology, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland (PL), dszybicki@prz.edu.pl .

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paper id: STA45

Primary and combined multi-frequency parametric resonances of a rotating thin-walled composite beam under harmonic base excitation

Jarosław Latalski, Jerzy Warmiński

Abstract: This study considers the stability of vibration of a rotating structure consisting of a rigid hub and a flexible thin-walled laminated composite beam under harmonic base excitation. The partial differential equations of motion representing a complex elastic deformation of the blade including bending, shear and twisting effects have been derived by the Hamilton's least action principle. Next, these equations have been transformed to a dimensionless ordinary differential form by adopting the Galerkin method. It is shown the final equation of motion includes time-varying coefficients that depend on the system angular velocity as well as on the base excitation frequency. Due to the doubly periodic external excitation terms this form of the governing equation is different from the typical Mathieu-Hill's equation. Two numerical examples are presented to illustrate the influence of selected model parameters on the dynamic stability of the system.

[1] Jarosław Latalski, Associate Professor: Lublin University of Technology, Nadbystrzycka 36, Lublin, Poland (PL), j.latalski@pollub.pl, the author presented this contribution at the conference in the special session: "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

[2] Jerzy Warmiński, Professor: Lublin University of Technology, Nadbystrzycka 36, Lublin, Poland (PL), j.warminski@pollub.pl.

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paper id: ENG61

Dynamic monitoring and online automatic modal parameters of a super high arch dam

Shuai Li, Jin-Ting Wang, Guang-Heng Luo, Zhi-Qian Xiang

Abstract: Laxiwa arch dam is a 250m-high arch dam in north-west of China, and it is being monitored by a dynamic monitoring system that comprise 25 sensors, which is mainly used to recorder earthquake. This paper focus on the automatic modal identified algorithm based on covariance driven stochastic subspace identification method (SSI-COV) and DBSCAN clustering algorithm. The first five modes during seven months from 2016/06/04 to 2016/12/31 are successfully tracked, and the effect of water level and temperature is discussed. The results show that the first two modes of Laxiwa arch dam are not closely, and the first mode shape and the fourth mode shape are very similar in the top crest. Compared with the water level, temperature has a greater influence on the natural frequency, and it is positively correlated with temperature. At the end of the paper, the frequencies obtained using an earthquake recorder and a numerical model is developed to verified the identified results.

[1)] Shuai Li, M.Sc. (Ph.D. student): Tsinghua univ, Tsinghua garden, Haidian district, Beijing, China, China (CN), shuai-li16@mails.tsinghua.edu.cn, the author presented this contribution at the conference in the special session: "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

[2)] Jin-Ting Wang, Professor: Tsinghua univ, Tsinghua university, Beijing, China, China (CN), wangjt@tsinghua.edu.cn.

[3)] Guang-Heng Luo, B.A. (M.Sc. student): Tsinghua univ, Tsinghua university, Beijing, China, China (CN), luogh18@mails.tsinghua.edu.cn.

[4)] Zhi-Qian Xiang, B.A.: Tsinghua univ, Tsinghua university, Beijing, China (CN), xiangzq15@mails.tsinghua.edu.cn.

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paper id: MAT334

On the decoupling of electromechanical systems

Roberta Lima, Rubens Sampaio, Peter Hagedorn

Abstract: Electromechanical systems are a type of coupled systems. The mutual influence between electromagnetic and mechanical subsystems characterizes coupling. Each subsystem affects the behavior of the other. Typically, the dynamics of an electromechanical system is expressed by an initial value problem (IVP) that comprises a set of coupled differential equations involving electrical and mechanical variables. This paper discusses a hypothesis found in the some references of the literature that deals with electromechanical systems that simplifies the dynamics greatly. Apparently, it is a nice hypothesis and reduces the number of equations in the IVP that gives the dynamics. The hypothesis originates a reduced system. However, the hypothesis contradicts itself and changes the dynamics. The objective of this paper is to show that the hypothesis leads to wrong results. The reduced system does not represent the complete system and moreover, decouples the electromagnetic and mechanical subsystems. The dynamics of the electromagnetic part is ignored. To highlight these problems, we analyze the effects of the hypothesis for a simple electromechanical system, a motor-cart system, with parametric excitation. This hypothesis is part of a group of errors that are found in the literature that deals with electromechanical systems (called as non-ideal systems or system with a limited power supply) at least since 1943. All errors somehow decouples an electromechanical system, transforming it into a purely mechanical system. In this work we discuss one of these errors.

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1) Roberta Lima, Associate Professor: PUC-Rio, R. Marquês de São Vicente, 225 - Gávea, Brazil (BR), roberta_10_lima@hotmail.com.

2) Rubens Sampaio, Professor: PUC-Rio, R. Marquês de São Vicente, 225 - Gávea, Brazil (BR), rsampaio@puc-rio.br, the author presented this contribution at the conference in the special session "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

3) Peter Hagedorn, Professor: TU Darmstadt, Dolivostr. 15 64293 Darmstadt, Germany, Germany (DE), peter.hagedorn@dyn.tu-darmstadt.de.

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paper id: STA311

Vortex induced vibrations (VIV) in rotating blade structures

Grzegorz Stachyra, Jerzy Warmiński

Abstract: Aerodynamic forces play an important role in rotating structures like helicopter blades or wind turbines. They may lead to complex dynamics if flutter condition arises. In this paper we consider model of a rotating composite blade deformed by flow pressure. These deformations influence airflow and composite blade vortex induced vibrations. Therefore, Fluid-Structure Interactions (FSI) analysis is needed to evaluate rotating blade and accompanying effects. In the analytical part of this paper Euler-Bernoulli beam theory is used for the composite beam and Van der Pol equation is applied to represent the vortex induced vibrations. The influence of fluid flow and composite blade vibrations are investigated in this study.

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[1] Grzegorz Stachyra, M.Sc. (Ph.D. student): Lublin University of Technology, Department of Applied Mechanics, ul. Nadbystrzycka 36 20-618 Lublin, Poland, Poland (PL), g.stachyra@pollub.pl.

[2] Jerzy Warmiński, Professor: Lublin University of Technology, Department of Applied Mechanics, ul. Nadbystrzycka 36 20-618 Lublin, Poland, Poland (PL), j.warminski@pollub.pl.

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paper id: ASY230

Systems with fast limit cycles and slow interaction

Ferdinand Verhulst

Abstract: Systems with fast limit cycles and slow interaction We will review the theory of slow-fast systems that started with papers by Tykhonov, Pontryagin, Levinson, Anosov, Fenichel and other scientists. After this review we focus on systems with limit cycles. The Pontryagin-Rodygin theorem for slow-fast systems has an ingenious proof, it has as advantage that it can be applied if the slow manifolds of the slow-fast system are all unstable. A serious disadvantage is that for application we have to know the fast solutions explicitly with the slow part in the form of parameters. Another disadvantage is the relatively short timescale where the results are valid. In practice there are very few cases where the theorem applies. However, the Pontryagin-Rodygin idea can be used again on assuming that the fast limit cycle arises in higher order approximation; this allows an approximation approach to study the slow motion. At this point we have still a restricted timescale but extension is then possible by looking for continuation on stable, in particular slow manifolds. We will demonstrate this extension of the theory by studying various types of self-excited, coupled slow and fast Van der Pol oscillators.

[1)] Ferdinand Verhulst, Professor: University of Utrecht, PO Box 80.010, 3508 TA Utrecht, Netherlands (NL), f.verhulst@uu.nl, the author presented this contribution at the conference in the special session "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

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paper id: STA47

Dynamics and control of self-excited system under parametric or external excitations and time delay

Jerzy Warminski

Abstract: Self-excited vibrations which may occur in many mechanical systems are well known and deeply studied in the literature. However, the phenomena typical for this type of vibrations may change if they interact with different vibrations which may occur at the same time. Classical examples are vortex–induced vibrations occurring owing to fluid flow, which may interact with vibrations generated by different mechanisms, such as parametric excitation or external loading. One of the important effect of such interactions is quasi-periodic oscillation composed of at least two incommensurate frequencies which near the resonance zones bifurcates into periodic one via Hopf bifurcation of the second kind. Then, the so called frequency locking phenomenon is observed. The self-excitation frequency is locked by parametric or external excitation and large periodic oscillations arise. Dynamics of the system can be controlled by added time delay input. The goal of this paper is to study analytical model of a self-excited oscillator driven by parametric or external excitation with added time delay signal which is treated as an input supplied from the controller. The influence of time delay on bifurcation scenario and vibration control will be demonstrated analytically by the multiple time scale method applied to time delayed system and also numerically by direct numerical simulations of the original delayed ordinary differential equations.

[1)] Jerzy Warminski, Professor: Lublin University of Technology, Nadbystrzycka 38D, Poland (PL), j.warminski@pollub.pl, the author presented this contribution at the conference in the special session "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

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Dynamics of MEMS Coriolis Vibrating Gyroscope with an annular disk resonator under parametric excitation

Ekaterina Zavorotneva, Alexei Lukin, Ivan Popov

Abstract: Dynamics of MEMS Coriolis Vibrating Gyroscope with an annular disk resonator under parametric excitation In the present work the dynamics of MEMS Coriolis Vibrating Gyroscope (CVG) with an annular disk resonator is investigated. The analytical formulation of the problem of disk free in-plane bending-mode oscillations is derived and investigated. The frequencies and modes of the disk oscillations on a fixed and rotating platforms are determined using the collocation method for boundary value problems as well as using the finite element method. Comparison of solutions with the thin ring formulation is performed. On the basis of the Hamilton variational principle, an analytical formulation of the problem of plane oscillations of a rotating disk is formulated, taking into account the assumption of the inextensibility of annular fibers of the disk. The Bryan effect is studied for an ideal disk resonator, namely, the effect of centrifugal and Coriolis inertial forces on the frequencies and modes of oscillation. An analytical discrete model of a CVG with a disk resonator is constructed. Based on well-known in literature methods of electronic restoration of an imperfect vibratory gyro to an ideal state, the dynamics of a CVG in parametric excitation regime is analyzed taking into account anisotropic viscosity of the resonator and action of Coriolis forces.

[1] Ekaterina Zavorotneva, M.Sc. (Ph.D. student): Peter the Great St.Petersburg Polytechnic University (SPbPU), Russia, 195251, St.Petersburg, Polytechnicheskaya, 29, Russia (RU), zavorotneva.ev@gmail.com, the author presented this contribution at the conference in the special session "Dynamics of parametric and self-excited systems: analysis and applications" organized by F. Dohnal and J. Warmiński.

[2] Alexei Lukin, M.Sc.: Peter the Great St.Petersburg Polytechnic University (SPbPU), Russia, 195251, St.Petersburg, Polytechnicheskaya, 29, Russia (RU), lukinalexei@yandex.ru.

[3] Ivan Popov, M.Sc.: Peter the Great St.Petersburg Polytechnic University, St.Petersburg, Russia, 195251, St.Petersburg, Polytechnicheskaya, 29, Russia (RU), lukinalexei@yandex.ru.

SPECIAL SESSION 5

15th INTERNATIONAL CONFERENCE
Dynamical Systems — Theory and Applications
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paper id: VIB134

Two-mode low-frequency approximations for anti-plane shear of a high-contrast asymmetric laminate

Mohammed Alkinidri, Ludmila Prikazchikova, Julius Kaplunov

Abstract: The anti-plane shear of a three-layered laminate of an asymmetric structure is considered. The chosen geometry of the laminate couples its symmetric and anti-symmetric motions. A high contrast in mechanical properties of the inner and outer layers is assumed. The types of contrast for which the lowest cut-off frequency of the first harmonic is close to zero are revealed. In case of a laminate with traction-free faces two-mode approximations of the exact dispersion relations incorporating both the fundamental mode and the first harmonic are derived. The accuracy of the asymptotic approximations is tested versus the solutions of the original dispersion relation. The associated 2D differential equations of motion are developed. In addition, the boundary conditions based on the Saint-Venant principle are proposed.

[1] Mohammed Alkinidri, M.Sc. (Ph.D. student): Keele University, Keele, Staffordshire, ST5 5BG, England (GB), m.o.s.alkinidri@keele.ac.uk .

[2] Ludmila Prikazchikova, Ph.D.: Keele University, Keele, Staffordshire, ST5 5BG, England (GB), l.prikazchikova@keele.ac.uk .

[3] Julius Kaplunov, Professor: Keele University, Keele, Staffordshire, ST5 5BG, England (GB), j.kaplunov@keele.ac.uk , the author presented this contribution at the conference in the special session: "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

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Low and high frequency dynamic models and modes coupling in vibration of a non-linear lattice

Igor Andrianov, Vladyslav Danishevskyy, Bernd Markert

Abstract: Lattice-type models are widely used to describe vibrations in crystals, cellular structures, bone tissues, polymer molecules and atomic lattices. We study vibrations of a 1D monatomic cubically non-linear lattice. Continualization procedure is developed and coupled macroscopic equations for low frequency (acoustic) and high frequency (optical) modes are derived. Numerical simulations are performed using the Runge-Kutta procedure. Asymptotic solutions are obtained by the method of multiple time scales. Non-linearity gives rise to internal resonances and induces energy transfers from low to high order modes. In the continuous limit, an infinite number of modes can be coupled, so the system does not allow truncation. It is shown that heterogeneity compensates the influence of non-linearity and restricts energy transfers between the resonant modes. Therefore, it becomes possible to justify a truncation to only a few leading modes. The obtained results can be applied to facilitate the development of new methods of non-destructive testing. Measuring the characteristics of non-linear vibrations at different amplitudes allows one to receive more precise information about the properties of heterogeneous structures. Changing characteristics of the microstructure (e.g., using piezoelectric effects) makes it possible to tune the macroscopic dynamic response. This can be useful for a design of new acoustic control devices and smart materials. This work was supported by the Exploratory Research Space RWTH Aachen University through Theodore von Kármán Fellowship (for V.V. Danishevskyy).

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[1] Igor Andrianov, Professor: Institute of General Mechanics, RWTH Aachen University, Templergraben 64, 52062 Aachen, Germany (DE), igor_andrianov@hotmail.com.

[2] Vladyslav Danishevskyy, Professor: Department of Structural Mechanics and Strength of Materials, Prydniprovska State Academy of Civil Engineering and Architectute, Chernyshevskogo St. 24a, Dnipro 49600, Ukraine (UA), vladyslav.danishevskyy@gmail.com, the author presented this contribution at the conference in the special session "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[3] Bernd Markert, Professor: Institute of General Mechanics, RWTH Aachen University, Templergraben 64, 52062 Aachen, Germany (DE), markert@iam.rwth-aachen.de.

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paper id: ASY303

Bolotin's reduce beam model for various boundary conditions

Igor V. Andrianov, Jan Awrejcewicz, Wim T. van Horssen

Abstract: This paper is devoted to the construction of asymptotically correct symplified models of nonlinear beam equations for various boundary conditions. V.V.Bolotin mentioned that in some cases (e.g., if compressed load is near the buckling value) the so-caled „nonlinear inertia" must be taken into account. The effect of nonlinear inertia on the oscillations of the clamped-free beam is investigated in many papers. Bolotin used some physical assumption and did not compare order of nonlinear terms in original equations. Below we propose our way for obtaining this equation, which we will named „Bolotin equations". This approach is based on fractional analysis of original boundary value problems.

[1)] Igor V. Andrianov, Professor: RWTH Aachen University, D-52062, Aachen, Germany (DE), igor.andrianov@gmail.com, the author presented this contribution at the conference in the special session "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[2)] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

[3)] Wim T. van Horssen, Associate Professor: RWTH Aachen University, D-52062, Aachen, Germany (DE), wim.horssen@gmail.com.

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paper id: CON62

Approximate solutions of some classes of dynamic and control problems based on Pade approximations

Mikhail Dmitriev, Yulia Danik

Abstract: Different asymptotic approximations techniques for regularly and singularly perturbed problems are demonstrated on several classes of dynamic and control problems. We consider the initial value problem for a dynamic system of ordinary differential equations with fast and slow motions. We also study the problem of program and synthesizing control functions construction for continuous and discrete systems without constraints, where a small parameter in the system dynamics equations generates regular or singular perturbations. Special attention is paid to Pade approximations construction for the solutions of matrix Riccati equations. Both single-point and two-point Pade approximations are considered. Examples illustrating the algorithms are presented.

[1] Mikhail Dmitriev, Professor: FRC CSC RAS, 119333, Moscow, Vavilova str., 44-2, Russia (RU), mdmitriev@mail.ru, the author presented this contribution at the conference in the special session: "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[2] Yulia Danik, Ph.D.: FRC CSC RAS, 119333, Moscow, Vavilova str., 44-2, Russia (RU), yuliadanik@gmail.com.

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paper id: ASY211

Interchain energy exchange in the DNA coarse-grained model

Margarita Kovaleva, Leonid Manevitch

Abstract: In our report we consider the coarse-grained model of the DNA double-helix. In previous works only small amplitude excitations and stationary dynamics were investigated. We do not restrict our study to small amplitudes and focus on the non-stationary dynamics of the double-helix. Using the approximation of the weak coupling we reduce the system order and consider the interchain energy exchange. Reduced-order model allows us to make analytical prediction of the energy exchange or localization of energy for different parameters of the system. This work was supported by Russian Science Foundation according to the research project no. 16-13-10302

[1)] Margarita Kovaleva, Professor: Semenov Instute of Chemichal Physics Russian Academy of Sciences, Moscow 119991 Kosygin st,4, Russia (RU), margo.kovaleva@gmail.com, the author presented this contribution at the conference in the special session "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[2)] Leonid Manevitch, Professor: Semenov Instute of Chemichal Physics Russian Academy of Sciences, 119991 Moscow, Kosygin st, 4, Russia (RU), margo.kovaleva@gmail.com.

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paper id: ASY213

Beam-like and shell-like nonlinear normal modes interaction of single-walled carbon nanotubes

Leonid Manevitch, Valery Smirnov

Abstract: In the framework of the linear theory, NNMs in the bulk are independent, and therefore, no interactions between them can exist. In order to reveal the mode interaction and the effects, which can arise as its results, we need in the transition to the nonlinear vibration theory. We consider the CNT oscillations in the framework of the nonlinear Sanders-Koiter theory (Amabili 2008). We demonstrate that the effective reduction in the equations of motion in the combination with the asymptotic analysis allows to study the nonlinear mode coupling and to reveal new stationary oscillations, which are absent in the framework of the linear approach, as well as to describe the non-stationary dynamics under condition of the 1:1 resonance. This work was supported by Russian Science Foundation according to the research project no. 16-13-10302

[1] Leonid Manevitch, Professor: Semenov Instute of Chemichal Physics Russian Academy of Sciences, 119991 Moscow, Kosygin st, 4, Russia (RU), manevitchleonid3@gmail.com, the author presented this contribution at the conference in the special session "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[2] Valery Smirnov, Ph.D.: Semenov Instute of Chemichal Physics Russian Academy of Sciences, 119991 Moscow, Kosygin st, 4, Russia (RU), smirnovvv@gmail.com.

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paper id: VIB133

Surface waves in a multi-layered elastic half-space

Ali Mubaraki, Danila Prikazchikov

Abstract: The study is focussed on surface waves on an isotropic elastic half-space coated with a thin multi-layer laminate induced by a prescribed vertical surface stress. The effective boundary conditions modelling a multi-layered coating are derived at the long-wave limit, generalising the effective boundary conditions for a thin single layer, see e.g. [1,2]. A singularly perturbed hyperbolic equation on the interface is then derived, extending the previous consideration in [3,4]. The effect of the perturbative pseudo-differential operator including the structure of the emerging quasi-front is analysed. Finally, some numerical illustrations of surface wave field are presented. 1. Tiersten, H. F. "Elastic surface waves guided by thin films." Journal of Applied Physics 40.2 (1969): 770-789. 2. Vinh, P.C., and Linh, N.T.K. "An approximate secular equation of Rayleigh waves propagating in an orthotropic elastic half-space coated by a thin orthotropic elastic layer." Wave Motion 49.7 (2012): 681-689. 3. Dai, H-H., Kaplunov, J., and Prikazchikov, D.A. "A long-wave model for the surface elastic wave in a coated half-space." Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences 466.2122 (2010): 3097-3116. 4. Kaplunov, J., and Prikazchikov, D.A. "Asymptotic theory for Rayleigh and Rayleigh-type waves." Advances in Applied Mechanics. Vol. 50. Elsevier, 2017. 1-106.

[1] Ali Mubaraki, M.Sc. (Ph.D. student): Keele University, Keele, Staffordshire, ST5 5BG, England (GB), a.m.a.mubaraki@keele.ac.uk , the author presented this contribution at the conference in the special session: "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[2] Danila Prikazchikov, Ph.D.: Keele University, Keele, Staffordshire, ST5 5BG, England (GB), d.prikazchikov@keele.ac.uk .

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paper id: ENG21

Mathematical model and a prototype of a linear motor controlled by a periodic magnetic field

Klaus Zimmermann, Igor Zeidis, Simon Gast, Florian Schale, Michel Rohn, Victor Lysenko

Abstract: A mathematical model and a prototype of a linear motor in which the rod moves progressively are presented. The motion of the rod occurs due to the periodic motion of cylinders with electric coils integrated in them. The net displacement of the cylinders for a period is equal to zero. The periodic motion of the cylinders is caused by the force generated by a periodic magnetic field (the magnetic field periodically switches on and off). The space between the rod and the cylinders is filled in with a magnetorheological fluid. The viscosity of the magnetorheological fluid (and, hence, friction) at constant temperature depends on the magnitude of the magnetic field and the concentration of the particles and changes as the magnetic field changes. This provides an asymmetry of the friction for forward and backward motions, which enables the forward net displacement of the rod for the period. A mathematical model of such a motion is presented. An expression for the average velocity of the motion of the rod is obtained for the case where the force of friction is assumed to be small in comparison of the motive force. The value of the average velocity is studied as a function of the excitation parameters and the properties of the magnetorheological fluid. On the basis of the theoretical principles outlined above, a prototype of the linear motor was created.

[1] Klaus Zimmermann, Professor: Technische Universitaet Ilmenau, PF 100565 D-98684 Ilmenau, Germany (DE), klaus.zimmermann@tu-ilmenau.de, the author presented this contribution at the conference in the special session: "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[2] Igor Zeidis, Ph.D.: Technische Universitaet Ilmenau, PF 100565 D-98684 Ilmenau, Germany (DE), igor.zeidis@tu-ilmenau.de.

[3] Simon Gast, M.Sc. (Ph.D. student): Technische Universitaet Ilmenau, PF 100565 D-98684 Ilmenau, Germany (DE), simon.gast@tu-ilmenau.de.

[4] Florian Schale, Ph.D.: Technische Universitaet Ilmenau, Pf 100565 D-98684 Ilmenau, Germany (DE), florian.schale@tu-ilmenau.de.

[5] Michel Rohn, B.A. (M.Sc. student): Technische Universitaet Ilmenau, PF 100565 D-98684 Ilmenau, Germany (DE), michel.rohn@tu-ilmenau.de.

[6] Victor Lysenko, Associate Professor: Belarusian National Technical University, Belarus, 220013, Minsk, Nezavisimosty Ave., 65, Belarus (BY), victor_lysenko@mail.ru.

SPECIAL SESSION 6

15th INTERNATIONAL CONFERENCE

Dynamical Systems — Theory and Applications

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paper id: LIF189

Bending vibration systems as tactile sensors for contact point detection using natural frequencies

Carsten Behn, Daniel Baldeweg, Christoph Will

Abstract: In recent years, bending beam vibrations are analyzed in context to develop biologically inspired sensor systems. Here, this paper contributes to this field and we extend results from conservative systems to dissipative ones herein. We use mechanical models – inspired by the vibrissae of rats and mice – to determine the distance to an object (contact detection) and to get hints for a technical implementation. In contrast to literature, we extend our models to more realistic ones in incorporating fundamental features of a vibrissae: the viscoelasticity of the Follicle-Sinus complex (FSC, support of the vibrissa) and of the skin. Moreover, the conical shape is taken into account, as well, to study the impact of these features on the dynamics. Due to the complexity of previous models, we model the FSC as a viscoelastic-foundation, the skin as a discrete spring-damper-combination, and the conical shape using a three segmented rod with different diameters. The contact point is firstly modeled as a (fixed) bearing. To determine the distance out of the eigenvalues / natural frequencies (later measured in experiments), we develop an algorithm that is tested to be valid for our models.

[1] Carsten Behn, Professor: Schmalkalden University of Applied Sciences, Faculty of Mechanical Engineering, Blechhammer 4-9, 98574 Schmalkalden, Germany (DE), c.behn@hs-sm.de, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

[2] Daniel Baldeweg, M.Sc.: Schaeffler Technologies AG&Co. KG, Industriestraße 1-3, 91074 Herzogenaurach, Germany (DE), daniel.baldeweg@schaeffler.com.

[3] Christoph Will, Ph.D.: Daimler AG, RD/USN, HPC X901, 71059 Sindelfingen, Germany (DE), christoph.c.will@daimler.com.

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The mechanical background of devices for balancing skill development

László Bencsik, Dalma Nagy, Ambrus Zelei, Tamás Insperger

Abstract: In the studies dealing with the analyses of balancing, the falling in elderly age is mentioned as the main motivation. It can be considered as a generation problem in our aging society. Besides, the motion therapy is another important field, where the understanding of the mechanism of balancing can help. In our society the number of premature babies is increasing, many of them requires intensive motion therapy. The natural learning of different motions and upright standing is a really long process during infancy and childhood. In case of children with dyspraxia or other disabilities the learning process has to be assisted and accelerated. Most of the balancing improvement trainings are based on simple devices like the balance board, the Bosu ball or the Huple which is a Hungarian development especially for children. By means of the destabilization effect, these devices make the upright standing harder, which is not simple anyway. One can feel that standing on one of these devices is much more unstable and requires high concentration. The aim of this is work is to analyse the mechanical background of this problem and verify the usability of these devices with motion capturing. By using engineering approaches, quantitative performance measures are introduced, which assist the mainly visual observation based existing scoring systems. The proposed process utilizes the mechanical model of the human and the balancing device.

[1)] László Bencsik, Ph.D.: MTA BME Research Group on Dynamics of Machines and Vehicles, Muegyetem rkp. 3-5. Budapest, 1111, Hungary (HU), bencsik@mm.bme.hu.

[2)] Dalma Nagy, M.Sc. (Ph.D. student): Budapest University of Technology and Economics, Muegyetem rkp. 3-5. Budapest, 1111, Hungary (HU), dalma.nagy@mm.bme.hu.

[3)] Ambrus Zelei, Ph.D.: MTA BME Research Group on Dynamics of Machines and Vehicles, Muegyetem rkp. 3-5. Budapest, 1111, Hungary (HU), zelei.ambrus@gmail.com, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

[4)] Tamás Insperger, Professor: MTA BME Lendület Human Balancing Research Group, Muegyetem rkp. 3-5. Budapest, 1111, Hungary (HU), insperger@mm.bme.hu.

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paper id: LIF200

Synchronisation of biological oscillators in reproductive biology

Andjelka Hedrih

Abstract: Sex hormones influence many physiological processes in organism including neuronal excitability and behaviour. Secretion and concentrations of sex hormones in both genders show circadian rhythm as well as seasonal variations. Secretion of sex hormones together with secretion of FSH, LH and GRH can be considered as a complex dynamical system with oscillatory character. The aim of this study is to model dynamics of secretion of male sex hormones and FSH, LH and GRH as a complex oscillator. This complex oscillator consists of several coupled subsystems. Conditions for synchronisation between units of this complex oscillator is analysed and discussed. Synchronisation is important for keeping the homeostasis of an individual. Key words: sex hormones, complex oscillator, synchronisation Acknowledgement: Parts of this research were supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia through the Mathematical Institute of the SASA, Belgrade Project ON174001 “Dynamics of hybrid systems with complex structures. Mechanics of materials”. References: Åshild Bjørnerem Bjørn Straume Pål Øian Gro K. R. Berntsen. Seasonal Variation of Estradiol, Follicle Stimulating Hormone, and Dehydroepiandrosterone Sulfate in Women and Men. The Journal of Clinical Endocrinology and Metabolism, 2006, 91(10):3798–380. Katica (Stevanović) Hedrih. Rheonomic coordinate method applied to nonlinear vibration systems with hereditary elements. Facta Universitatis, 2000, 2(10):1111-1135. UDC 534.01:531.53(045)

[1] Andjelka Hedrih, Ph.D.: Department of mechanics, Mathematical institute of Serbian Academy of Sciences and Arts, Kneza Mihaila 36, 11 000 Belgrade, Serbia (RS), handjelka@hm.co.rs, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

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Influence of the shoe type on the ground reaction forces during gait

Małgorzata Klepczyńska, Bartłomiej Zagrodny, Wiktoria Wojnicz, Michał Ludwicki, Jan Awrejcewicz

Abstract: Aim: The aim of this research was to estimate a relationship between the type of footwear and ground reactions forces during gait, and its influence on postural stability. Background: Most of the experiments dedicated to gait analysis are made barefoot. This type of research does not give any information about the influence of shoe-type on GRF. Also, the influence of the shoe type on postural stability, like body sway and center of pressure displacement is still unclear. In the literature no complex study performed by male and female volunteers in different shoe types can be found, i.e. no experiment was done in which each of the volunteers was performed gait in different footwear and barefoot in one session. Materials and methods: 7 women and 5 men took part in the experiment. Each of them performed a gait on the force platform in different shoe types - with different heel height and stiffness. Women walk: barefoot, in shoes with flat, profiled sole, high-heels and men: barefoot, suit shoes and sports shoes Also, one minute stabilograms were recorded. Results: Results revealed differences in maximal values of ground reaction forces for different footwear types and their influence on static stability, like amplitude of COP medio-lateral and anterio-posterior. Also kinetic, like time of support phase, heel-off and toe-off phase changed. Moreover, an influence of the shoe type on the M-L, A-P and vertical forces are described. Acknowledgment: The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700.

[1] Małgorzata Klepczyńska, M.Sc.: Lodz University of Technology, Stefanowskiego 1/15, Poland (PL), bartlomiej.zagrodny@p.lodz.pl.

[2] Bartłomiej Zagrodny, Ph.D.: Lodz University of Technology, Stefanowskiego 1/15, Poland (PL), bartlomiej.zagrodny@p.lodz.pl, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

[3] Wiktoria Wojnicz, Associate Professor: Gdańsk University of Technology, Gdańsk, ul. Gabriela Narutowicza 11/12, Poland (PL), wiktoria.wojnicz@pg.edu.pl.

[4] Michał Ludwicki, Ph.D.: Lodz University of Technology, Stefanowskiego 1/15, Poland (PL), michal.ludwicki@p.lodz.pl.

[5] Jan Awrejcewicz, Professor: Lodz University of Technology, jan.awrejcewicz@p.lodz.pl, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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Snake robot based on McKibben Pneumatic Artificial Muscles

Katarzyna Koter, Lukasz Fracczak, Kalina Chojnacka, Konrad Jablonski, Sandra Zarychta, Leszek Podsedkowski

Abstract: This paper presents a novel design of a snake robot based on McKibben Pneumatic Artificial Muscles. The construction is created of serially connected McKibben PAMs in order to create long muscle line, which can be instantly inflated with compressed air. The innovative construction allows an achievement of efficient snake-type movement irrespective of the robot length. The use of pneumatic drive ensures a long working range and a much smaller diameter than conventional solutions. External control system, which is robot supported with, does not impact on size of the robot. These features support the robot with various of applications, impossible to achieve for conventional snake–like constructions. The paper shows construction and research results of McKibben snake robot.

[1)] Katarzyna Koter, Ph.D.: Lodz University of Technology, Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), katarzyna.koter@p.lodz.pl, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

[2)] Lukasz Fracczak, Ph.D.: Lodz University of Technology, Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), lukasz.fracczak@p.lodz.pl.

[3)] Kalina Chojnacka, M.Sc.: Lodz University of Technology, Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), 182798@edu.p.lodz.pl.

[4)] Konrad Jablonski, M.Sc.: Lodz University of Technology, Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), 174404@edu.p.lodz.pl.

[5)] Sandra Zarychta, B.A. (M.Sc. student): Lodz University of Technology, Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), 202662@edu.p.lodz.pl.

[6)] Leszek Podsedkowski, Professor: Lodz University of Technology, Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), leszek.podsedkowski@p.lodz.pl.

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paper id: CON199

A double pendulum in 3 dimensions – a model-based analysis of the balancing human body

Balint Petro, Rita M. Kiss

Abstract: Typically, the dynamic model applied in the analysis of upright human posture is a single- or multi-segment model, i.e. an inverted pendulum. Most pendulum models are constrained in a single plane and therefore unable to capture the cross-dimensional compensatory effects that humans demonstrate. We aim to show our most recent work utilising a 4-degrees-of-freedom, two-link double pendulum model to identify or mimic the natural controller in the case of free swaying in bipedal stance. We simulated the forward kinematics of the model with several different types of controllers and control strategies, including various control variables and a range of control parameters. Comparing the simulated motion with human motion capture recordings, the goal is to identify the control strategies that most closely resemble natural movement.

1) Balint Petro, M.Sc. (Ph.D. student): Budapest University of Technology and Economics, 1111 Budapest, Muegyetem rkp 3, Hungary (HU), petro@mogi.bme.hu, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

2) Rita M. Kiss, Professor: Budapest University of Technology and Economics, 1111 Budapest, Muegyetem rkp 3, Hungary (HU), rita.kiss@mogi.bme.hu.

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Bio-Inspired Tactile Sensing: Distinction of the overall object contour and macroscopic surface features

Moritz Scharff, Lukas Merker

Abstract: Vibrissae of rats are part of the somatosensory system. A tactile stimulus along the hair shaft is transmitted to the Follicle-Sinus complex and transduced into an action potential by mechanoreceptors. The signal contains information about the texture of the contacted object including the overall contour, the waviness (macroscopic feature) and the roughness (microscopic feature). Here, the overall contour and the waviness of an object are analyzed using an artificial vibrissa-like sensor that is dynamically swept along the object. The natural vibrissa is replaced by a cylindrical steel wire and the Follicle-Sinus complex by a force / torque sensor, respectively. The overall object contour is designed as a sine wave (long wavelength) and is super-imposed by a second sine wave with a shorter wavelength in order to represent the waviness. A procedure to distinguish both components is developed and successfully applied. The combination of the sensor shape and the scanning conditions -- for example, the large, nonlinear deformation of the sensor shaft -- operate like a morphological filter and consequently influences the detected profile features.

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1) Moritz Scharff, M.Sc. (Ph.D. student): Technical Mechanics Group, Technische Universität Ilmenau, Max-Planck-Ring 12 (Werner-Bischoff-Building), 98693 Ilmenau, Germany (DE), moritz.scharff@tu-ilmenau.de .

2) Lukas Merker, M.Sc. (Ph.D. student): Technical Mechanics Group, Technische Universität Ilmenau, Max-Planck-Ring 12 (Werner-Bischoff-Building), 98693 Ilmenau, Germany (DE), lukas.merker@tu-ilmenau.de , the author presented this contribution at the conference in the special session: "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: LIF305

Biomechanical analysis of different foot morphology during standing on a dynamic support surface

Yang Shu, Jan Awrejcewicz, Bartłomiej Zagrodny

Abstract: From the research of habitually barefoot people and habitually shod people, there were significant differences in distance between the hallux and the interphalangeal joint of the second toe. Habitually shod males had a high risk of injury because of the lack of toes function. Based on these differences, expanding the distance between the hallux and other toes could increase the ability of hallux, especially the balance. In order to analyse the influence of hallux during balance, three conditions were set with light silica instruments: 1) normal toes, 2) expanding toes, 3) binding toes. A total of 20 young healthy males participated in this study. The six degrees of freedom (6-DOF) transportation vibration platform was used to be undergoing continuous sinusoidal translation. The amplitude of the platform used a sine wave with frequency of amplitude 3 and 1 rad/s ($y = 3\sin 2\pi x$). The PEDAR insole system was used to measure the trajectory of the centre of pressure (COP) and plantar pressure distribution. The plantar surface of the foot was divided into eight areas based on the anatomy of the foot. From the results, Binding Toes showed large postural sway in not only COP, but also forefoot. It indicated that control the toes function would cause instability. Conversely, Expending Toes has less postural sway and instability than normal toes and binding toes. It suggested that the balance ability would increase with the increasing of toes function.

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[1] Yang Shu, M.Sc. (Ph.D. student): Department of Automation, Biomechanics and Mechatronics. Lodz University of Technology, Piotrkowska 277a, IX Dom Studenta Politechniki Lodzkiej, 90-457, Lodz, Poland (PL), earlshu@aliyun.com, the author presented this contribution at the conference in the special session "A special session dedicated to Prof. Miguel A.F. Sanjuán on the occasion of the celebration of his 60th anniversary" organized by J. Awrejcewicz.

[2] Jan Awrejcewicz, Professor: Department of Automation, Biomechanics and Mechatronics. Lodz University of Technology, 1/15 Stefanowski Street (building A22), 90-924 Łódź, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[3] Bartłomiej Zagrodny, Ph.D.: Department of Automation, Biomechanics and Mechatronics. Lodz University of Technology, 1/15 Stefanowski Street (building A22), 90-924 Łódź, Poland (PL), bartlomiej.zagrodny@p.lodz.pl.

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Identification of muscle forces of upper limbs based on the registration of motion capture system

Tomasz Walczak, Grażyna Sypniewska-Kamińska, Renata Ferduła, Adam Pogorzała

Abstract: The biomechanical model of the human body with the aim of identification of the muscles forces of the upper limb during basic activities is proposed in the paper. In the assumed multibody model of the human body which is relatively simple, the body segments are treated as rigid bodies interconnected via ideal joints, and only the forces of the main muscles of the upper limbs are taken into account. At other joints of the model are identified the torques produced by whole groups of the muscles. The equations of motion are obtained using the Lagrange formalism. Such a description allows to determining the forces and the torques generated by the human muscles for any considered motion, where the geometrical and mass properties of the body segments, and their velocities and accelerations are known. The necessary data concerning the chosen kind of motion of the human body are registered and collected by the system BTS dedicated to the analysis of motion. The proposed mechanical model together with its mathematical description and the optimization method applied could be useful to more accurate research of human muscles work properties, and overloading of the joints during many human physical activities.

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[1] Tomasz Walczak, Ph.D.: Institute of Applied Mechanics, Poznan University of Technology, pl. M. Skłodowskiej-Curie 5, 60-965 Poznań, Poland (PL), tomasz.walczak@put.poznan.pl, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

[2] Grażyna Sypniewska-Kamińska, Ph.D.: Institute of Applied Mechanics, Poznan University of Technology, pl. M. Skłodowskiej-Curie 5, 60-965 Poznań, Poland (PL), grazyna.sypniewska-kaminska@put.poznan.pl.

[3] Renata Ferduła, M.Sc. (Ph.D. student): Institute of Applied Mechanics, Poznan University of Technology, pl. M. Skłodowskiej-Curie 5, 60-965 Poznań, Poland (PL), renata.ferdula@gmail.com.

[4] Adam Pogorzała, Ph.D.: Institute of Health Sciences, Hipolit Cegielski State College of Higher Education in Gniezno, ul. Ks. Kard. Stefana Wyszyńskiego 38 62-200 Gniezno, Poland (PL), adampogorzala@gmail.com.

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paper id: LIF142

Multibody models for gait analysis

Wiktoria Wojnicz, Bartłomiej Zagrodny, Michał Ludwicki, Jerzy Mrozowski, Jan Awrejcewicz, Edmund Wittbrodt

Abstract: The aim of this study was to create multibody biomechanical models for normal gait analysis. Proposed models can be used to identify joint moments of the lower limbs during normal gait in the single support and the double support phase. Applying Newton-Euler formulation, six planar models were developed: 1) a mathematical 6DOF model describing a gait in the sagittal plane of the body for single support phase; 2) a mathematical 6DOF model describing a gait in the sagittal plane of the body for double support phase; 3) a mathematical 7DOF model describing a gait in the sagittal plane of the body for single support phase; 4) a mathematical 7DOF model describing a gait in the sagittal plane of the body for double support; 5) a mathematical 7DOF model describing a gait in the frontal plane of the body for single support phase; 6) a mathematical 7DOF model describing a gait in the frontal plane of the body for double support phase. Proposed mathematical models can be applied to solve a forward dynamic task or an inverse dynamic task. A validation of these models had been performed by comparing results measured over examination of normal human gait and results calculated by solving an inverse dynamic task. Acknowledgment: The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700.

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[1] Wiktoria Wojnicz, Associate Professor: Gdansk University of Technology, str. G. Narutowicza 11/12, 80-233 Gdansk, Poland (PL), wiktoria.wojnicz@pg.edu.pl, the author presented this contribution at the conference in the special session "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

[2] Bartłomiej Zagrodny, Ph.D.: Lodz University of Technology, str. Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), bartlomiej.zagrodny@p.lodz.pl.

[3] Michał Ludwicki, Ph.D.: Lodz University of Technology, str. Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), michal.ludwicki@p.lodz.pl.

[4] Jerzy Mrozowski, Associate Professor: Lodz University of Technology, str. Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), jerzy.mrozowski@p.lodz.pl.

[5] Jan Awrejcewicz, Professor: Lodz University of Technology, str. Stefanowskiego 1/15, 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[6] Edmund Wittbrodt, Professor: Gdansk University of Technology, str. G. Narutowicza 11/12, 80-233 Gdansk, Poland (PL), edmund.wittbrodt@pg.edu.pl.

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paper id: LIF167

Antropomorfic parameters of a nonlinear dynamic model of self-sustained hopping

Liliána Zajcsuk, Giuseppe Habib, Ambrus M. Zelei

Abstract: In this work, we study the dynamics of legged locomotion adopting a combination of experiments and mathematical models. Our recently developed planar model is capable of self-sustained human-like hopping motion. However, the biomechanical indicators, such as joint angle ranges, joint velocities and joint torques which provide stable motions are not compatible with realistic parameter values. In general, parameters can be optimized with respect to a variety of cost functions, such as energy efficiency, impact reduction, locomotion speed or hopping height. In contrast to these performance measures, our current objective is to minimize the gap between the measurement and simulation results of human locomotion in terms of the aforementioned biomechanical indicators. This will finally provide realistic anthropomorphic motion, reducing the gap between real life legged locomotion and locomotion based on mathematical models.

1) Liliána Zajcsuk, B.A. (M.Sc. student): Dept. of Applied Mechanics - Budapest University of Technology and Economics, 1111 Budapest, Műegyetem rkp. 5., Hungary (HU), lilizajcsuk@gmail.com .

2) Giuseppe Habib, Ph.D.: Dept. of Applied Mechanics - Budapest University of Technology and Economics, 1111 Budapest, Műegyetem rkp. 5., Hungary (HU), habib@mm.bme.hu .

3) Ambrus M. Zelei, Ph.D.: Dept. of Applied Mechanics - Budapest University of Technology and Economics, 1111 Budapest, Műegyetem rkp. 5., Hungary (HU), zelei@mm.bme.hu , the author presented this contribution at the conference in the special session: "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: MTR121

Structure and control strategies of exoskeletons for fatigue limitation of a healthy man

Adam Zawadzki, Tomasz Mirosław, Jakub Deda, Zbigniew Żebrowski

Abstract: During last few years an idea of exoskeletons amplifying human force and reducing body effort during activities turned to be a real solution. Because of many interdisciplinary problems – medical, mechanical and mechatronics – and individual features of human body, designs are still looking for better and better solutions. A lot of money are spent for research, especially when we take into account almost unlimited application of such an equipment. Some designers are following the leaders in this domain and don't see other efficient solutions which are well known for many years. In this paper authors present overview of solutions and applications of exoskeletons for healthy men with oriented on ergonomics and energy management aspects. For energy management aspects authors present analyses of typical movement and energy conversion in human body. The mechanic, electric and hydraulic drive solutions are presented and characterized by their possibilities to follow the human body. The new hybrid solution with energy saving and recuperation is presented. Authors of this paper aim on providing a concise comparison between most commonly used control strategies for exoskeletons for healthy persons. The paper will focus on reviewing most common strategies and analyzing them in terms of utilizing in products for the rescue services and the army. The conclusions for each solution will be backed up with authors experiences on this field coming from developing own solution of a lower limb exoskeleton for soldiers and rescue services.

[1] Adam Zawadzki, M.Sc.: Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), adam.zawadzki@pw.edu.pl , the author presented this contribution at the conference in the special session: "Analysis and control of bioinspired and biomimetic dynamical systems — sensors, manipulators and locomotors" organized by C. Behn and A.M. Zelei.

[2] Tomasz Mirosław, Ph.D.: Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), tomasz.miroslaw@pw.edu.pl .

[3] Jakub Deda, M.Sc. (Ph.D. student): Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), jakub.deda@pw.edu.pl .

[4] Zbigniew Żebrowski, Associate Professor: Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), zbigniew.zebrowski@pw.edu.pl .

SPECIAL SESSION 7

15th INTERNATIONAL CONFERENCE
Dynamical Systems — Theory and Applications
December 2-5, 2019. Lodz, POLAND.
paper id: CON155

Dynamic identification method for determining the plastic properties of the material used as a front layer of impact shields

Miroslaw Bocian, Krzysztof Jamroziak, Maciej Kulisiewicz

Abstract: Impact shields are now being built from several layers of materials with various mechanical properties. Substantially the first protective layer (front one) is made of lightweight materials with plastic or plastic-elastic properties, while the next layer is remarkably elastic (e.g., armored steel). The above makes it necessary to analyze the phenomenon of piercing using a model in the form of a dynamic Maxwell-type system, and to determine its parameters. This paper presents the original method of determining the parameters characterizing the plastic properties of the front layer. In the Maxwell model it was assumed that these properties describe two rheological elements. These are a linear silencer in a parallel connection with a Coulomb friction element. The components occur next to a linear elastic part. However, the next layer appearing in the model has elastic properties. In the development of the identification method, the method of energy balance for harmonic excitation was used.

[1] Miroslaw Bocian, Ph.D.: Department of Mechanics, Materials Science and Engineering, Wroclaw University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wroclaw, Poland (PL), miroslaw.bocian@pwr.edu.pl .

[2] Krzysztof Jamroziak, Associate Professor: Department of Mechanics, Materials Science and Engineering, Wroclaw University of Science and Technology, Wybrzeże Wyspiańskiego 27 50-370 Wrocław, Poland (PL), krzysztof.jamroziak@pwr.edu.pl .

[3] Maciej Kulisiewicz, Professor: Faculty of Technology and Engineering, Wroclaw University of Science and Technology, Wybrzeże Wyspiańskiego 27 50-370 Wrocław, Poland (PL), maciej.kulisiewicz@pwr.edu.pl , the author presented this contribution at the conference in the special session: "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: OPT18

Optimal thrust control for the Modified Brachistochrone Problem

Oleg Cherkasov, Nina Smirnova, Sheng Huang

Abstract: The brachistochrone problem with penalty for fuel expenditures of mass-point moving in the vertical plane driven by gravity, nonlinear viscous drag, and thrust is considered. The lifting force or normal component of the reaction force of the curve and the thrust are considered as a control variables. Principle maximum procedure allows to reduce the optimal control problem to the boundary value problem for a set of systems of two nonlinear differential equations. The qualitative analysis of the resulting system allows to study the key features of the extremal trajectories, including asymptotic behavior. Thrust control depending on the velocity and slope angle is designed. The structure of the extremal thrust control program is determined and consequency of the subarcs is established analytically.

[1)] Oleg Cherkasov, Ph.D.: Lomonosov Moscow State University, 119991, Leninskie Gory, 1, Russia (RU), oyuche@yandex.ru, the author presented this contribution at the conference in the special session: "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

[2)] Nina Smirnova, M.Sc.: Lomonosov Moscow State University, 119991, Leninskie Gory, 1, Russia (RU), ninasmirnova247@yandex.ru.

[3)] Sheng Huang, B.A.: National Taiwan University, 10617 No.1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Taiwan (TW), b05501112@ntu.edu.tw.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: MAT34

On features of the contact model of an elastic brake shoe with a wheel

Marat Dosaev

Abstract: A mechanical system consisting of a wheel rotating around a fixed point and a brake shoe fixed by a cylindrical joint is considered. The flexibility of the shoe is modelled using a “small” body-platform, attached to the shoe by means of an elastic spring. The shoe is pressed against the wheel using a pusher device located at a point opposite to the cylindrical hinge. A constant torque is applied to the wheel. The contact between the shoe and the wheel occurs with Coulomb friction. Nonlinear equations of motion of the mechanical system are obtained. The linearised dynamic system is a system of variable structure of the 3rd order. The variability of the structure gives the system properties that are characteristic for nonlinear systems. A second-order system describing the rotation of the shoe is separated (partially?). In this system, depending on the mode of the motion, there are several special points. A numerical simulation of the dynamic system in the in the neighbourhood of singular points has been carried out in order to identify the features of the behaviour of a mechanical system. Two characteristic types of motion were found: damping of the oscillations of the shoe after the wheel stopped, and oscillations of the shoe with increasing amplitude and simultaneous “rattling” of the wheel with constant amplitude and frequency. In particular, it is shown that due to dry friction in the presence of torque, the shoe begins oscillating even from the position of static equilibrium.

[1)] Marat Dosaev, Professor: Lomonosov Moscow State University, 1, Michurinskiy pr-t, Moscow, Russia (RU), dosayev@imec.msu.ru, the author presented this contribution at the conference in the special session: "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

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paper id: MAT35

Friction coefficient estimating in problem of planar motion of a friction-powered robot

Marat Dosaev, Shyh-Shin Hwang, Vitaly Samsonov

Abstract: The design of the robot, driven by friction against the surface of the support and displacement of internal masses, is considered. The robot has one unbalanced rotor and one flywheel. A mathematical model of its plane-parallel motion is constructed. Friction is modelled using Coulomb's law. Angular accelerations of rotating structural elements are selected as control functions. To implement the forward translational motion of the robot, it is necessary to know the coefficient of friction of the body against the surface of the support. An algorithm for estimating this coefficient is proposed.

[1)] Marat Dosaev, Professor: Lomonosov Moscow State University, 1, Michurinskiy pr-t, Moscow, Russia (RU), dosayev@imec.msu.ru, the author presented this contribution at the conference in the special session "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

[2)] Shyh-Shin Hwang, Professor: Chien Hsin University of Science and Technology, 229, Jiang Hsin Rd., Chung-Li District, Taoyuan County, 32097, Taiwan (TW), stanhwang@uch.edu.tw.

[3)] Vitaly Samsonov, Professor: Lomonosov Moscow State University, Institute of Mechanics, 119192, Russia (RU), samson@imec.msu.ru.

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Dynamical Systems — Theory and Applications

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paper id: MAT46

Quasistatic frictional contact problem governed by a variational–hemivariational inequality

Piotr Gamorski

Abstract: A quasistatic nonsmooth frictional contact problem for a viscoelastic material is studied. The contact is modeled by a multivalued normal damped response condition with the Clarke generalized gradient of a locally Lipschitz superpotential and the friction is described by a version of the Coulomb law of dry friction with the friction bound depending on the regularized normal stress. The weak formulation of the contact problem is a history-dependent variational-hemivariational inequality coupled with an operator equation for the stress field. A result on the unique weak solvability to this coupled system is proved through a recent contribution on history-dependent subdifferential inclusions and a fixed point approach.

[1] Piotr Gamorski, M.Sc. (Ph.D. student): Politechnika Łódzka, 90-924 Łódź,ul. Wólczańska 215, Poland (PL), piotrgamorski@gmail.com, the author presented this contribution at the conference in the special session: "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

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Dynamical Systems — Theory and Applications

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paper id: STA151

Singularity analysis of planar 8-bar lever mechanism using screw theory

Elena Gebel, Victor Glazunov

Abstract: As a complexity of robotic application increases, new demands for lighter and quicker mechanism arise. The planar 8-bar lever mechanism under consideration can be viewed as one alternative solution to conventional mechanisms. Singularities are critical configurations in which a mechanism (it does not matter either a planar or spatial mechanism) loses its stiffness and gains or loses some degree of freedom (DOF). These configurations can be found using analytical, numerical or geometrical approaches. Most research works are focused on parallel manipulators, although it is important for planar mechanisms especially for multi-bar linkages because of theirs complex structure. In this paper we have described the novel approach to identifying the singularities of the planar 8-bar lever mechanism based on the inverse matrix of the Plucker coordinates of mechanism's joints.

[1] Elena Gebel, Ph.D.: Omsk State Technical University, Mira avenue, 11, Omsk, 644050, Russia (RU), gebel_es@mail.ru, the author presented this contribution at the conference in the special session "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

[2] Victor Glazunov, Professor: Mechanical Engineering Research Institute of the Russian Academy of Sciences, M. Kharitonʼevskii per., 4, Moscow, 101990, Russia (RU), vaglznv@mail.ru.

15th INTERNATIONAL CONFERENCE

Dynamical Systems — Theory and Applications

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paper id: EXP221

Study on the properties of the microcellular injection molded Polyolefin/Beta Cyclodextrin composites

Chi-chuan Hsu, Shia-chung Chen, Shyh-shin Hwang

Abstract: This study investigated the effects of Beta Cyclodextrin (0.5, 1, 3 wt%) on the tensile strength/thermal properties of microcellular injection molded PP/Beta Cyclodextrin and PPgMA/Beta Cyclodextrin composites. The fillers used, Beta Cyclodextrin, is micro-materials in size. The injection molding process was done by non-foam and microcellular molding. Results showed that the 0.5 wt% loading of Beta Cyclodextrin also had the best tensile strength in three different loading (0.5, 1.0, 3.0 wt%). Tensile strength is related to the filler dispersion in the matrix. Good dispersion resulted in good tensile strength. Tensile strength decreased with addition of Beta Cyclodextrin but impact strength and Young's modulus increased with increasing Beta Cyclodextrin loading. The enhancement was significantly for microcellular molding. The 5wt% Beta Cyclodextrin loading of the composites had the largest storage modulus for PP/ Beta Cyclodextrin micro-composites and 0.5 wt% Beta Cyclodextrin loading had the largest tensile strength for Beta Cyclodextrin nanocomposites. The 1 wt% of Beta Cyclodextrin loading had the highest degradation temperature for PP/Beta Cyclodextrin micro-composites and 3 wt% had the highest degradation temperature for PP/Beta Cyclodextrin nano-composites. Cell size decreased and cell density increased with addition of Beta Cyclodextrin of the PP and PPgMA composites.

[1)] Chi-chuan Hsu, M.Sc. (Ph.D. student): Chung-yuan Christian University, 200 Chung Pei Road, Chung Li District, Taoyuan City, Taiwan 32023, Taiwan (TW), g10102306@cycu.edu.tw.

[2)] Shia-chung Chen, Professor: Chung-yun christian University, 200 Chung Pei Road, Chung Li District, Taoyuan City, Taiwan 32023, Taiwan (TW), scchen@cycu.edu.tw.

[3)] Shyh-shin Hwang, Professor: Chien-hsin University of Science and Technology, No. 229 Chien-hsin RD. Jhongli Dist. Taoyuan, Taiwan (TW), stanhwang@uch.edu.tw, the author presented this contribution at the conference in the special session "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

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Dynamical Systems — Theory and Applications

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paper id: LIF350

Bond graph modeling and simulation of left ventricle of human heart

Mohit Makkar, Saransh Jain

Abstract: To ensure proper functioning of the left ventricle of Human Heart, it is very important to know about its functioning in detail and how other muscles of heart are affecting it. Bond graphs are ideally suited to the modeling of nonlinear, multi-energy systems like left ventricle. The bond graph model for the anatomy of blood around the left ventricle is studied in detail and using this model, suitable results were obtained for different cases like varying after-load conditions. Various parameters and variables were analysed with respect to voume of blood in Left Ventricle and pressure inside it. The results obtained are clearly depicting the mechanism of the left ventricle and looked very promising. A careful study about the constant values has really made the results equivalent to actual results. The model has therefore cast a significant influence over the prediction of performance of left ventricle.

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[1] Mohit Makkar, Ph.D.: The LNMIIT Jaipur, The LNMIIT, Jaipur-302031, India (IN), mohit.makkar@lnmiit.ac.in.

[2] Saransh Jain, B.A. (M.Sc. student): The LNMIIT Jaipur, The LNMIIT, Jaipur-302031, India (IN), saransh.j1997@gmail.com, the author presented this contribution at the conference in the special session "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

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paper id: VIB147

On dynamics of a rigid block on visco-elastic foundation

Yury Selyutskiy, Rinaldo Garziera, Luca Collini

Abstract: We consider a rigid block installed on a visco-elastic foundation in such a way that the foundation interacts both with bottom and lateral sides (partially) of the block. The foundation is modeled using distributed springs and dashpots. It is supposed that oscillation amplitudes are small, so that the bottom of the block always remains in contact with the foundation. Oscillations of the system induced by horizontal harmonic motion of the foundation are studied. The influence of parameters of the system, as well as of the amplitude and frequency of the excitation, upon characteristics of such oscillations is analyzed.

[1)] Yury Selyutskiy, Professor: Lomonosov Moscow State University, 119192, Michurinsky prosp., 1, Russia (RU), seliutski@imec.msu.ru , the author presented this contribution at the conference in the special session: "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

[2)] Rinaldo Garziera, Professor: University of Parma, via Università, 12 - I 43121 Parma, Italy (IT), yds@inbox.ru .

[3)] Luca Collini, Professor: University of Parma, via Università, 12 - I 43121 Parma, Italy (IT), luca.collini@unipr.it .

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paper id: STA93

Piezoaeroelastic system based on a double aerodynamic pendulum

Yury Selyutskiy, Andrei Holub, Ching-Huei Lin

Abstract: During last decades, possibilities of using piezoelectric generators to harvest energy from the flow using various mechanical devices that perform flow-induced oscillations are intensively studied. (for instance, those that can be classified as aeroelastic systems). In this work, an electromechanical system is considered that consists of a double aerodynamic pendulum connected with a piezoelectric element. The element is connected to a load resistance. When the pendulum oscillates, the piezoelectric element is deformed, and electric voltage is generated. Aerodynamic forces acting upon the pendulum are described using the quasi-steady approach. Periodic solutions of the resulting dynamic system are studied depending on values of different parameters (such as wind speed, load resistance, etc.). It is shown, in particular, that it is possible to choose parameters of the system in such a way that the trivial equilibrium (where both links of the pendulum are oriented along the wind) is unstable when the wind speed belongs to a certain finite range of values, and asymptotically stable outside this range.

[1] Yury Selyutskiy, Professor: Lomonosov Moscow State University, 119192, Michurinsky prosp. 1, Moscow, Russia (RU), seliutski@imec.msu.ru , the author presented this contribution at the conference in the special session: "Mathematical modeling of nonlinear systems involving interaction with the medium" organized by M. Dosaev and Y. Selyutskiy.

[2] Andrei Holub, M.Sc. (Ph.D. student): Lomonosov Moscow State University, 119192, Michurinsky prosp., 1, Russia (RU), holub.imech@gmail.com .

[3] Ching-Huei Lin, Associate Professor: Chien-Hsin University of Science and Technology, 229 Jianxing Road, Zhongli District, Taoyuan City, Taiwan (TW), chlin@gapps.uch.edu.tw .

SPECIAL SESSION 8

15th INTERNATIONAL CONFERENCE
Dynamical Systems — Theory and Applications
December 2-5, 2019. Lodz, POLAND.

paper id: CON293

Secondary feedback control in smart grids

David Angulo-Garcia, Fabiola Angulo, Luz-Adriana Ocampo

Abstract: In this paper, we propose the improvement of a secondary feedback control of a droop-controlled smart grid, modeled via the first order Kuramoto model described in some papers. The technique is aimed to stabilize (synchronize) a network, through the modification of the dynamics of a small number of driver nodes. We improve aspects of the original control by applying a combination of harmonic signals on each driver oscillator which only makes use of the node's state and the desired equilibrium (synchronization). We propose a criterion to choose driver nodes and the strength of the control signal based on the topological properties of the network. Altogether, our modified control algorithm solves issues related with the fine tunning of parameters present in the original controller.

[1] David Angulo-Garcia, Ph.D.: Universidad de Cartagena, Carrera 6 No. 36 - 100. Cartagena, Colombia (CO), dangulog@gmail.com.

[2] Fabiola Angulo, Professor: Universidad Nacional de Colombia, Sede Manizales, Campus La Nubia, km. 8, via al aeropuerto, Bloque Q, Departamento de Ingeniería Eléctrica, Electrónica y Computación. Manizales, Colombia (CO), fangulog@unal.edu.co, the author presented this contribution at the conference in the special session "MegaCities: Nonlinear dynamics and networks" organized by G. Olivar.

[3] Luz-Adriana Ocampo, M.Sc. (Ph.D. student): Universidad Nacional de Colombia, Sede Manizales, Campus La Nubia, km. 8, via al aeropuerto, Bloque Q, Departamento de Ingeniería Eléctrica, Electrónica y Computación. Manizales, Colombia (CO), laocampona@unal.edu.co.

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paper id: ENG125

Nonlinear tourist flows in Barcelona

Enric Trullols, Imma Massana, Joana d'arc Prat, Josefina Antonijuan, Gerard Olivar

Abstract: Tourism is not only a source of wealth, but also a positive way of knowing and mixing local and foreign cultures. However, overexploitation of natural resources and inadequate behaviors (among other factors) can lead to a conflict between tourists and locals that makes the tourist economy not sustainable. The modeling of tourist flows is a good tool to face and overcome this problem, looking for the balance between natural and socioeconomic resources, the interests and rights of tourists and locals. This paper proposes a mathematical model of nonlinear differential equations, which allows to study the dynamic interaction between the main factors that affect the tourist flows of Barcelona. We have used nonlinear EDOs to represent the interactions between residents, tourists and investors. Political/economic decisions and geopolitical factors have been added as external forces. Specific aspects of Barcelona have been taken into account, such as the impossibility of extending the city, the lack of regulation (and excessive regulation), the affluence of investors and the increase in prices (which pressures residents outside from the city). Our results show that sustainability, that is, the positive values of the population of tourists, locals and investors, in the long run is possible under the appropriate economic and social decisions.

1) Enric Trullols, Professor: Universitat Politecnica de Catalunya, Jordi Girona, 31; 08034 Barcelona, Spain (ES), enric.trullols@upc.edu, the author presented this contribution at the conference in the special session "MegaCities: Nonlinear dynamics and networks" organized by G. Olivar.

2) Imma Massana, Professor: Universitat Politecnica de Catalunya, Jordi Girona, 31; 08034 Barcelona, Spain (ES), immaculada.massana@upc.edu.

3) Joana d'arc Prat, Professor: Universitat Politecnica de Catalunya, Jordi Girona, 31; 08034 Barcelona, Spain (ES), joana.darc.prat@upc.edu.

4) Josefina Antonijuan, Ph.D.: Universitat Politecnica de Catalunya, Jordi Girona, 31; 08034 Barcelona, Spain (ES), josefina.antonijuan@upc.edu.

5) Gerard Olivar, Professor: Universidad Nacional de Colombia, Carrera 27 # 64-60 Manizales, Caldas, Colombia (CO), golivart@unal.edu.co.

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paper id: ENG70

Evolution models for urban metabolism in Bogota

Hernán Darío Toro Zapata, Gerard Olivar Tost

Abstract: The concept of urban metabolism is defined as the sum of all technological and socioeconomic processes that result in growth, energy production, and elimination of effluents, emissions, and waste. For the modeling of urban metabolism it is necessary to apply the material flow analysis (AFM), which based on the laws of conservation of matter and energy, allows to measure and systematically analyze the flows and accumulations of materials, goods, substances, nutrients, water, electricity and waste through conservation laws. The analysis of urban metabolism systems can be carried out using a steady state approach. In this case, non-linear dynamics methods and bifurcations can be applied to systems of non-linear differential equations, which can be solved numerically. The paper will show the case of the city of Bogotá, through traffic evolution and energy models.

1) Hernán Darío Toro Zapata, M.Sc. (Ph.D. student): Universidad del Quindio, Armenia, Colombia (CO), hdtoro@uniquindio.edu.co .

2) Gerard Olivar Tost, Professor: Universidad Nacional de Colombia, Campus La Nubia, Manizales, Colombia (CO), golivart@unal.edu.co , the author presented this contribution at the conference in the special session: "MegaCities: Nonlinear dynamics and networks" organized by G. Olivar.

SPECIAL SESSION 9

15th INTERNATIONAL CONFERENCE

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paper id: EXP97

Experimental nonlinear localisation in a system of two coupled beams

Aurélien Grolet, Zein Alabidin, Sadaf Arabi, Olivier Thomas

Abstract: This study presents results showing experimental nonlinear localisation in a (macro) system of two coupled beams. First a reduced order model of the system is introduced, using the so called STEP method, leading to a two dof model with cubic nonlinearity. This model allows to shows that nonlinear localisation is possible through a 1:1 internal resonance mechanism. Moreover, one can show, using Harmonic Balance Method, that the forced localised solution stems from the principal resonance curve through pitchforck bifurcation, and the numerical model allows to compute the amplitude of bifurcation as well as the bifurcated branch. The experimental results are presented and compared to the numerical ones showing very good agreements.

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1) Aurélien Grolet, Associate Professor: ENSAM- Campus de Lille, boulevard Louis XIV, 59000 Lille, France (FR), aurelien.grolet@ensam.eu , the author presented this contribution at the conference in the special session: "Synchronization and nonlinear normal modes in physics and structural dynamics" organized by M. Kovaleva, L. Manevitch and V. Pilipchuk.

2) Zein Alabidin, M.Sc.: ENSAM- Campus de Lille, boulevard Louis XIV, 59000 Lille, France (FR), zein_alabidin.shami@ensam.eu .

3) Sadaf Arabi, M.Sc.: ENSAM- Campus de Lille, boulevard Louis XIV, 59000 Lille, France (FR), sadaf2.arabi@gmail.com .

4) Olivier Thomas, Professor: ENSAM- Campus de Lille, boulevard Louis XIV, 59000 Lille, France (FR), olivier.thomas@ensam.eu .

paper id: ASY194

Damped driven response of granular chain

Victor Kislovsky, Margarita Kovaleva, Yuli Starosvetsky

Abstract: Over the past few decades, dynamics of one-dimensional (1D) granular lattices has become a subject of immense theoretical and experimental research. In the present talk we will discuss the fundamental problem of nonlinear wave propagation in the damped-driven, granular lattice mounted on a linear elastic foundation which assumes the general type of strongly nonlinear, inter-site potential and subject to an external harmonic forcing in the form of a traveling wave. To the best of authors knowledge this is the first theoretical study which addresses the damped-driven response of the granular lattice mounted on elastic foundation and is given to the special type of resonant external loading in the form of a traveling wave. Assuming the limit of small amplitude excitation and using the regular multi-scale analysis, we derive the discrete, damped-driven p-Schrödinger equation. In the first part of the talk we will focus on the analysis of slowly evolving, moving breather solutions forming in the non-driven — dissipative chain. Then in the second part of the talk we will present the analysis of non-linear wave solutions i.e. flat solutions as well as spatially localized (discrete breather) solutions emerging in the damped-driven granular lattice. This work was supported by Russian Foundation for Basic Research according to the research project no. 18-03-00716.

[1] Victor Kislovsky, Ph.D.: Faculty of Mechanical Engineering, Technion Israel Institute of Technology, Technion City, Haifa 32000, Israel, Israel (IL), victotach@gmail.com.

[2] Margarita Kovaleva, Professor: Semenov Instute of Chemichal Physics Russian Academy of Sciences, Moscow 119991 Kosygin st,4, Russia (RU), margo.kovaleva@gmail.com.

[3] Yuli Starosvetsky, Professor: Faculty of Mechanical Engineering, Technion Israel Institute of Technology, Technion City, Haifa 32000, Israel, Israel (IL), staryuli@technion.ac.il, the author presented this contribution at the conference in the special session "Synchronization and nonlinear normal modes in physics and structural dynamics" organized by M. Kovaleva, L. Manevitch and V. Pilipchuk.

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paper id: ASY208

Non-conventional synchronization in the chains of weakly coupled nonlinear autogenerators

Margarita Kovaleva, Leonid Manevitch

Abstract: The phenomenon of synchronization in the system of two autogenerators was first observed by Huygens. It was a stationary synchronization, or in modern terminology the synchronization on Nonlinear Normal Mode (NNM). Synchronization of this type (conventional synchronization) was intensively studied, especially during last decades. We have revealed an alternative, non-conventional synchronization or synchronization on the Limiting Phase trajectory, which corresponds to beatings as attractor[2,3]. To prove the existence of LPT-synchronization we used the group Lie theory which allowed to find additional symmetry (to the temporal shift) and a corresponding integral of motion. It was shown numerically that one can obscure the LPT synchronization even out of the symmetry conditions. We propose now a new topological criterion of LPT synchronization existence in nonlinear chains of self-sustained oscillators. It is based on the analysis of the stationary states stability in the slow time-scale. Absence of the stationary attractors provides existence of LPT synchronization. The discussed method does not require closeness of the amplitudes of the oscillators, while such limit is supposed in the Kuramoto approximation.
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[1] Margarita Kovaleva, Professor: Semenov Instute of Chemichal Physics Russian Academy of Sciences, Moscow 119991 Kosygin st,4, Russia (RU), margo.kovaleva@gmail.com, the author presented this contribution at the conference in the special session "Synchronization and nonlinear normal modes in physics and structural dynamics" organized by M. Kovaleva, L. Manevitch and V. Pilipchuk.

[2] Leonid Manevitch, Professor: Semenov Instute of Chemichal Physics Russian Academy of Sciences, 119991 Moscow, Kosygin st, 4, Russia (RU), manevitchleonid3@gmail.com.

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paper id: ASY212

New development of non-stationary resonant dynamics

Leonid Manevitch

Abstract: We present a new development of the non-stationary resonant dynamics based on the concepts of the limiting phase trajectories and the coherence domains (clusters). This development allows to consider more wide class of autonomic conservative and non-conservative systems (in connection with the problem of synchronization), and to take into account external fields. It requires introducing the such notion as resonant attractor and using the additional analytical procedure which is semi-inverse method. Several problems relating to efficient energy exchange between weakly coupled resonant clusters in different mechanical systems are discussed together with significant applications. This work was supported by Russian Science Foundation according to the research project no. 16-13-10302

[1)] Leonid Manevitch, Professor: Semenov Instute of Chemichal Physics Russian Academy of Sciences, 119991 Moscow, Kosygin st, 4, Russia (RU), manevitchleonid3@gmail.com, the author presented this contribution at the conference in the special session "Synchronization and nonlinear normal modes in physics and structural dynamics" organized by M. Kovaleva, L. Manevitch and V. Pilipchuk.

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December 2-5, 2019. Lodz, POLAND.

paper id: STA237

Stability of steady states with regular or chaotic behaviour in time

Yuri Mikhlin, Nataliia S. Goloskubova, Tatyana V. Shmatko

Abstract: A stability of the NNMs is analyzed by two approaches. One of them is the method of Ince algebraization, when a new independent variable associated with the unperturbed solution is used instead of time. In this case equations in variations with periodic coefficients transform to equations with singular points. A problem of determination of solutions corresponding to boundaries of the stability/ instability regions is reduced here to the Sturm-Liouville problems for functions that are either regular, or have singularity at the mentioned points. An advantage of the Ince algebraization is that we do not need in use of the unperturbed solution time-presentation. The NNMs concept can be used not only for periodic vibrations. In particular, the NNMs having smooth trajectories in configuration space and chaotic in time behavior can be found in post-buckling forced dynamics of elastic systems that have lost stability under external compressive force. The problem of the chaotic in time modes stability has no analytical solutions. Here some test which is a consequence from the classical Lyapunov definition of stability is proposed and used. It permits to obtain boundaries between the stability/ instability regions in the system parameter space. Both proposed approaches can be used also for other stationary regimes such as traveling or standing waves in nonlinear chains, or in one-dimensional nonlinear media.

[1] Yuri Mikhlin, Professor: National Technical University "Kharkov Polytechnic Institute", NTU "KhPI" Dept. of Appl. Mathematics, 2 Kyrpychev str., Kharkiv 61002, Ukraine (UA), Yuri_Mikhlin@mail.ru, the author presented this contribution at the conference in the special session "Synchronization and nonlinear normal modes in physics and structural dynamics" organized by M. Kovaleva, L. Manevitch and V. Pilipchuk.

[2] Nataliia S. Goloskubova, M.Sc. (Ph.D. student): National Technical University , NTU, Ukraine (UA), nataligoloskubova1992@ukr.net.

[3] Tatyana V. Shmatko, Ph.D.: National Technical University "Kharkov Polytechnic Institute", NTU "KhPI" Dept. of Higher Mathematics, 2 Kyrpychev str., Kharkiv 61002, Ukraine (UA), ktv_ua@yahoo.com.

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paper id: VIB143

On mode formation and transitions in self-sustained friction induced vibrations

Valery Pilipchuk

Abstract: Despite of intensive attempts to understand the dynamics of friction interface, many unanswered questions still persist. For instance, it remains unclear how the interaction between molecular structures of two bodies eventually triggers large scale acoustic modes producing the squeal effect. Although a large number of experimental and theoretical studies have been conducted in order to clarify physical conditions under which the system prefers acoustic wave radiation to heat generation, no satisfactory answer has been found yet. Note that the situation is complicated by the plurality of friction phenomena due to different material properties. It is known that qualitative features of the friction induced dynamics are very sensitive to variations of the adapted friction law. This makes reliable quantitative predictions hardly possible. However, formation of spatial-temporal wave shapes in the interacting layers and their transitions may appear to follow qualitatively universal scenarios. In the present work such scenarios are analyzed on relatively simple discrete models of mass-spring chains interacting with moving surfaces. Under different conditions imposed on physical parameters of conservative and non-conservative forces different mode formations can be observed. In the case of two degrees-of-freedom, nonlinear in-phase, antiphase, and local synchronous vibration modes, as well as transitions between them can be observed.

[1)] Valery Pilipchuk, Ph.D.: Wayne State University, 5050 Anthony Wayne Dr., 2118, Detroit, Michigan 48202, United States (US), pilipchuk@wayne.edu , the author presented this contribution at the conference in the special session: "Synchronization and nonlinear normal modes in physics and structural dynamics" organized by M. Kovaleva, L. Manevitch and V. Pilipchuk.

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paper id: STA90

Analytical and numerical study of piecewise linear Mathieu equation with non-zero offset

Jayaprakash Kalkunte Raghunath, Yuli Starosvetsky

Abstract: The current work considers the analytical and numerical study of piecewise linear Mathieu equation with non-zero offset. The considered parametrically excited dynamical system is such that the stiffness coefficient is unity for $q<a$ and $\delta\geq1$ for $q\geq a$, where δ is the asymmetry parameter and a is the offset at which the system exhibits asymmetry. The system under consideration is essentially nonlinear and as such, not linearizable. Thus the application of Floquet theory is seldom possible. The previous work by Chatterjee et al. ("Asymmetric Mathieu Equation," Proc. of the Royal Soc. A, vol. 462, p. 1643–1659, 2006) introduced a numerical measure to ascertain the stability of the oscillator response in the limit of zero offset. This was rendered possible due to the scalable property of the system with zero offset and in fact the system exhibits isochronous oscillations. In contrast, the presence of non-zero offset precludes the applicability of such a measure and the general quasi-linear asymptotic analysis is seldom applicable. Furthermore, the system under consideration exhibits non-isochronous oscillations and the frequency of oscillation approaches an asymptotic limit (frequency of oscillation with zero offset) with increase in energy. In this study we invoke the canonical variable of action-angle (AA) and consider appropriate averaging to project the dynamics on a resonance manifold. The averaged equations provide a measure of the instability boundaries in this class of systems. The numerical simulations are observed to match quite well with the asymptotic solutions.

[1] Jayaprakash Kalkunte Raghunath, Ph.D.: Assistant Professor, Discipline of Mechanical Engineering, IIT Gandhinagar, 5/360, IIT Gandhinagar, Palaj, Gandhinagar-382355, India (IN), jp.kalkunte@iitgn.ac.in, the author presented this contribution at the conference in the special session "Synchronization and nonlinear normal modes in physics and structural dynamics" organized by M. Kovaleva, L. Manevitch and V. Pilipchuk.

[2] Yuli Starosvetsky, Associate Professor: Faculty of Mechanical Engineering, Israel Institute of Technology Technion, D.Dan and Betty Kahn Mechanical Engineering Building, 419, Faculty of Mechanical Engineering, Technion – Israel Institute of Technology, Haifa, 32000, Israel (IL), staryuli@technion.ac.il.

SPECIAL SESSION 10

15th INTERNATIONAL CONFERENCE

Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: MAT102

Modeling of dynamics of coopereiting wheeled mobile robots

Andrzej Burghardt, Piotr Gierlak, Wincenty Skwarek

Abstract: The work presents the dynamics of the system of two wheeled mobile robots cooperating in the transport of large-size cargo in the form of a beam. The purpose of modeling such a system was to obtain a mathematical model in an applicable form. The Lagrange equations of the second type were used to describe the dynamics, and then the projective method was used to eliminate Lagrange multipliers. Thanks to this approach, unknown dry friction forces at the contact points of robot wheels with the ground were eliminated from the description and the dynamics in controllable coordinates was obtained. In addition, the obtained model has structural properties that enable its use in the synthesis of a control system based on a mathematical model.

[1)] Andrzej Burghardt, Associate Professor: Rzeszow University of Technology, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland (PL), andrzejb@prz.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

[2)] Piotr Gierlak, Ph.D.: Rzeszow University of Technology, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland (PL), pgierlak@prz.edu.pl .

[3)] Wincenty Skwarek, M.Sc. (Ph.D. student): Rzeszow University of Technology, al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland (PL), d334@stud.prz.edu.pl .

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Dynamical Systems — Theory and Applications

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paper id: EXP73

On the influence of rubber tracks vibrations upon energy losses in crawler vehicles drive systems

Jakub Chołodowski, Piotr Dudziński

Abstract: Nowadays, earthmoving machinery and off-road vehicles are often fitted with rubber tracked undercarriages. In order to properly estimate power demand of vehicles of this type and improve the efficiency of their undercarriages, computational models of their external and internal motion resistance are required. The issue of external motion resistance has been described in the literature, however, models of the internal motion resistance are still hardly available. Hence, a research in this field is conducted by The Department of Off-Road Machine and Vehicle Engineering (DORMVE) at Wrocław University of Science and Technology. While driving a tracked vehicle, transverse vibrations of track spans are often induced due to a number of reasons, e.g.: radial run-out of wheels of the undercarriage, non-uniform track weight distribution, dynamic loads acting on the vehicle while negotiating uneven terrain etc. High amplitude vibrations of metal link tracks of high speed vehicles usually lead to noticeable increase in their motion resistance. On the other hand, the influence of rubber tracks vibrations on energy efficiency of crawler vehicles has not been already discussed. The article presents the main assumptions of a model for estimation of energy losses attributed to rubber tracks vibrations that is being currently developed by DORMVE. A method for determination of parameters involved in the model, i.e. bending stiffness and logarithmic decrement of vibrating track, as well as the results of the experiments carried out on an exemplary rubber track will be discussed.

[1] Jakub Chołodowski, M.Sc. (Ph.D. student): The Department of Off-Road Machine and Vehicle Engineering, Wrocław University of Science and Technology, Łukasiewicza 7/9, 50-371 Wrocław, Poland (PL), jakub.cholodowski@pwr.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

[2] Piotr Dudziński, Professor: The Department of Off-Road Machine and Vehicle Engineering, Wrocław University of Science and Technology, Łukasiewicza 7/9, 50-371 Wrocław, Poland (PL), piotr.dudzinski@pwr.edu.pl .

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: VIB80

Modelling of torsional vibrations in a motorcycle steering system

Andrzej Dębowski, Dariusz Żardecki

Abstract: Torsional vibrations of steering systems are significant problems for the active safety of motorcycles. These vibrations may occur even with slight disturbances of the steady state motion, and their causes result from the improper mechanical parameters and characteristics of the steering system affecting the dynamic properties of the vehicle. In many cases, full elimination of torsional vibrations requires the use of special dampers acting as mechatronic systems. They enable appropriate action of the steering systems in a wide range of changes of dynamic characteristics resulting from changes of operating parameters (load, speed, etc.). Identifying the causes of vibrations and finally the proper synthesis of the active damper requires research studies using mathematical modelling and computer simulation. Due to the complex nature of motorcycle dynamics, which prompts the creation of complex forms of the mathematical model, and at the same time the obvious paradigm of the relative simplicity of the model used in mechatronic systems, the synthesis of such a model requires a special approach. The paper presents a method of model synthesis including determination of nonlinear equations of motion in an extreme "expanded" version, then their linearisation, Laplace transformation and determination of the transfer functions, frequency analysis based on Bode plots, reduction of the transfer functions and finally calculation of state equations allowing a synthesis of the active damper algorithm.

[1] Andrzej Dębowski, M.Sc.: Wojskowa Akademia Techniczna, 00 – 908 Warszawa 46, Gen. Sylwestra Kaliskiego 2, Poland (PL), andrzej.debowski@wat.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

[2] Dariusz Żardecki, Professor: Wojskowa Akademia Techniczna, 00 – 908 Warszawa 46, Gen. Sylwestra Kaliskiego 2, Poland (PL), dariusz.zardecki@wat.edu.pl .

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The influence of lateral swaying on the trajectory of articulated rigid body vehicles

Piotr Dudzinski, Aleksander Skurjat

Abstract: The phenomenon of snaking of articulated vehicles is affected by many factors. One of them is lateral swaying of the vehicle caused by driving on uneven road, which can significantly affect the vehicle's steering angle and the trajectory of its motion. Typically, articulated vehicles are fitted with a rear oscillating axle. The wheels that prevent the vehicle from tipping over are the front ones, which are attached directly to the vehicle frame. For this reason, the front wheels are loaded with lateral forces. Since the front wheels are distant from the steering joint, the resulting torque caused by the lateral forces tends to rotate the front body of the vehicle about the steering axle. This torque is counteracted (compensated) by the torque created by the steering system. Changes in the steering angle are proportional to the hydraulic steering system stiffness. Numerous experimental tests indicate that the relationship between stiffness and steering angle is not linear and might be approximated with an exponential function. The lateral (roll axis) oscillations are cyclical, an alternate angle change in the steering joint is observed. There is an alternate change in the steering angle due to changes in lateral forces acting on the front wheels. The article presents the results of the research on the impact of oscillations about the vehicle's lateral symmetry axis on the trajectory of vehicle motion.

[1] Piotr Dudzinski, Professor: Faculty of Mechanical Engineering, Department of Off-Road Machine and Vehicle Engineering, Wybrzeze Wyspianskiego 27, 50-370, Wrocław, Poland (PL), piotr.dudzinski@pwr.edu.pl .

[2] Aleksander Skurjat, Ph.D.: Faculty of Mechanical Engineering, Department of Off-Road Machine and Vehicle Engineering, Wybrzeze Wyspianskiego 27, 50-370, Wrocław, Poland (PL), aleksander.skurjat@pwr.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

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Dynamical Systems — Theory and Applications

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paper id: EXP226

Modeling and experimental tests on motion resistance of double-flange rollers of rubber track systems due to sliding friction between the rollers and guide lugs of rubber tracks

Piotr Dudziński, Jakub Chołodowski

Abstract: Modern off-road vehicles are often equipped with rubber tracked undercarriages. While designing a rubber tracked crawler, an issue of high importance is to distinguish a power unit whose performance corresponds well with the actual power demand of the vehicle. In order to do so, algorithms for determination of external and internal motion resistance of rubber tracked vehicles are required. The Department of Off-Road Machine and Vehicle Engineering (DORMVE, Wrocław University of Science and Technology) conducts theoretical and experimental research aimed at development of advanced computational models of this type. Motion resistance of rollers (road wheels) is one of the factors affecting the energy consumption of rubber tracked undercarriages. Firstly, since the rollers are loaded with vertical force, they indent into rubbery envelope of the track. Consequently, some amount of energy is lost due to mechanical hysteresis of rubber. Secondly, motion resistance of rollers is attributed to sliding friction between the rollers and guide lugs of the track. Energy losses caused by this phenomenon are noticeable if rollers are loaded with high lateral force, i.e. while turning or operating a vehicle on a slope inclined along the lateral axis of the vehicle. The article presents a model for estimation of motion resistance of double-flange rollers of rubber tracked undercarriages allowing for both abovementioned phenomena. The results of exemplary model computations will be compared with experimental data.

[1)] Piotr Dudziński, Professor: The Department of Off-Road Machine and Vehicle Engineering, Wrocław University of Science and Technology, Łukasiewicza 7/9, 50-371 Wrocław, Poland (PL), piotr.dudzinski@pwr.edu.pl.

[2)] Jakub Chołodowski, M.Sc. (Ph.D. student): The Department of Off-Road Machine and Vehicle Engineering, Wrocław University of Science and Technology, Łukasiewicza 7/9, 50-371 Wrocław, Poland (PL), jakub.cholodowski@pwr.edu.pl, the author presented this contribution at the conference in the special session "Dynamics of vehicles" organized by A. Harlecki.

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Dynamical Systems — Theory and Applications

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paper id: CON116

Influence of control system parameters and it's disturbances on lane change process

Mirosław Gidlewski, Leszek Jemioł, Dariusz Żardecki

Abstract: Automatic control of lane change is a key to automate more complex maneuvers. According authorial concept the lane change controller has a mixed structure. In the open-loop structure it works as a set-point signal generator which generates three variables determining the lane change maneuver: a set-point input signal of steering system angle, and two set-point output signals describing desirable vehicle's trajectory (lateral and angular shifts of the car). In the closed-loop structure it works as a steering signal corrector which corrects on-line (by two Kalman regulators) the steering system angle signal. Error signals are calculated by comparison of reference (generated) and real (measured) signals expressing vehicle's trajectory. The set-point reference signals, as well as regulators are based on a simple linear reference model (simplified "bicycle model"). For validation of the controller algorithm extensive simulation investigations have been executed. In these investigations, as the virtual object of control – the very detailed (MBS-type, 3D, nonlinear, and verified experimentally) mathematical model of medium-duty truck has been used. The authors' model of a conceptual control system and extensive simulation investigations were presented at several authors' papers. This paper presents unpublished results of the studies, which are concerned on sensitivity of the control system to it's parameters and it's disturbances (dead zone of measure process, time delay of data processing, etc).

[1] Mirosław Gidlewski, Ph.D.: University of Technology and Humanities in Radom, Automotive Industry Institute, 26-600 Radom, Chrobrego 45, Poland (PL), miroslaw.gidlewski@uthrad.pl .

[2] Leszek Jemioł, M.Sc.: University of Technology and Humanities in Radom, 26-000 Radom, ul. Chrobrego 45, Poland (PL), leszek.jemiol@uthrad.pl .

[3] Dariusz Żardecki, Associate Professor: Military University of Technology, 00-908 Warsaw 49, gen. Sylvester Kaliski 2, Poland (PL), dzardecki@wat.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

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paper id: EXP153

Stability of three wheeled narrow vehicle

Witold Grzegożek, Krzysztof Weigel-Milleret

Abstract: A serious problem in modern cities are congestions and a lack of parking space, especially in cities centers. The narrow, three-wheeled vehicles seems to be solution to these problems. The work presents a description of the designed and developed urban individual mean of transport. The implemented prototype is a narrow, three-wheeled vehicle with electric drive designed as a delta type vehicle. Road tests of controllability were performed — a constant radius of turn and constant steering angle tests and stability of the vehicle using the single lane change maneuver. A mathematical vehicle model with three degrees of freedom (3DOF) was arranged, including lateral displacement, roll and yaw angle rotation. These road tests were used to validate parameters in the vehicle model. A vehicle motion simulation was performed in accordance with the NHTSA J-turn maneuver procedure. The results of the simulation allowed the assessment of the impact of driving speed on the lateral stability of the vehicle by the determination of the dynamic roll angle limit.

[1] Witold Grzegożek, Professor: Politechnika Krakowska, al. Jana Pawła II, 37, Poland (PL), witek@mech.pk.edu.pl .

[2] Krzysztof Weigel-Milleret, M.Sc.: Politechnika Krakwoska, al. Jana Pawła II 37, Poland (PL), krzysztof.weigel-milleret@mech.pk.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

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Dynamical Systems — Theory and Applications

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paper id: MAT162

Application of homogenous transformations in dynamic analysis of truck trailers

Andrzej Harlecki, Adam Przemyk, Szymon Tengler

Abstract: A dynamic analysis of the combination of truck with trailer, constituting a multi¬body system, is presented in the paper. A mathematical model of this combination of vehicles was developed by using formalism of Lagrange's equations of motion. based on the joint coordinates and matrices of homogeneous transformations, taken from robotics. The main elements of truck and trailer (frames, axes and wheels) can be treated as branched open kinematic chain containing links (wheels) which are in contact with the road. The considered system has 156 degrees of freedom. In the analysed model, a rear drive system was assumed. Driving torques were applied to rear wheels of the truck. The generalized forces, included in the equations of motion, result from driving torques and reaction forces of the road surface which act on the wheels of truck and trailer. A selected model of tires should be taken into account. The constraint equations result from assumed courses of steer angles of the front wheels of the truck in the case of different road maneuvers. The negative phenomenon, called as "snaking motion of the trailer", was also analysed. According to the authors, the proposed method can have practical significance and it can be used in designing the trailers.

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[1] Andrzej Harlecki, Associate Professor: University of Bielsko-Biala, 43-309 Bielsko-Biala, Willowa 2 Street, Poland (PL), aharlecki@ath.bielsko.pl .

[2] Adam Przemyk, M.Sc.: University of Bielsko-Biala, 43-309 Bielsko-Biala, Willowa 2 Street, Poland (PL), a.przemyk@gmail.com , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

[3] Szymon Tengler, Ph.D.: University of Bielsko-Biala, 43-309 Bielsko-Biala, Willowa 2 Street, Poland (PL), stengler@ath.bielsko.pl .

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Dynamical Systems — Theory and Applications

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paper id: NON265

Stability of snaking trailers

Hanna Zsófia Horváth, Dénes Takács

Abstract: The mechanical model of a two-wheeled trailer is constructed to describe the spatial motion and the roll-over of the trailer. The governing equations are derived with special attention to the non-smoothness and non-linearities that strongly affect the dynamics of the trailer. The presence of unstable limit cycles related to these properties makes the vibrations of the trailers intricate from practical point of view. Bistable parameter domains may be observed where large amplitude oscillations and the stable rectilinear motion coexist. The aim of the study is to investigate the effects of the parameters (such as payload position, the stiffness and damping of the suspension and speed) on the linear stability and on the non-linear vibrations. The analysis is based both on analytical and numerical techniques.

[1] Hanna Zsófia Horváth, B.A. (M.Sc. student): Budapest University of Technology and Economics, Department of Applied Mechanics, 1111 Budapest, Műegyetem rkp. 3., Hungary (HU), horvath.hanna.zsofia@gmail.com, the author presented this contribution at the conference in the special session "Dynamics of vehicles" organized by A. Harlecki.

[2] Dénes Takács, Associate Professor: MTA-BME Research Group on Dynamics of Machines and Vehicles, Budapest, Hungary, 1111 Budapest, Műegyetem rkp. 3., Hungary (HU), takacs@mm.bme.hu.

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paper id: NON122

Model of a pneumatic tire and road cooperation based on 3-state flexible elements.

Tomasz Mirosław

Abstract: The problem of wheel–ground cooperation has been investigated and modeled for hundreds of years, but still new models are created for various purposes like tire designing, power train simulations, driver's training devices or for computers games. Wheels are the most important parts in vehicle because they are the contact points between road and vehicle. The problem is more and more important for remote controlled or autonomous vehicles, where pilot cannot rely on its direct sensors. The control systems have to foresee the vehicle's behavior in dynamic state and dynamically changing conditions. In this paper author presents overview of most important models of wheel ground cooperation with its characteristic. Based on models synthesis new concept of modelling is presented based on flexible element modeling. This model is based on simple and intuitive models of elementary processes, with a simple mathematical description. The main aim of this model is to eliminate the advanced mathematical operations which can hide from the designer the real physical phenomena like deformation of a tire and a ground and sliding effect. Based on this phenomenon we can react on process running changes and track the optimal work parameters like propelling/braking torques. It became not so difficult when we take into account electric drive systems.

[1)] Tomasz Mirosław, Ph.D.: Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), tomasz.miroslaw@pw.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

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Dynamical Systems — Theory and Applications

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paper id: ENG68

Dynamics of logistic train

Wojciech Paszkowiak, Tomasz Bartkowiak

Abstract: A rapid development in intralogistics is the argument for seeking new solutions in this field. An example of such a solution is a logistics train. An important problem in the application of intralogistics trains is the choice of adequate parameters of the kinematic system and the possibility to check before the commissioning whether the train is able to pass the given path without a collision with surrounding objects. In this paper, we present a dynamic model of a logistic train which was developed for the three most common steering systems: virtual clutch and drawbar, conventional clutch and drawbar as well as double Ackermann steering. In the paper, we consider a three-wheeled tractor towing passive wheeled trailers. The tractor consists of actuated steering wheel at front and a two passive rear wheels used for stable motion. Two types of trailers are considered. First one is connected to the tractor via a passive joint and it has two rear fixed wheels and two caster wheels in front. The latter has front wheels that follow Ackermann steering principle. The turn of front wheels is caused by rotation of drawbar. The rear wheels are synchronized with front ones but they rotate in the opposite direction. Dynamic model was created following Lagrange's theorem including the possibility of lateral slip. In order to calculate the side-slip angle we used relation between relative velocities for a given wheel. Then, the system of differential equations was numerically solved. The results obtained are presented in the form of animations presenting train run in various conditions.

1) Wojciech Paszkowiak, M.Sc. (Ph.D. student): Poznan University of Technology, pl. Marii Skłodowskiej – Curie 5, 60-965 Poznań, Poland (PL), wojciech.z.paszkowiak@doctorate.put.poznan.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

2) Tomasz Bartkowiak, Ph.D.: Poznan University of Technology, pl. Marii Skłodowskiej – Curie 5, 60-965 Poznań, Poland (PL), tomasz.bartkowiak@put.poznan.pl .

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paper id: EXP222

Analysis of the kinematics of the process of deformation of motorcar bodies during side impact crash tests carried out to the FMVSS 214 and conventional test procedures

Leon Prochowski, Miroslaw Gidlewski, Mateusz Ziubiński, Krzysztof Dziewiecki

Abstract: The kinematics of the process of deformation of the motorcar body side in the culminating phase of a front-to-side vehicle collision has been examined as a possible basis for analysing and modelling the process of development of threats to car occupants during a road accident. The course of such accidents has a complex nature and their models are necessarily based on the approximation of strongly non-linear characteristics of impact processes, especially during the transition from the compression phase to the restitution phase of the deformation process. For such characteristics to be obtained, a lot of experimental tests have to be carried out. The modelling was based on results of specific FMVSS 214 crash tests carried out at NHTSA (USA) and conventional right-angle crash tests carried out at PIMOT (Poland). The kinematics of the contact phase and the vehicle deformation processes was modelled with taking into account experimental test results, inclusive of the characteristic curves representing the strongly non-linear processes that have a decisive effect on the vehicle body deformation. The analysis of the processes of deformation of the car body side, based on the experiment results, simultaneously revealed the range of penetration of body side parts into the car interior and showed the process of development of threats to car occupants. This danger was evaluated on the grounds of the velocity and energy of the impact against the occupant's body, resulting from the penetration of the deformed body side structure into the car interior.

[1] Leon Prochowski, Professor: Military University of Technology (WAT), Automotive Industry Institute (PIMOT), 00-908 Warszawa 46, ul. gen. Sylwestra Kaliskiego 2, Poland (PL), leon.prochowski@wat.edu.pl.

[2] Miroslaw Gidlewski, Ph.D.: University of Technology and Humanities in Radom, 26-600 Radom, Chrobrego 45, Poland (PL), miroslaw.gidlewski@uthrad.pl, the author presented this contribution at the conference in the special session "Dynamics of vehicles" organized by A. Harlecki.

[3] Mateusz Ziubiński, M.Sc.: Military University of Technology (WAT), 00-908 Warszawa 46, ul. gen. Sylwestra Kaliskiego 2, Poland (PL), mateusz.ziubinski@wat.edu.pl, the author presented this contribution at the conference in the special session "Dynamics of vehicles" organized by A. Harlecki.

[4] Krzysztof Dziewiecki, Ph.D.: University of Technology and Humanities in Radom, 26-600 Radom, Stasieckiego 54, Poland (PL), krzysztof.dziewiecki@uthrad.pl.

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paper id: CON180

The control model's impact on the car and trailer set movement in experimental and simulation research

Leon Prochowski, Mateusz Ziubiński, Patryk Szwajkowski, Tomasz Pusty, Mirosław Gidlewski

Abstract: Parameters and characteristics of the one of the control algorithm modules' of the autonomous passenger car with a trailer has been considered in this study, during avoiding suddenly appearing obstacle. It is a driver-controller model, working in fuzzy logic as a signals processing system, which signals are measured while driving a car with a trailer. According to that, model identifies situations that require reaction. The trailer affects the vehicle which may lead to critical situations specific to analysed set like snapping or jackknifing. The issue under consideration includes analysis of relationship between several non-linear models (car, trailer, tire cooperation with a road surface and driver-controller model). Significant areas of stability reduction have been identified, especially when there is a sudden obstacle to a vehicle traveling at high speed. During the experimental research, main focus was on validating the vehicles' model and their reactions while avoiding the obstacle, to determine the symptoms of critical situations resulting from the movement of a set of vehicles. In the next step, parameters and characteristics that may determine the dynamics and stability of the models in similar situation was analysed and selected. The signals and indicators selected for the analysis, describing the vehicle's reaction, were treated as input information to the driver's model. The values increase rapidly with the driving speed and the towing car's steering wheel's rotation angle. Signals of particularly high sensitivity in various road conditions have been indicated.

[1] Leon Prochowski, Professor: Military University of Technology, gen. Sylwestra Kaliskiego 2, 01-476 Warsaw, Poland (PL), leon.prochowski@wat.edu.pl.

[2] Mateusz Ziubiński, M.Sc. (Ph.D. student): Military University of Technology, gen. Sylwestra Kaliskiego 2, 01-476 Warsaw, Poland (PL), mateusz.ziubinski@wat.edu.pl, the author presented this contribution at the conference in the special session "Dynamics of vehicles" organized by A. Harlecki.

[3] Patryk Szwajkowski, B.A. (M.Sc. student): Automotive Industry Institute, ul. Jagiellońska 55, 03-301 Warsaw, Poland (PL), p.szwajkowski@pimot.eu.

[4] Tomasz Pusty, Ph.D.: Automotive Industry Institute, ul. Jagiellońska 55, 03-301 Warsaw, Poland (PL), t.pusty@pimot.eu.

[5] Mirosław Gidlewski, Ph.D.: Automotive Industry Institute, ul. Jagiellońska 55, 03-301 Warsaw, Poland (PL), m.gidlewski@pimot.eu.

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paper id: CON150

A system for improving directional stability involving individual braking of 1, 2, or 3 wheels of articulated rigid body vehicles

Aleksander Skurjat, Andrzej Kosiara

Abstract: Road-safety of wheeled vehicles depends on the systems used to assist the driver while operating the vehicle. For commercial vehicles, i.e. cars and trucks, numerous systems supporting the driver and influencing the trajectory of vehicle motion are developed. Stiffness of the articulated vehicles' steering systems is relatively low. Consequently, in order to meet normative requirements for the steering system the maximum velocity of vehicles of this type is very limited. The article presents the results of both computer simulation tests and tests carried out on a real vehicle of the control system which involves individual braking of 1, 2 or 3 wheels of the vehicle in order to improve its directional stability. The principles of operation of various motion stabilization systems were also compared. Furthermore, the article presents a method for measuring the motion trajectory of a vehicle.

[1] Aleksander Skurjat, Ph.D.: Faculty of Mechanical Engineering, Department of Off-Road Machine and Vehicle Engineering, Wybrzeze Wyspianskiego 27, 50-370, Wrocław, Poland (PL), aleksander.skurjat@pwr.edu.pl , the author presented this contribution at the conference in the special session: "Dynamics of vehicles" organized by A. Harlecki.

[2] Andrzej Kosiara, Ph.D.: Faculty of Mechanical Engineering, Department of Off-Road Machine and Vehicle Engineering, Wybrzeze Wyspianskiego 27, 50-370, Wrocław, Poland (PL), andrzej.kosiara@pwr.edu.pl .

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paper id: NON112

Non-smooth nonlinear model of suspension system based on piecewise linear luz(…) and tar(…) projections

Dariusz Żardecki

Abstract: Strong nonlinear phenomena are attributes of suspension systems of vehicles operated at high dynamic loads and high speeds. The causes of these phenomena are dry friction and clearance in the mechanisms, detachment of the wheel from the roadway, impact on the bumper element, etc. Therefore detailed descriptions of vehicle "vertical dynamics" should express these non-smooth nonlinearities, also in the case their structural physical models are discrete mechanical systems with only several masses. Modeling of strong nonlinear phenomena can be based on a piecewise linear approach. For simplification mathematical description of such phenomena special piecewise linear luz(…) and tar(…) projections have been proposed and elaborated by Żardecki. These projections have surprisingly simple mathematical apparatus which enable analytical operations (eg. reductions) for differential and algebraic equations and inclusions with non-smooth nonlinearities. They also simplify numerical simulations. Applications of this method due to modeling of car steering systems with inclusion freeplay and stick-slip processes have been reported in several authors' papers. This paper presents examples due to suspension systems.

[1)] Dariusz Żardecki, Professor: Wojskowa Akademia Techniczna, 00 – 908 Warszawa 46, ul. gen. Sylwestra Kaliskiego 2, Poland (PL), dariusz.zardecki@wat.edu.pl, the author presented this contribution at the conference in the special session "Dynamics of vehicles" organized by A. Harlecki.

SPECIAL SESSION 11

15th INTERNATIONAL CONFERENCE

Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: MAT67

Comparisons of various fractional order controllers on a poorly damped system

Isabela Birs, Ioan Nascu, Eva Dulf, Cristina Muresan

Abstract: Poorly damped systems exhibit a high oscillatory behavior making them harder to control. The paper explores the possibilities of controlling a poorly damped system using different fractional order control approaches such as the Fractional Order Internal Model Control (FOIMC) and the Fractional Order Proportional Integral (FOPI) controllers. The case study is chosen to be a highly nonlinear experimental platform consisting of a vertical take-off and landing platform. The performances of the closed loop systems with the two fractional order controllers are compared experimentally by analyzing reference tracking, disturbance rejection and robustness.

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[1] Isabela Birs, M.Sc. (Ph.D. student): Technical University of Cluj-Napoca, 400000, Romania (RO), isabela.birs@aut.utcluj.ro .

[2] Ioan Nascu, Professor: Technical University of Cluj-Napoca, 400000, Romania (RO), ioan.nascu@aut.utcluj.ro .

[3] Eva Dulf, Professor: Technical University of Cluj-Napoca, 400000, Romania (RO), eva.dulf@aut.utcluj.ro .

[4] Cristina Muresan, Associate Professor: Technical University of Cluj-Napoca, 400000, Romania (RO), cristina.muresan@aut.utcluj.ro , the author presented this contribution at the conference in the special session: "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

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paper id: STA185

A Rulkov neuronal model with Caputo fractional variable-order differences of convolution type

Oana Brandibur, Eva Kaslik, Dorota Mozyrska, Malgorzata Wyrwas

Abstract: In this paper, a theoretical and numerical investigation is undertaken for a fractional-order version of the Rulkov neuronal model, involving Caputo fractional variable-order differences of convolution type. As a first step, using liniarization techniques and the Z-transform method, sufficient conditions are explored which guarantee the stability or instability of the unique equilibrium point of the system. Numerical simulations are further carried out to illustrate the theoretical findings, emphasizing the differences between the current model and simpler versions involving fractional-order difference with constant fractional orders, as well as the classical integer-order Rulkov model.

[1] Oana Brandibur, M.Sc. (Ph.D. student): West University of Timisoara, Institute e-Austria Timisoara, cam. 045B, Romania (RO), oana.brandibur@e-uvt.ro .

[2] Eva Kaslik, Associate Professor: West University of Timisoara, IInstitute e-Austria Timisoara, cam. 045B, Romania (RO), eva.kaslik@e-uvt.ro .

[3] Dorota Mozyrska, Associate Professor: Bialystok University of Technology, Wiejska 45A, Poland (PL), d.mozyrska@pb.edu.pl .

[4] Malgorzata Wyrwas, Ph.D.: Bialystok University of Technology, Wiejska 45A, Poland (PL), m.wyrwas@pb.edu.pl , the author presented this contribution at the conference in the special session: "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

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paper id: LIF158

Role of the immune system in AIDS-defining malignancies

João Maurício de Carvalho, Carla Pinto

Abstract: The Center for Disease Control and Prevention considers AIDS-defining illnesses Kaposi's sarcoma, non-Hodgkin's lymphoma and cervical cancer. These cancers have higher incidence in HIV-infected individuals than in the general population. Additionally, cancers' clinical courses in HIV-positive individuals are increasingly aggressive when compared to those in HIV-negative patients. It is thus compelling to further understand the dynamics of AIDS-related cancer growth. In this paper, we propose a non-integer order model to describe the role of the immune system in cancer cells' growth in a HIV-infected individual. The model incorporates anti-retroviral therapy and chemotherapy. Numerical simulations of the model are performed for different proliferation functions of the cytotoxic T lymphocytes (CTLs), and other relevant parameters, namely the HIV-infection rate, the elimination rate of infected T cells by CTLs, and the elimination rate of cancer cells by the immune system. The results are discussed from a physiological perspective. The order of the fractional derivative completes the discussion of the results.

[1] João Maurício de Carvalho, M.Sc. (Ph.D. student): Faculdade de Ciências da Universidade do Porto, Rua do Campo Alegre, s/n, 4169-007 Porto, Portugal (PT), up200902671@fc.up.pt , the author presented this contribution at the conference in the special session: "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

[2] Carla Pinto, Ph.D.: School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, 4249-015 Porto, Portugal (PT), cpinto@fc.up.pt .

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paper id: CON111

Adaptive fractional order control of a quadrotor

Eva-H. Dulf, Cristina-I. Muresan, Daniel D. Timis

Abstract: Due to their exceptional flying maneuverability and simple dynamics, multirotor systems are widely used for various applications. Such systems vary over time due to external disturbances or unmeasured changes to which they are subjected. In this case, a simple PID controller cannot provide the desired response, unless the controller parameters are re-tuned. An adaptive control algorithm responds to this need. Moreover, to increase robustness, fractional order controllers are designed, being recognized for this property. Such control provides the entire process with good robustness and ensures good operation for major process changes. The present paper describes a comparison between such an algorithm and a classical PID applied to a quadrotor system.

[1] Eva-H. Dulf, Professor: Technical University of Cluj-Napoca, 400114 Cluj-Napoca, Memorandumului str. 28, Romania (RO), Eva.Dulf@aut.utcluj.ro.

[2] Cristina-I. Muresan, Associate Professor: Technical University of Cluj-Napoca, 400114 Cluj-Napoca, Memorandumului str. 28, Romania (RO), Cristina.Muresan@aut.utcluj.ro, the author presented this contribution at the conference in the special session "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

[3] Daniel D. Timis, M.Sc.: Technical University of Cluj-Napoca, Memorandumului 28, 400014 Cluj-Napoca, Romania (RO), Daniel.Timis@aut.utcluj.ro.

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Dynamical Systems — Theory and Applications

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paper id: LIF109

Risk related prediction for recurrent stroke and post-stroke epilepsy using Fractional Fourier Transform analysis of EEG signals

Eva-H Dulf, Clara-M. Ionescu, Cristina Ioana Muresan

Abstract: Stroke is a medical condition which can easily affect the quality of life, depending on how extended the stroke is and what regions of the brain are involved. According to the most recent data cited in WHO, Romania is in top three of the countries with increased frequency of stroke and has the second place for having the most deaths and disabilities caused by stroke. Actually, stroke is the second death cause in Romania after cardiac arrest. Today, there are various prevention methods concerning stroke. The hypothesis of the research context is that EEG signal can provide useful information on risk related prediction for recurrent stroke and post-stroke epilepsy. Knowing that there is a certain risk on developing secondary epilepsy after stroke, based on the EEG rhythms, may help in prevention and maybe in reconsidering a new approach in the treatment of this pathology. On the other hand Fractional Fourier Transform (FFT), a generalization of conventional Fourier Transform, is used with success in many applications like detection of signals in noise, image compression, reduction of side lobe levels using convolutional windows, time-frequency analysis, etc. It can be used in more effective manner compared to Fourier transform with additional degrees of freedom. That was the motivation to analyze the spectra of each component of the EEG signals using FFT in order to predict recurrent stroke and post-stroke epilepsy incidence. The results prove the efficiency of the method.

1) Eva-H Dulf, Professor: Technical University of Cluj-Napoca, 400114 Cluj-Napoca, Memorandumului str. 28, Romania (RO), Eva.Dulf@aut.utcluj.ro, the author presented this contribution at the conference in the special session "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

2) Clara-M. Ionescu, Professor: Ghent University, Research group on Dynamical Systems and Control, Campus Ardoyen, Technologiepark 125, 2nd floor, B-9052 Ghent, Belgium, Belgium (BE), ClaraMihaela.Ionescu@ugent.be.

3) Cristina Ioana Muresan, Associate Professor: Technical University of Cluj-Napoca, Memorandumului 28, 400014 Cluj-Napoca, Romania (RO), Cristina.Muresan@aut.utcluj.ro, the author presented this contribution at the conference in the special session "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

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paper id: CON13

Special session on advances in fractional order modelling and control

Cristina Muresan, Carla Pinto, Eva Dulf

Abstract: Fractional order differentiation is a generalization of classical integer differentiation to real or complex orders. In the last couple of decades, the use of fractional order calculus in modelling and control applications has seen a tremendous increase in research papers. This is mainly due to arguments recommending fractional calculus as an optimal tool to describe the dynamics of complex systems and to enhance the performance and robustness of control systems. Among these, fractional order PID controllers tuning, implementation and experimental validation occupy an important place. However, there are still many issues and open problems that need to be addressed in this area. This special session welcomes papers dealing with fractional calculus in modelling and control applications and aims at presenting some recent developments in this area of research. We welcome any contribution within the general scope of the Special Session theme "Advances in Fractional Order Modelling and Control".

[1)] Cristina Muresan, Associate Professor: Technical University of Cluj-Napoca, Str. Memorandumului no. 28 400114 Cluj-Napoca, Romania (RO), cristina.muresan@aut.utcluj.ro, the author presented this contribution at the conference in the special session: "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

[2)] Carla Pinto, Professor: Instituto Superior de Engenharia do Porto, Rua Dr. António Bernardino de Almeida, 431 4249-015 Porto, Portugal (PT), cpinto@fc.up.pt.

[3)] Eva Dulf, Professor: Technical University of Cluj-Napoca, Str. Memorandumului no. 28 400114 Cluj-Napoca, Romania (RO), eva.dulf@aut.utcluj.ro.

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paper id: MAT264

Closed loop system identification using fractional order model

Pritesh Shah, Ravi Sekhar

Abstract: The use of the mathematical model is vital for the design of the model based controller and prediction of the system response. This mathematical model can be derived using first principle method and empirical method. The empirical method is deriving the model based on input and output data. This method is also called as system identification. Many real-time systems are inherited closed loop systems. Moreover, it is not possible to get data in an open loop system from the process industry. In such cases, the closed loop system identification is useful. In system identification, the selection of model structure is critical. In this paper, a fractional order model is proposed for the closed-loop system identification. The model parameters of fractional order model are optimized using minimization or maximization of performance indices.

[1] Pritesh Shah, Ph.D.: Symbiosis institute of technology, symbiosis international (Deemed University), PRITESH SHAH , A103, viva sarovar, jambhulwadi road. Ambegaon, pune, India (IN), pritesh.ic@gmail.com, the author presented this contribution at the conference in the special session "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

[2] Ravi Sekhar, Professor: Symbiosis Institute of Technology, Symbiosis International (Deemed University), Pune, Symbiosis Institute of Technology, Lavale, near lupin research park, India (IN), totagopinath@gmail.com.

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Asymptotic stability of fractional variable order discrete-time equations with terms of convolution operators

Małgorzata Wyrwas, Dorota Mozyrska, Piotr Oziablo

Abstract: Recently, fractional calculus has been considered in many scientific and engineering fields. There two important cases: continuous-time as discrete-time equations. The importance of discrete case can be examined in applications.In the paper we discuss asymptotic stability of linear fractional difference equations with variable order.We consider operators of convolution type. The stability of fractional variable order systems is one of the important property that is analysed in order to study the behaviour of the considered systems. As our definition of fractional variable order difference is a convolution type, the Z-transform is used as an effective tool for the stability analysis. In the equations we put two operators with different order functions and then describe stability regions for them. We describe regions of the stability for systems accordingly to locus of parameters of considered equation. We compare our results to those with constant order terms as with continuous fractional operators of constant order. Our results are illustrated by numerical examples for different order functions.

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[1] Małgorzata Wyrwas, Ph.D.: Bialystok University of Technology, Wiejska 45A, Poland (PL), m.wyrwas@pb.edu.pl .

[2] Dorota Mozyrska, Associate Professor: Bialystok University of Technology, Wiejska 45A, Poland (PL), d.mozyrska@pb.edu.pl , the author presented this contribution at the conference in the special session: "Advances in fractional order modelling and control" organized by C. Muresan, C. Pinto and E. Dulf.

[3] Piotr Oziablo, M.Sc. (Ph.D. student): Bialystok University of Technology, Wiejska 45A, Poland (PL), p.oziablo@stident.pb.edu.pl .

SPECIAL SESSION 12

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paper id: STA241

Free vibration analysis of FGM shell with complex planform in thermal environments

Jan Awrejcewicz, Lidiya Kurpa, Tetyana Shmatko

Abstract: Summary. In the present study free vibrations of FGM shallow shells of an arbitrary planform in thermal environment are investigated via R-functions method (RFM). First-order shear deformation theory of shallow shells is employed. Material properties are assumed to be temperature-dependent and expressed as nonlinear functions of temperature. The generic material properties are not only functions of temperature, but also functions of thickness direction. It is supposed that material properties vary through thickness according to a power-law distribution of the constituent's volume fraction. The developed method is based on the combined applications of the R-functions theory, variational Ritz's method. A comparison of the obtained results with available ones is carried out for rectangular plates and shallow shells. Vibration of shell panels with complex planform and different boundary conditions including mixed ones are studied. Solution structures and related admissible functions for shells with complex planform have been constructed by the R-functions theory. The effect of the temperature rise, geometry of the shell, material properties and constituent volume fraction index is examined. Keywords: R–functions theory, FGM shallow shells, free vibrations, thermal environment.

[1] Jan Awrejcewicz, Professor: 3 Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, Lodz, Poland, 1/15 Stefanowski Street (building A22), 90-924 Łódź, Poland 1/15 Stefanowski Street, 90-924 Łódź, Poland, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Lidiya Kurpa, Professor: National Technical University , Kyrpychova, 2, Kharkiv, Ukraine, 61002, Ukraine (UA), kurpalidia@gmail.com.

[3] Tetyana Shmatko, Associate Professor: National Technical University "Kharkiv Polytechnic Institute", Kyrpychova, 2, Kharkiv, Ukraine, 61002, Ukraine (UA), ktv_ua@yahoo.com, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

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Comparison using FEA between cylindrical, spherical, and conical configurations of optical choppers with shafts

Eduard-Sebastian Csukas, Dorin Demian, Virgil-Florin Duma

Abstract: Optomechanical choppers are commonly built as rotational disks, but this configuration is limited in terms of the frequency of the laser impulses they produce. This chop frequency is limited to maximum 10 kHz for macroscopic choppers, but in reality it does not exceed 3 kHz because of vibration issues. While Micro-Electro-Mechanical Systems (MEMS) are a solution to this drawback, we have adopted another, lower cost strategy and introduced (patent pending) a novel type of macroscopic device: choppers with rotational shafts. The aim of this paper is to present our final study, using Finite Element Analysis (FEA), regarding the three possible shapes of shafts we have introduced: cylindrical, spherical, and conical. For each shape of shafts, a range of characteristic parameters is considered: shaft diameter, number and width of the slits, and rotational speeds of the shafts — the latter of up to 120 krpm. Both the structural integrity and the deformations of the shafts are compared, for the three shapes, and the specific differences are calculated. The most appropriate material, an Al alloy is considered, for all devices, as from our studies it behaves better than steel for such applications, while it has lower costs than beryllium (which is also toxic during manufacturing). From the multi-parameter analysis carried out, conclusions are drawn on the optimal configuration and parameters of such optical choppers with shafts.

[1] Eduard-Sebastian Csukas, M.Sc. (Ph.D. student): UNIVERSITATEA POLITEHNICA TIMIŞOARA, VICTORIEI SQUARE NO. 2 TIMIŞOARA, Romania (RO), eduardsebastian.csukas@student.upt.ro , the author presented this contribution at the conference in the special session: "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

[2] Dorin Demian, Ph.D.: Aurel Vlaicu University of Arad, Str. Elena Dragoi nr. 2, Romania (RO), demian_arad@yahoo.com .

[3] Virgil-Florin Duma, Professor: Aurel Vlaicu University of Arad, Str. Elena Dragoi nr. 2, Romania (RO), duma.virgil@osamember.org .

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Application of the wheel-flat detection algorithm using advanced acoustic signal analysis

Pawel Komorski, Grzegorz M. Szymanski, Tomasz Nowakowski, Malgorzata Orczyk

Abstract: Urban rail communication is one of the most attractive public modes of transport. There are plenty of advantages for the community and environment of using this kind of transport. Furthermore, vibroacoustic comfort and noise annoyance aspects during urban rail vehicles operations are significant topics for passengers and city dwellers. These problems are also important for rail fleet managers and city authorities. Therefore, dynamic interaction between wheel and rail during vehicle passage should be kept in good technical condition. On the other side, the impact noise is the one of the most annoying noise emitted by urban rail vehicles inside the cities. The flat spots (wheel-flats) on the wheel or rail surfaces are one of the main causes of increasing rolling noise level. The main aim of the article is to present the novel approach of the wheel-flat detection algorithm using advanced acoustic signal analysis. The measurement equipment was placed in the near field of track in one of the tram depots. Several measured cases are distinguished by high impact noise level. The wheel-flat detection system is described by implementation of different kind of frequency and time processing methods on measured acoustic data.

[1] Pawel Komorski, M.Sc. (Ph.D. student): Poznań University of Technology, Divison of Rail Vehicle, Piotrowo 3, Poland (PL), pawel.komorski@put.poznan.pl, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

[2] Grzegorz M. Szymanski, Associate Professor: Poznań University of Technology, Divison of Rail Vehicle, Piotrowo 3, Poland (PL), grzegorz.m.szymanski@put.poznan.pl.

[3] Tomasz Nowakowski, M.Sc. (Ph.D. student): Poznań University of Technology, Divison of Rail Vehicle, Piotrowo 3, Poland (PL), tomasz.zb.nowakowski@doctorate.put.poznan.pl.

[4] Malgorzata Orczyk, Ph.D.: Poznań University of Technology, Divison of Rail Vehicle, Piotrowo 3, Poland (PL), malgorzata.orczyk@put.poznan.pl.

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Vibration and buckling of laminated plates of complex form under in-plane uniform and non-uniform loading

Lidiya Kurpa, Victoriya Tkachenko, Anna Linnik

Abstract: Abstract: The vibration and buckling analysis of symmetrically laminated plates with complex form subjected to in–plane uniform and non–uniform loading is performed using variational Ritz method and the R-functions theory. Classical and First order shear deformations theory of Timoshenko’s type are adopted. Each ply is assumed to be as an orthotropic homogeneous one without slip at interfaces. The developed approach includes several stages: determination of the heterogeneous subcritical state of the plate; finding buckling critical load; solving linear vibration problem. Ritz’s method is applied on each stage. Systems of the admissible functions, that satisfy at least main (kinematic) boundary conditions have been built by the R-functions method. Validation of the proposed method and created software are confirmed by comparison of buckling load and frequencies vibration with known results for square laminated plates with free circle or rectangular cut-outs. Buckling loads for laminated rectangular plates with two clamped and free rectangular cut-outs have been obtained. It is assumed that plates can be made of different materials and have the different ply orientation. Effect of the cut-outs sizes and their position inside of the domain also as ways of cuts fixing on critical load and frequencies values are studied in details. Number of layers, degree of orthotropic, boundary conditions, ply orientation, type of loading (uniform and non-uniform) on buckling critical load and frequencies value are investigated.

[1] Lidiya Kurpa, Professor: Heard of Applied Mathematics Department NTU"KhPI", NTU"KhPI",2, Cyrpychova Str, Kharkov,61002,Ukraine, Ukraine (UA), kurpalidia@gmail.com, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

[2] Victoriya Tkachenko, Ph.D.: Assistant of Applied Mathematics Department NTU, NTU, Ukraine (UA), viktoryatkachenko@gmail.com, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

[3] Anna Linnik, Associate Professor: Associate Professor, NTU, Ukraine (UA), linnik2105@gmail.com, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

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paper id: VIB168

Sensitivity analysis of the new concept of a vibration-reduction system for continuous miner

Mariusz Pawlak, Wojciech Klein, Jan Kania, Arkadiusz Mężyk

Abstract: In this paper are presented results from sensitivity analysis of the new concept of a vibration-reduction system for continuous miner developed by authors. In previous publications were applied the identifications of the vibration-control system parameters by tuning the excitation frequency to the eigenfrequency no. 4, which was dependent on the angular velocity ω. Because, at that mode, the centre of cutter drum does not vibrate, the excitation frequency during cutting could be tuned to that eigenfrequency. The obtained results were very promising, as the vibration of cutter drum was reduced with a specified angular velocity of 6.44 rad/s, exactly as it was assumed in the new concept of the vibration-reduction system. There is a need to apply different angular velocities when cutting various materials, and the sensitivity analysis of angular velocity and system stiffness parameters k1 and k2 must be applied. In this paper is presented the sensitivity analysis of the vibration-control system for a continuous miner in a wide range of angular velocity ω and system stiffness defined by parameters k1 and k2.

[1] Mariusz Pawlak, Ph.D.: Silesian University of Technology, Akademicka 2A, Poland (PL), mariusz.pawlak@polsl.pl, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

[2] Wojciech Klein, Ph.D.: Silesian University of Technology, Akademicka 2A, Poland (PL), wojciech.klein@polsl.pl.

[3] Jan Kania, Ph.D.: Silesian University of Technology, ul. Akademicka 2A, 44-100 GLIWICE, Poland (PL), jan.kania@polsl.pl.

[4] Arkadiusz Mężyk, Professor: Silesian University of Technology, ul. Akademicka 2A, 44-100 GLIWICE, Poland (PL), arkadiusz.mezyk@polsl.pl.

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Damage detection in beams using an additional roving mass based on the natural frequency shifting

Juliana Santos

Abstract: Damage detection plays an exceptional role in the safe maintenance of structures. Techniques which require just the response of the damaged structure are more relevant once in most of the time the intact structure analysis is impracticable. Thus, our purpose is to present a technique that consists in the application of an additional mobile mass along the length of free-free and simply supported beams and the investigation of the variation of the natural frequencies. Next, the Discrete Wavelet Transform (DWT) is applied in the simple and robust signal where the wavelet coefficients amplitude increase allowing the localization of the damage. The obtained results in this paper were satisfactory, this is, the spatial evolution of the natural frequencies of the damaged beam caused a significative change in the damaged region. Finally, the DWT magnified the discontinuities effects becoming a great tool in damage detection studies.

[1)] Juliana Santos, B.A. (M.Sc. student): University of Brasilia, Chac 12 Casa 14 , Fercal, Brasília, Brazil (BR), julianasaaantos@gmail.com, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

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Testing and analysis of vibrations of a tension transmission with a thermally sealed belt

Grzegorz M. Szymański, Piotr Krawiec

Abstract: The advantages of heat-sealable belts include: the possibility of welding their ends, which allows to obtain a strip of any length and its quick replacement in case of damage, excellent resistance to abrasion, resistance to oil, grease, dirt and some chemicals, resistance to temperature from -30 °C to + 80 °C, significant elasticity at a relatively low level of stretching, high value of the friction coefficient, and thus very good anti-slip properties even at changes in load, safety in use in contact with food. There are few publications devoted to these belts, therefore the authors have built a stand for experimental studies of such drives. The analysis of vibrations of a draw gear with a thermally sealed belt was carried out in accordance with the assumptions of an active experiment. It was assumed that the input parameters are: belt tension force, torque loading the gearbox and rotational speed of the drive shaft, and the output parameters are the values of vibration acceleration of selected elements of the stand (the transducers are mounted on the bearing housings of the drive and driven shafts). During the research, the load of the gearbox was changed and the influence of its action on the value of point measures of vibration signals was observed. The following point measures were analyzed: rms value, peak value and kurtosis. The results of the research will certainly be useful for designers and people involved in the operation of drawstring drives with thermally weldable belts.

[1] Grzegorz M. Szymański, Associate Professor: Poznan University of Technology, Rail Vehicles Division, Piotrowo 3 St, PL-60-965 Poznan, Poland (PL), grzegorz.m.szymanski@put.poznan.pl , the author presented this contribution at the conference in the special session: "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

[2] Piotr Krawiec, Associate Professor: Poznan University of Technology, Chair of Basics of Machine Design, Piotrowo 3 St, PL-60-965 Poznan, Poland (PL), piotr.krawiec@put.poznan.pl .

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paper id: ENG79

Analytical model of a circular membrane with damage in the form of scratches

Aleksandra Waszczuk-Młyńska, Stanislaw Radkowski

Abstract: The paper presents the analytical model of a circular membrane with damage lacated in the middle of the membrane in shape of scratches. The obtained model is based on a partial differential equation, describing vibration of the torus filled in the middle. The obtained differential equation was analytically calculated using existing tools, eg substitution of Bessel. On the basis of the original model, the natural frequencies of the object were determined and, as a result, the damage assessment of the circular membrane was determined.

[1)] Aleksandra Waszczuk-Młyńska, Ph.D.: Warsaw University of Technology, ul. Narbutta 84, 02-524 Warsaw, Poland (PL), aleksandra.mlynska@pw.edu.pl .

[2)] Stanislaw Radkowski, Professor: Warsaw University of Technology, ul. Narbutta 84, 02-524 Warsaw, Poland (PL), stanislaw.radkowski@pw.edu.pl , the author presented this contribution at the conference in the special session: "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo

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paper id: EXP343

Synchronicity phenomenon of circular cylindrical shell under random excitation

Antonio Zippo, Francesco Pellicano, Giovanni Iarriccio

Abstract: In the present paper is deeply described an experimental campaign focused on the random vibrations of circular cylindrical shells under thermal gradients across the shell thickness and broadband random loading. Many engineering fields are involved in this subject and in real environments, the excitations are likely non-deterministic, moreover, extreme thermal conditions can cause differences of the temperature inside and outside the shell, as in thermal ex-changers. Due to the importance of the subject the literature on shell vibration is extremely wide, it is not analyzed here for the sake of brevity; however, it is to note that the number of papers containing experimental results is not large. Under a random forcing, a system generally expects a random response, however, in some particular conditions (e.g. internal resonances, parametric resonances, ...) the presence of nonlinearity in the systems can give rise to a surprising phenomenon: the synchronization of non-linear oscillators subjected to random forcing that has been partially studied in the literature for its remarkable characteristic of conveying the spectral energy of a random forcing over specific frequencies. This work takes advantage of previous setup and experimental techniques developed by the present research team. The phenomenon of synchronicity is clearly observed for some particular thermal conditions: a strong transfer of energy from a broadband excitation signal to an almost harmonic response is experimentally observed.

[1] Antonio Zippo, Ph.D.: DIEF, Università di Modena e Reggio Emilia, Dipartimento di Ingegneria "Enzo Ferrari", Via Pietro Vivarelli 10, 41125, modena, Italy (IT), antonio.zippo@unimore.it, the author presented this contribution at the conference in the special session "Modeling and experiments of complex continuous systems" organized by F. Pellicano and A. Zippo.

[2] Francesco Pellicano, Professor: DIEF, Università di Modena e Reggio Emilia, Via Pietro Vivarelli, 10 - 41125 Modena, Italy (IT), frank@unimore.it.

[3] Giovanni Iarriccio, M.Sc. (Ph.D. student): DIEF, Università di Modena e Reggio Emilia, Dipartimento di Ingegneria "Enzo Ferrari", Via Pietro Vivarelli 10, 41125 Modena, Italy (IT), Giovanni.Iarriccio@unimore.it.

LECTURES

15th INTERNATIONAL CONFERENCE

Dynamical Systems — Theory and Applications

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paper id: VIB204

Influence of bending and torsional flexibility on displacements and loading of risers

Iwona Adamiec-Wójcik, Lucyna Brzozowska, Stanisław Wojciech

Abstract: The paper presents the application of the finite segment method to analysis of coupled bending torsional vibrations of risers. The method is formulated by means of joint coordinates using multibody methods for kinematics and dynamics. The mathematical model and computer program enable us to analyse both free and forced vibrations of the riser in water. The forced vibrations may be caused by the motion of the base (vessel or platform). The model is validated by comparing frequencies of free vibrations calculated with authors' own models with the results presented by other researchers. The influence of sea currents on loads (also those which cause torsion) on a non-symmetrical riser is analysed.

[1] Iwona Adamiec-Wójcik, Professor: University of Bielsko-Biala, Willowa 2, 43-309 Bielsko-Biała, Poland (PL), i.adamiec@ath.bielsko.pl.

[2] Lucyna Brzozowska, Associate Professor: University of Bielsko-Biala, Willowa 2, 43-309 Bielsko-Biała, Poland (PL), lbrzozowska@ath.bielsko.pl.

[3] Stanisław Wojciech, Professor: University of Bielsko-Biala, Willowa 2, 43-309 Bielsko-Biała, Poland (PL), swojciech@ath.bielsko.pl.

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paper id: CON64

Modeling the spatiotemporal transmission of Cholera disease involving infectiology, epidemiology and controls

Shohel Ahmed, Md. Kamrujjaman

Abstract: This study divided into two parts. First, we consider a mathematical model consisting of systems of ordinary differential equations (ODEs) describing the disease dynamics using general incidence rate. Model parameters are estimated using cholera outbreak data of Bangladesh and stability analysis is performed using the basic reproduction number of the system. Some numerical results for the optimal control problem are investigated where controls representing vaccination of individuals and disposal of a pathogen in order to minimize the number of infected individuals, the cost of vaccination and pathogen disposal. Next, we extend the model to a system of PDEs coupled with ODEs to include spatial movement within a region. Both time and space dependent controls are applied to the hybrid system. Existence and uniqueness results are established for weak solutions of the system. The existence of an optimal control pair is proven and the characterization of the controls is derived from corresponding adjoint systems. Numerical results are completed to illustrate various scenarios.

[1] Shohel Ahmed, M.Sc.: Bangladesh University of Engineering and Technology, Assistant Professor, Department of Mathematics, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh., Bangladesh (BD), shohel2443@math.buet.ac.bd.

[2] Md. Kamrujjaman, Associate Professor: Department of Mathematics, University of Dhaka., Associate Professor, Department of Mathematics, University of Dhaka, Dhaka 1000, Bangladesh., Bangladesh (BD), kamrujjaman@du.ac.bd.

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Full spectrum analysis for studying the backward whirl in accelerated rotor systems

Mohammad AL-Shudeifat, Oleg Shiryavev, Tariq Alzarooni, Chandrasekhar Nataraj

Abstract: The backward whirl (BW) phenomena in intact and cracked rotor systems that exhibit recurrent acceleration and deceleration during startup and coast down operations has not been well-studied in the literature. However, for startup and cost down operations during which a frequent passage through critical forward whirl speeds takes place, the BW orbits are found to be immediately captured after the passage through the critical FW rotational speeds. The zones of BW orbits are observed to be significantly affected by the appearance of crack damages that are accompanied with using isotropic or anisotropic bearings at the shaft supports. The finite element model of the cracked rotor-bearing-disk system is employed to obtain the system linear-time-variant (LTV) equations of motion for the numerical simulation. The obtained LTV mathematical model of the system represents a nonlinear dynamical model of the considered systems. Consequently, the full spectrum analysis (FSA) is successfully employed here to the numerical simulation response of the considered systems to verify the existence of these BW zones of shaft rotational speeds after the passage through the critical and subcritical FW whirl rotational speeds. The obtained results for the intact shaft with anisotropic bearing, cracked shaft with isotropic bearings and the cracked shaft with anisotropic bearings verify the robustness of the FSA as a powerful tool of capturing the BW zones in the cracked rotor systems.

[1] Mohammad AL-Shudeifat, Associate Professor: Associate Professor and Associate Chair, Aerospace Engineering Department, Khalifa University, United Arab Emirates (AE), mohd.shudeifat@ku.ac.ae.

[2] Oleg Shiryavev, Ph.D.: Assistant Professor, University of Alaska Anchorage, AK, United States (US), oshiryavev@alaska.edu.

[3] Tariq Alzarooni, M.Sc. (Ph.D. student): Ph.D Student, Khalifa University, United Arab Emirates (AE), tariq.alzarooni@ku.ac.ae.

[4] Chandrasekhar Nataraj, Professor: Professor, Villanova University, Villanova, United States (US), nataraj@villanova.edu.

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paper id: ENG328

On backward whirl excitation in linear-time-variant intact and cracked rotor systems

Tariq Alzarooni, Mohammad AL-Shudeifat, Oleg Shiryavev, Chandrasekhar Nataraj

Abstract: In a recent study of intact and cracked rotor systems with an open crack model and anisotropic bearings, capturing of BW phenomena immediately after the passage through the critical forward whirl speeds has been numerically and experimentally confirmed. Accordingly, this phenomena is further investigated here for rotor systems with a breathing crack model. The Finite Element Model (FEM) is used to develop the linear-time-variant (LTV) equations of motion of the considered cracked rotor systems in which startup acceleration is considered. In addition to incorporating the breathing crack, the effect of both bearings scenarios; anisotropic and isotropic, on the excitation of this BW phenomena is also examined. In addition, the dynamic transient response during startup is evaluated at various unbalance force vector orientations with respect to the crack opening direction. It is found that the variation in unbalance force vector angle with respect to crack opening direction has a significant impact on the extent of BW zones. It is also observed that, at wide range of unbalance force vector angles, the BW whirl zones are always associated with an abrupt drop in whirl amplitudes. The dynamic transient response is also evaluated at various angular acceleration rates where the appearance of BW zones is more prominent in the case of anisotropic bearing model. It is found that the BW zones are captured at nearly all ranges of crack depth ratios for the anisotropic bearing case. However, these zone are only captured at relatively high crack depths for the isotropic bearing case.

[1] Tariq Alzarooni, M.Sc. (Ph.D. student): Ph.D Student, Khalifa University, United Arab Emirates (AE), tariq.alzarooni@ku.ac.ae.

[2] Mohammad AL-Shudeifat, Associate Professor: Associate Professor and Associate Chair, Aerospace Engineering Department, Khalifa University, United Arab Emirates (AE), mohd.shudeifat@ku.ac.ae.

[3] Oleg Shiryavev, Ph.D.: Assistant Professor, University of Alaska Anchorage, AK, United States (US), oshiryavev@alaska.edu.

[4] Chandrasekhar Nataraj, Professor: Professor, Villanova University, Villanova, United States (US), nataraj@villanova.edu.

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Critical tolerance evolution: Classification of the chain-recurrent set

Carlos Argaez, Peter Giesl, Sigurdur Freyr Hafstein

Abstract: Complete Lyapunov functions for non-linear dynamical systems can be obtained by approximately solving a partial differential equation that describes the condition for its orbital derivative. Efficient algorithms to compute them have been implemented. The fact that the partial differential equation is not satisfied at points of the chain-recurrent set is used to determine this set; more precisely, all points where the value of the orbital derivative is larger than a fixed, critical tolerance parameter, are an estimate of the chain-recurrent set. The mathematical conditions of smoothness over the orbital derivative are obtained by averaging the values of the orbital derivative locally. Furthermore, convergence to zero is avoided by normalizing the sum of the orbital derivative condition. However, the tolerance parameter to describe the chain-recurrent set has not been considered. This results in an overestimation of the chain-recurrent set. Several algorithms have been proposed to reduce the overestimation of the chain-recurrent set, but no systematic analysis on the dependence on the critical parameter has been made so far. In this paper, we focus on studying this parameter. To proceed, the chain-recurrent set is divided into different subsets of connected components; their evolution per iteration and their different behaviour are studied. The outcome of this research will create an efficient analysis method for the chain-recurrent set and aims to reduce the overestimation by obtaining the lowest possible tolerance parameter necessary to classify the chain-recurrent set.

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[1] Carlos Argaez, Ph.D.: University of Iceland, Science Institute, Department of Mathematics, University of Iceland, Dunhagi 5, 107 Reykjavík, Iceland, Iceland (IS), carlos@hi.is.

[2] Peter Giesl, Professor: University of Sussex, Department of Mathematics , School of Mathematical and Physical Sciences ,University of Sussex, Falmer Campus, Brighton BN1 9QH, Great Britain, England (GB), P.A.Giesl@sussex.ac.uk.

[3] Sigurdur Freyr Hafstein, Professor: University of Iceland , Science Institute, Department of Mathematics, University of Iceland, Dunhagi 5, 107 Reykjavík, Iceland, Iceland (IS), shafstein@hi.is.

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paper id: OPT181

Great persons and results make biomimetics incredibly inspirational

Ivana Atanasovska, Dejan Momcilovic

Abstract: The concept of using ideas from nature as inspiration for innovation and technological development is in focus last decades, while the similar approach can be found in the ancient civilizations. In any kind of such progress it is important to remember the founders and pioneers and to understand their character and the circumstances that push them to go beyond existing knowledge. This is predominantly important in interdisciplinary science areas such as biomimetics. The importance of biomimetics in development of modern dynamical systems and optimal design in mechanical systems is emphasized in this paper. The authors viewpoint of future development of biomimetics as original discipline and the principles for future research is also presented in this paper. The short presentation of existing results of authors based on the application of biomimetics principles on real problems will be presented, too.

[1)] Ivana Atanasovska, Associate Professor: Mathematical Institute of the Serbian Academy of Sciences and Arts, Kneza Mihaila 36, 11000 Belgrade, Serbia (RS), iviatanasov@yahoo.com .

[2)] Dejan Momcilovic, Ph.D.: Institute for testing of materials IMS, Bulevar vojvode Misica 43, 11000 Belgrade, Serbia (RS), dejan.b.momcilovic@gmail.com .

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paper id: STA340

Estimation of the domain of attraction for a nonlinear mechanical system with three degrees of freedom

Jan Awrejcewicz, Dmytro Bilichenko, Akram Khalil Cheib, Nataliya Losyeva, Volodymyr Puzyrov

Abstract: The paper deals with the problem of obtaining estimates of the domains of attraction (DA) and stability for a nonlinear mechanical system with three degrees of freedom and uncertain parameters. The system under consideration consists of two coupled linear oscillators, to one of which a dynamic absorber with damping and nonlinear stiffness is connected. Two models are studied: a) the linear component of the stiffness of the absorber is positive; b) a case of a bistable absorber, i.e. the stiffness of the absorber is characterized by negative linear and positive nonlinear (cubic) spring coefficients. The Lyapunov functions (LF) are used to obtain the approximations for regions of attraction/stability. Various methods of LF construction are discussed: the representation of the equations of motion in different coordinates (Cartesian and polar), the use of polynomial and rational functions, etc. The results of numerical simulations are presented. The influence of absorber's parameters (mass ratio and dimensionless damping and stiffness coefficients) onto shape and size of the DA is discussed.

[1] Jan Awrejcewicz, Professor: Lodz University of Technology, 1/15 Stefanowski Str., 90-924 Łódź, Poland, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Dmytro Bilichenko, B.A.: Vasyl Stus Donetsk National University, 600-richia 21, Vinnitsia, Ucraine, Ukraine (UA), bilichenko.d@donnu.edu.ua.

[3] Akram Khalil Cheib, M.Sc. (Ph.D. student): Vasyl Stus Donetsk National University, 600-richia 21, Vinnitsia, Ucraine, Ukraine (UA), akram_cheaib@hotmail.com.

[4] Nataliya Losyeva, Professor: Vasyl Stus Donetsk National University, 600-richia 21, Vinnitsia, Ucraine, Ukraine (UA), n.losieva@donnu.edu.ua.

[5] Volodymyr Puzyrov, Professor: Vasyl Stus Donetsk National University, 600-richia 21, Vinnitsia, Ucraine, Ukraine (UA), v.puzyryov@donnu.edu.ua.

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Shells subjected to mechanical and thermal loads and corrosion

Jan Awrejcewicz, Anton V. Krysko, E.Yu. Krylova, T.Y. Yaroshenko, M.V. Zhigalov, Vadim A. Krysko

Abstract: Two mathematical models of flexible shallow shells have been derived, taking the account of the geometric non-linearity: (i) mathematical model under coupled temperature and deformation (equations in terms of displacements) fields; (ii) mathematical model taking into account also physical non-linearity. In both models, the one-sided corrosion wear has been taken considered in terms of Dolinskii and Gutman models. We have proposed and successfully employed the method to decrease the order of the governing equations and to conduct their linearization by reduction of the problem to study the bi-harmonic equation. In order to solve the reduced problem numerically, the method of variational iterations (MVI) and the method of variable stiffness parameter have been used. It has been shown that the velocity of the decrease in the plate thickness depends essentially on the load. The change in plate thickness depends on the chosen (Dolinskii or Gutman) model. The studied plates reach the strength material limit practically with the same volume, but after different time intervals.

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[1] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

[3] E.Yu. Krylova, Associate Professor: Department of Mathematical and Computer Modeling, Saratov State University, 410054 Saratov, Russia (RU), Kat.Krylova@bk.ru.

[4] T.Y. Yaroshenko, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tyyaroshenko@gmail.com.

[5] M.V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[6] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Comparative analysis of the theories of nano-mechanical systems on the example of contact interaction of nano-Bernoulli-Euler beams

Jan Awrejcewicz, Anton V. Krysko, Maxim V. Zhigalov, Vadim A. Krysko

Abstract: In this paper, for the problem of contact interaction of Bernoulli-Euler nanoblock, a comparative analysis of the most commonly used theories, i.e. modified couple stress theory, nonlocal theory and strain gradient theory have been employed. With the help of Hamilton's variational principle the resolving system of differential equations and the corresponding boundary conditions for each mathematical model are obtained. To solve the system of nonlinear differential equations, the second-order finite difference and fourth-order Runge-Kutta methods are applied. Fourier and wavelet analysis, phase portraits, pseudo Poincare maps, and dynamic analysis of the largest Lyapunov exponents are used to analyze the nonlinear dynamics of the contact interaction. In addition, the phase chaotic synchronization is investigated. With the help of the developed programs, the influence of the type of mathematical model on the deflection of the beam, estimation of both the natural frequencies and the types of modes of vibration of the beam are carried out.

[1] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

[3] Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[4] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Nonlinear dynamics of Euler-Bernoulli nanobeams in temperature/magnetic fields and under radiation with an account of physical nonlinearity

Jan Awrejcewicz, Vadim A. Krysko-jr, Olga A. Saltykova, Irina V. Papkova, Vadim A. Krysko

Abstract: The theory of nonlinear dynamics of Euler-Bernoulli nano beams taking into account the inhomogeneity of the material in temperature/magnetic fields and subjected to radiation exposure is proposed. In order to construct this theory, the following hypotheses are introduced: (i) the beam material is isotropic, but non-uniform; (ii) modulus of elasticity E(x,z,e_i,T) and Poisson's ratio v(x,z,e_i,T) depend on coordinates and strain intensity; (iii) strain rate depends on temperature and radiation exposure; (iv) kinematic model of the first approximation (Euler-Bernoulli) is employed; (v) physical nonlinearity is taken into account according to the deformation theory of plasticity; (vi) nanostructures are taken into account according to the modified couple stress theory; (vii) the stationary temperature field is determined from the solution of the two-dimensional heat conduction equation (Poisson's equation) taking into account the internal heat sources for the boundary conditions of the first to the third kind; (viii) the magnetic field is determined by solving a Maxwell equation. The nonlinear dynamics and statics of Euler-Bernoulli nanobeams are analyzed depending on the intensity and type of temperature and magnetic fields, the intensity of radiation and the size-dependent parameter. A static solution is obtained from a dynamic solution by means of a continuation method with regard to a parameter.

[1] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Vadim A. Krysko-jr, M.Sc. (Ph.D. student): Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), vadimakrysko@gmail.com.

[3] Olga A. Saltykova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), olga_a_saltykova@mail.ru.

[4] Irina V. Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), ikravzova@mail.ru.

[5] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Size-dependent nonlinear vibrations of micro-plates subjected to in-plane magnetic field

Jan Awrejcewicz, Olga Mazur

Abstract: Nonlinear vibrations of the microplates subjected to the influence of a longitudinal magnetic field are considered. Size-depended model based on a modified couple stress theory is employed. The governing equations for geometrically nonlinear vibrations use the von Karman plate theory. Effect of the magnetic field is taken into account due to the Lorentz force deriving from the Maxwell's equations. Developed approach is based on applying of the Bubnov-Galerkin method and reducing partial differential equations to an ordinary differential equation. Some calculations are performed to validate the proposed algorithm in comparison with the known from literature results. Influence of the magnetic field, material length scale-parameter, plate aspect ratio on the system behavior is studied.

[1] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Olga Mazur, Ph.D.: National Technical University “KhPI”, 2, Kyrpychova str., 61002, Kharkiv, Ukraine (UA), mazuroly@gmail.com.

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Nonlinear dynamics of flexible nanobeams taking into account the Casimir, van der Waals and Coulomb forces

Jan Awrejcewicz, Olga A. Saltykova, Vadim A. Krysko

Abstract: We construct a mathematical model of the flexible nano beam based on the Sheremetev-Pelekh kinematic model, subject to the following hypotheses: (i) the beam is elastic and isotropic; (ii) the nanostructure of the beam is described by the modified moment theory of elasticity; (iii) the beam is in a stationary temperature field, which is described by the Duhamel-Neumann model; (iv) geometric nonlinearity is taken into account by the von Karman model; (v) the Sheremet'ev-Pelekh kinematic model taking into account; (vi) the stationary temperature field is determined from the solution of the two-dimensional heat equation taking into account the internal heat sources (boundary conditions of the first-third kind); (vii) the influence of Casimir, van der Waals and Coulomb forces is taken into account. PDEs, boundary and initial conditions are yielded by the Hamilton principle. They are next reduced to the Cauchy problem by the finite differences method of the second order of accuracy. The Cauchy problem is solved by Runge-Kutta and Newmark methods. The convergence of the methods is investigated depending on the number of beam length partition intervals and boundary conditions. The effects of the velocity of the longitudinal waves, the size-dependent parameter, the Casimir, van der Waals and Coulomb forces, the intensity and nature of the temperature field, the amplitude and frequency of the transverse alternating load, geometric nonlinearity, kinematic models (first, second, third order approximation) are analyzed.

[1] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

[2] Olga A. Saltykova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), olga_a_saltykova@mail.ru.

[3] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Vibration of nonlinear lumped systems with serially connected elastic elements

Jan Awrejcewicz, Roman Starosta, Grażyna Sypniewska-Kamińska

Abstract: The mechanical systems with the nonlinear springs connected in series are considered in the paper. The mathematical model of that kind of systems consists of the differential and algebraic equations (DAEs). Adequately modified multiple scales method (MSM) in time domain have been applied to solve effectively the problem of harmonically forced vibration governed by DAEs. The obtained approximate solution in the analytical form allows for qualitative study of the considered systems, among others for identification of the resonance conditions. The selected cases of the main and internal resonances are analysed in details. The modulation equations of the amplitudes and phases which are the integral part of the MSM solution allow one to study both steady and unsteady resonant motion. The stability of the resonant curves concerning the steady states has been tested and verified by comparison with the numerically obtained solutions.

[1] Jan Awrejcewicz, Professor: Lodz University of Technology, 1/15 Stefanowski Str., 90-924 Łódź, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Roman Starosta, Associate Professor: Poznan University of Technology, 60-965 Poznań, ul. Jana Pawła II 24, Poland (PL), roman.starosta@put.poznan.pl.

[3] Grażyna Sypniewska-Kamińska, Associate Professor: Poznan University of Technology, 60-965 Poznań, ul. Jana Pawła II 24, Poland (PL), grazyna.sypniewska-kaminska@put.poznan.pl.

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Methods of nonlinear dynamics for analyzing historical processes

Jan Awrejcewicz, Tatyana Y. Yaroshenko, Maxim V. Zhigalov, Igor I. Shulga, Ivan A. Bulatov, Vadim A. Krysko

Abstract: The development of a state in a certain period of time is investigated by a set of nonlinear dynamics methods including the wavelet analysis, changes of the sign of the spectrum of the Lyapunov exponents, Fourier analysis, and the value of Kolmogorov entropy. The main components method is used for preliminary processing of time series. With the help of continuous and discrete wavelets, the energy characteristics of the development of historical processes in time are obtained. Fourier analysis allows you to identify the dominant frequency of the time series. According to the values of the Lyapunov indicator spectrum, it is possible to obtain information on the nonlinear state of the process (regular or chaotic). The Wolf, Rosenstein, Kantz, Sano-Sawada and neural networks are used for the computation of the Largest Lyapunov exponents. In order to identify trends in the development of crisis states both of the state as a whole and its individual structures, the time variation of the values of the first Lyapunov indicator according to the Wolf method is investigated. In particular, the authors explore the development of Russia since 1914 till 2018. To do this, based on a study of real historical events, time series are compiled, reflecting the development of such key government areas as education, economics, and the dynamics of demographic changes.

[1)] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

[2)] Tatyana Y. Yaroshenko, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tyyaroshenko@gmail.com.

[3)] Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[4)] Igor I. Shulga, Associate Professor: Department of History of the Fatherland and Culture, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), igorshulga@yandex.ru.

[5)] Ivan A. Bulatov, Associate Professor: Department of History of the Fatherland and Culture, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), kicum-333@yandex.ru.

[6)] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Nonlinear dynamics of thermoelastic Sheremetiev-Pelekh nanobeams with topologically optimal microstructure

Jan Awrejcewicz, Maxim V. Zhigalov, Sergey P. Pavlov, Vadim A. Krysko

Abstract: First, for specific loading conditions, heating conditions and fastening of the mechanical structure, one of the dimensions of which is much larger than the other two, a topological optimization of its microstructure by the criterion of maximum stiffness is carried out. Second, a mathematical model of the nano beam is constructed on the basis of the Sheremetev-Pelekh-Reddy kinematic hypothesis, taking into account the size-dependent behavior on the basis of the modified couple stress theory and geometric nonlinearity of von Karman. On the basis of the constructed mathematical model, the static and dynamic behavior of inhomogeneous (optimal) and homogeneous beams is studied. The paper compares the static and dynamic results for optimal and homogeneous beams, taking into account the size-dependent behavior, and without it, for different boundary conditions, temperature distribution and types of the employed load. It is shown that for a homogeneous beam and a beam with an optimal microstructure, the stress-strain state, the magnitude of the natural frequencies and the nature of the dynamic regimes differ significantly both for linear and nonlinear cases.

[1] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[2] Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[3] Sergey P. Pavlov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), pspsar@yandex.ru.

[4] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Dynamical systems and stability in fractional solid mechanics

Peter Beda

Abstract: The use of fractional calculus gets more and more importance in material modeling. It can take into account non-localities in both space and time domains. Quite simply, for example, by changing (local) conventional derivative to one of the non-local fractional derivatives, the effect of the time history (or of the values in a neighborhood) can 'automatically' be taken into consideration. The reason is that such fractional derivative is a combination of a derivation and an integral operator. In stability analysis such models may cause problems starting from stability definitions to the complicated forms of characteristic equations. The selection of the fractional derivative (Caputo, Riemann-Liouville, Caputo-Fabrizio, Atangana-Baleanu etc.) has an important effect on that. The paper studies how the type of fractional derivatives effects the problems of stability investigation. From engineering point of view, the study aims constitutive modeling via instability phenomena. By observing the stability/instability behavior of some material we can be informed about the form of fractional derivative in its mathematical model.

[1)] Peter Beda, Professor: Budapest University of Technology and Economics, Muegyetem rkp. 1-3. Budapest H-1111, Hungary (HU), beda.peter.b@gmail.com .

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Using electromagnetic springs for tailoring dynamical characteristics

Maksymilian Bednarek, Donat Lewandowski, Jan Awrejcewicz

Abstract: The article presents a theoretical analysis of the characteristics of magnetic and electromagnetic springs as well as linear and non-linear mechanical springs. Analysis covered both static and dynamic properties. New physical and mathematical models of magnetic springs have been proposed and have been subjected to experimental verification on a specially designed and built experimental stand. The stand consists of an aerostatic guide that has one degree of freedom. Thanks to aerostatic supports, the friction in the system is minimized, damping is limited to viscous, damping resulting from eddy currents in the coil and extortion of the controller. The components of the station are made of non-ferromagnetic materials. The stand allows static and dynamic study of springs and systems with automatic regulation. The article presents a method of changing the characteristics of magnetic springs by controlling the current in the coil. A number of experiments were carried out to determine the characteristics of specific system components and verify the correctness of the proposed mathematical models. A controller has been developed to shape the characteristics of electromagnetic springs. Different algorithms with feedback were used and compared to find the best fit to the desired characteristics. The controller allows us to simulate and reproduce in real spring systems exactly the characteristics we need, for example, non-linear exponential, as well as linear, which is distinctive for mechanical springs.

[1] Maksymilian Bednarek, M.Sc. (Ph.D. student): Łódź University of Technology, 90-924, Poland (PL), maksimusbed@interia.pl.

[2] Donat Lewandowski, Associate Professor: Łódź University of Technology, 90-924, Poland (PL), donat.lewandowski@neostrada.pl.

[3] Jan Awrejcewicz, Professor: Łódź University of Technology, 90-924, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: VIB187

Bending vibrations with boundary damping – unlike behavior of tactile sensors

Carsten Behn, Christoph Will, Joachim Steigenberger

Abstract: The paper is devoted to an unlike behavior of natural frequencies in beam vibrations. Guided by the biological paragon vibrissa we investigate small vibrations of an Euler-Bernoulli beam and focus in particular on the question how the natural frequencies depend on the main features of this tactile system. Precisely, a clamped and boundary visco-elastically supported beam serves as a first model to determine the spectrum of natural frequencies (later using these frequencies to detect an obstacle contact). The damping element significantly increases the complexity of the two-point boundary-value problem and leads to a surprising phenomenon: there exist some natural frequencies which break down to zero for a certain range of parameters. This fact is well-known in 1-DoF systems (i.e., strong damping, creeping behavior). The study demonstrates that the oscillation behavior of an elastic beam differs remarkably from the behavior of such a classical system: a) The natural frequencies may increase with growing boundary damping; b) for specific damping parameter values, the natural frequencies grow for decreasing boundary stiffness.

[1)] Carsten Behn, Professor: Schmalkalden University of Applied Sciences, Faculty of Mechanical Engineering, Blechhammer 4-9, 98574 Schmalkalden, Germany (DE), c.behn@hs-sm.de.

[2)] Christoph Will, Ph.D.: Daimler AG, RD/USN, HPC X901, 71059 Sindelfingen, Germany (DE), christoph.c.will@daimler.com.

[3)] Joachim Steigenberger, Professor: Technische Universität Ilmenau, Institute of Mathematics, Weimarer Straße 25, 98693 Ilmenau, Germany (DE), joachim.steigenberger@tu-ilmenau.de.

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Bending vibration systems which are complementary with respect to eigenvalues

Carsten Behn, Christoph Will, Lukas Merker, Joachim Steigenberger

Abstract: In developing prototypes, one fundamental activity is to model appropriate systems which mimic fundamental features of (biological) paradigms. In this way, we set up different models for the investigation of natural frequencies. The aim is to detect object contacts of technical sensors in observing their vibration behavior. For this, we compare the range and the shift of natural frequencies determined from the analysis of the arising two-point boundary-value problems. In particular, we found two systems with complementary spectra of eigenvalues. Considering boundary damping we analyzed these eigenvalues in the first octant of the complex plane. The fundamental result is that these two systems offer no common eigenvalue, they are alternative. This is an interesting and unique observation.

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[1] Carsten Behn, Professor: Schmalkalden University of Applied Sciences, Faculty of Mechanical Engineering, Blechhammer 4-9, 98574 Schmalkalden, Germany (DE), c.behn@hs-sm.de.

[2] Christoph Will, Ph.D.: Technische Universität Ilmenau, Dept. of Mechanical Engineering, Max-Planck-Ring 12, 98693 Ilmenau, Germany (DE), christophwill@gmx.net.

[3] Lukas Merker, M.Sc. (Ph.D. student): Technische Universität Ilmenau, Dept. of Mechanical Engineering, Max-Planck-Ring 12, 98693 Ilmenau, Germany (DE), lukas.merker@tu-ilmenau.de.

[4] Joachim Steigenberger, Professor: Technische Universität Ilmenau, Institute of Mathematics, Weimarer Straße 25, 98693 Ilmenau, Germany (DE), joachim.steigenberger@tu-ilmenau.de.

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Analysis of switching strategies for the optimization of periodic chemical reactions with controlled flow-rate

Peter Benner, Andreas Seidel-Morgenstern, Alexander Zuyev

Abstract: An isoperimetric optimal control problem with non-convex cost is considered for a class of nonlinear control systems with periodic boundary conditions. This problem arises in chemical engineering as the maximization of the product of non-isothermal reactions by consuming a fixed amount of input reactants. It follows from the Pontryagin maximum principle that the optimal controls are piecewise constant in the considered case. We focus on a parametrization of optimal controls in terms of switching times in order to estimate the cost under different switching strategies. We exploit the Chen-Fliess functional expansion of solutions to the considered nonlinear system with bang-bang controls to satisfy the boundary conditions and evaluate the cost analytically for small periods. In contrast to the previous results in this area, the system under consideration is not control-affine, and the integrand of the cost depends on the state. This approach is applied to non-isothermal chemical reactions with simultaneous modulation of the input concentration and the volumetric flow-rate.

[1] Peter Benner, Professor: Max Planck Institute for Dynamics of Complex Technical Systems, Sandtorstr. 1, 39106 Magdeburg, Germany (DE), benner@mpi-magdeburg.mpg.de.

[2] Andreas Seidel-Morgenstern, Professor: Max Planck Institute for Dynamics of Complex Technical Systems, Sandtorstr. 1, 39106 Magdeburg, Germany (DE), seidel@mpi-magdeburg.mpg.de.

[3] Alexander Zuyev, Professor: Max Planck Institute for Dynamics of Complex Technical Systems, Sandtorstr. 1, 39106 Magdeburg, Germany (DE), zuyev@mpi-magdeburg.mpg.de.

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Analysis of dynamic properties of an aeroacoustic anechoic room

Jaroslaw Robert Blaszczak

Abstract: The objective of the paper is to present experimental results of the acoustic field inside an aeroacoustic anechoic chamber especially built to investigate sound phenomena correlated to aerodynamic flows. This aeroacoustic anechoic chamber was especially designed as an unusual modern test facility with all flat surfaces only to avoid additional noise phenomena due to the air flows inside the room. To check its parameters, the acoustic field inside the empty room was measured using sound generator and obtained characteristics were compared with the ISO standards. Additionally, an accelerometer was used to check dynamic properties of the chamber. Since, for such rooms, very low frequencies of the sound are critical, the transducer was connected to the main wall. This allowed testing interactions between emitted sound and the wall vibrations. All experimental investigations have been carried out at the Institute of Turbomachinery of Lodz University of Technology, Poland.

[1)] Jaroslaw Robert Blaszczak, Ph.D.: Lodz University of Technology, 90 - 924 Lodz, ul. Wolczanska 219/223, Poland (PL), Jaroslaw.Blaszczak@p.lodz.pl .

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Vibro-acoustic interactions of a dynamic system – the case of two contra-rotors

Jaroslaw Robert Blaszczak

Abstract: The paper presents results of vibroacoustic investigations of a dynamic system consisted with two contra-rotating rotors. Such solutions are used nowadays in modern aeroengines and ventilation fans. Lately, they are also popular in propeller systems of modern drones, especially for transporting packages and, as planned, people. Such solutions should be very reliable (for example when delivering human organs to hospitals) and they are found to be highly efficient, however their work in hard conditions causes emissions of higher levels of noise, what can be crucial in smart cities. The main aim of the researches was to provide an analysis allowing for identification of the main sources of noise in such designs and to propose solutions for noise reduction. Additionally, vibrations of the presented dynamic system were measured to check any influence of such phenomena on the emitted noise levels. The data were obtained during test sessions inside acoustic free-field conditions. All researches were conducted inside a modern aeroacoustic anechoic chamber, especially designed for such tests.

[1)] Jaroslaw Robert Blaszczak, Ph.D.: Lodz University of Technology, 90 - 924 Lodz, ul. Wolczanska 219/223, Poland (PL), Jaroslaw.Blaszczak@p.lodz.pl.

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paper id: CON135

Nonholonomic acceleration and chaotic dynamics of locomotion

Alexey Borisov, Ivan Mamaev, Ivan Bizyaev, Alexander Kilin

Abstract: An analysis is made of the dynamics of nonholonomic systems with mass distribution periodically varying with time. This analysis is carried out by considering the rolling of a rigid body and the motion of a wheeled vehicle. In these problems, various types of motion, including those associated with strange attractors, are observed. A detailed treatment is given of the problem of unbounded acceleration (an analog of Fermi's acceleration) by periodic action. We also show the possibility of chaotic dynamics related to strange attractors of equations for generalized velocities, which is accompanied by a two-dimensional random walk of the platform in a laboratory reference system.

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[1] Alexey Borisov, Professor: Moscow Institute of Physics and Technology, 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia (RU), borisov@rcd.ru .

[2] Ivan Mamaev, Professor: Kalashnikov Izhevsk State Technical University, 426034 Izhevsk, Universitetskaya str., 1, Russia (RU), mamaev@rcd.ru .

[3] Ivan Bizyaev, Professor: Moscow Institute of Physics and Technology, 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia (RU), bizaev_90@mail.ru .

[4] Alexander Kilin, Professor: Udmurt State University, 426034 Izhevsk, Universitetskaya str., 1, Russia (RU), aka@rcd.ru .

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Dynamical Systems — Theory and Applications
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paper id: CON144

Locomotion of a foil with a sharp edge in a fluid due to periodic controls

Alexey Borisov, Ivan Mamaev, Evgenii Vetchanin, Alexander Kilin

Abstract: This paper addresses the motion of a small boat with an oscillating rotor on a water surface. The body of the boat has the form of an airfoil with a sharp edge. For this system, experimental investigations have been carried out in which the trajectory of the boat and its orientation were filmed. To construct a mathematical model of the motion of this boat, numerical experiments were carried out on the basis of a joint numerical solution to the Navier-Stokes equations and the equations of rigid body motion.

[1)] Alexey Borisov, Professor: Moscow Institute of Physics and Technology, 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia (RU), borisov@rcd.ru .

[2)] Ivan Mamaev, Professor: Kalashnikov Izhevsk State Technical University, Universitetskaya, 1, Izhevsk, 426034, Russia (RU), mamaev@rcd.ru .

[3)] Evgenii Vetchanin, Ph.D.: Kalashnikov Izhevsk State Technical University, 426034 Izhevsk, Universitetskaya str., 1, Russia (RU), eugene186@mail.ru .

[4)] Alexander Kilin, Professor: Udmurt State University, 426034 Izhevsk, Universitetskaya str., 1, Russia (RU), aka@rcd.ru .

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paper id: VIB156

Finite element modelling and simulations of sandwich beam dynamics considering crack growth and contact

Vyacheslav Burlayenko

Abstract: Dynamic crack propagation in double cantilever beam (DCB) sandwich specimens is analysed numerically using the finite element method implemented into the ABAQUS code for a planar beam model with an initial interface skin/core crack subject to dynamic loading at the specimen's legs. The interface crack is constrained to grow along a weak skin/core interface directly ahead of the initial crack tip. A cohesive constitutive relation, which relates tractions and displacement jumps, is specified across the weak interface. The material on the constitutive layers of the specimen is assumed to be linear elastic. The contact effects between the DCB legs are also accounted for modelling, and corresponding numerical methods are discussed. Simulations are carried out using the plane strain elements available in ABAQUS to examine the statics and dynamics of the DCB modelling its configuration in the actual experiments. The dynamic strain energy rate at given crack speed or the crack history for a given fracture toughness is calculated. The stress wave effects on the dynamic strain energy release rate and the evolution of near crack tip stress fields are discussed. The finite element results are compared with the beam solutions and some experimental data available in the literature. The effects of various load conditions are also explored. It is found that a high loading rate results in developing on the interface in the crack tip vicinity shear stress waves and that the crack growth can take place at a load lower than a value determined by quasi-static or low rate values.

[1] Vyacheslav Burlayenko, Associate Professor: National Technical University "Kharkiv Polytechnic Institute", 61002, Ukraine (UA), burlayenko@yahoo.com .

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paper id: BIF271

Nonlinear dynamics of laser systems: Chaos, bifurcations and strange attractors

Vasily Buyadzhi, Anna Buyadzhi, Alexey Chernyshev

Abstract: We present the results of numerical investigation of generating a chaos (scenario, topological and dynamical invariants etc) in single-mode laser with absorbing medium and in the erbium one-ring fibre laser (EDFL, 20.9mV strength, 1550.190nm length) with the control parameters: the modulation frequency f and dc bias voltage of the electro-optical modulator. It is shown that in depending upon f, V values there are realized 1-period f = 75MHz, V = 10V and f = 60MHz, V = 4V), 2-period (f = 68 MHz, V = 10V or f = 60MHz, V = 6V), chaotic (f = 64MHz, V = 10 V and f = 60MHz, V = 10V) regimes. The calculational data on the Lyapunov's exponents (LE), correlation, embedding and Kaplan-York dimensions (D), Kolmogorov entropy (KE) are presented. The application of the non-linear analysis, chaos theory and information technology methods (in [1,2]) to studying non-linear dynamics of the studied laser system (with the control parameters: the modulation frequency f and dc bias voltage of the electro-optical modulator) shows that there is a deterministic chaos in the erbium fiber laser device, generated via intermittency by increasing the DC bias voltage and the period-doubling bifurcation scenario by reducing the frequency modulation. References: [1] A. Glushkov: Methods of a chaos theory, Odessa, Astroprint, 2012. [2] A.Glushkov et al.: Adv. in Neural Networks, Fuzzy Systems and Artificial Intelligence, Series: Recent Adv. in Computer Eng., Ed. J.Balicki (Gdansk, WSEAS), 21 (2014) 143.

[1] Vasily Buyadzhi, Associate Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), buyadzhivv@gmail.com.

[2] Anna Buyadzhi, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), buyadzhiaa@gmail.com.

[3] Alexey Chernyshev, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), buyadzhiaa@gmail.com.

paper id: LIF272

Nonlinear dynamics of the industrial city's atmospheric ventilation: New differential equations model and chaos

Vasily Buyadzhi, Olga Khetselius, Yuliya Bunyakova, Iryna Buchko

Abstract: We present a new approach to analysis and modelling the nonlinear dynamics of the industrial city's atmospheric ventilation with elements of chaos. New approach is based on an approximation of "shallow water" (in contrast to the standard difference methods of solution, here we use the spectral expansion algorithm [1]) and the Arakawa-Schubert and Glushkov differential equations models, modified to calculate the current involvement of the ensemble of clouds, and advanced mathematical methods of modelling an unsteady turbulence in the urban system. For the first time the methods of a plane complex field and spectral expansion algorithms are applied to calculate the complex system ventilation characteristics. Such a chaos theory algorithms as correlation integral, false nearest neighbors, surrogate data ones, the Lyapunov's exponents and Kolmogorov's energy analysis, non-linear prediction schemes, predicted trajectories algorithms, spectral methods etc (in [1-3]) are used for analysis of the corresponding time series. As illustration of a new approach we present the results of series of the PC experiments on computing the ventilation characteristics for a few industrial regions (Odessa, Gdansk etc). References: [1] Khetselius O., BunyakovaY., Proc.of 8th Int. Carbon Dioxide Conf.-Jena, Germany, 2009. [2] Glushkov A.V., Methods of a Chaos Theory. Odessa: Astroprint, 2012. [3] Glushkov A.V., Khetselius O.Yu., Svinarenko A.A., Buyadzhi V.V., Methods of computational mathematics and mathematical physics, P.1. Odessa: TEC, 2015.

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1) Vasily Buyadzhi, Associate Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), buyadzhivv@gmail.com.

2) Olga Khetselius, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), okhetsel@gmail.com.

3) Yuliya Bunyakova, Ph.D.: Department of Environmental Economics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), bunyakovayy@gmail.com.

4) Iryna Buchko, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), bunyakovayy@gmail.com.

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paper id: LIF261

Analysis of the movement of the load during the interaction of wind force

Dawid Cekus, Paweł Kwiatoń, Tomasz Geisler

Abstract: The present work pertains to the analysis of the load movement during the interaction of wind force. The load was treated as a rigid body, and the linear system model as a non-deformed. The influence of effective area of wind force on load movement was considered. Various shapes of the rigid body and different values of wind velocity were also analyzed. To define the orientation of the movable Cartesian coordinate system related to the load, Bryant angles were used. An algorithm and computational program were developed to allow for the analysis of dynamic phenomena. The initial problem was solved by means of the ode45 calculation procedure in the Matlab software on the basis of the Runge-Kutta 4th Order Method. The obtained results were compared with the experimental results achieved using the wind tunnel and the results get in the commercial program. After taking into account the control functions resulting from the nature of the work of any machine, the formulated model can be a full description of the movement of the carried load taking into account external forces.

[1] Dawid Cekus, Associate Professor: Czestochowa University of Technology, ul. J.H. Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), cekus@imipkm.pcz.pl.

[2] Paweł Kwiatoń, M.Sc. (Ph.D. student): Czestochowa University of Technology, ul. J.H. Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), kwiaton@imipkm.pcz.pl.

[3] Tomasz Geisler, Ph.D.: Czestochowa University of Technology, ul. J.H. Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), geisler@imipkm.pcz.pl.

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paper id: OPT17

Optimal rendezvous with proportional navigation unmanned aerial vehicle

Oleg Cherkasov, Elina Makieva

Abstract: Two-dimensional optimal rendezvous problem with proportional navigation unmanned aerial vehicle is analyzed using a non-linear model. The velocities of both players have a constant modulus, but vary in direction. The problem is to minimize the final distance between the pursuer and the drone in the transition from the given initial conditions. Meeting time is fixed. Examples include the rendezvous problem for a flying tanker with a drone or intercepting an attacking missile by a defensive missile that simulates the target. The principle of maximum procedure allows to reduce optimal control problem to the problem of analyzing the phase portrait of a system of two nonlinear differential the equations. The qualitative features of the optimal process are determined.

[1] Oleg Cherkasov, Ph.D.: Lomonosov Moscow State University, 119991, Leninskie Gory, 1, Russia (RU), oyuche@yandex.ru.

[2] Elina Makieva, B.A. (M.Sc. student): Lomonosov Moscow State University, 119991, Leninskie Gory, 1, Russia (RU), elinamakieva@live.com.

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paper id: OPT96

Finding globally optimal combinations of cranes drive mechanisms by the method of exhausting alternative design structures of mechanisms

Stefan Chwastek

Abstract: During certain crane operations: hoisting or lowering the payload connected with a slewing jib, generated are Euler and Coriolis forces whose impacts should be minimized already at the stage of selection of the system parameters and mechanism structure. The Machine and Mechanism Theory provides a method of exhausting kinematic chains which involves identification of all possible alternatives of kinematic structures with respect to the required number of degrees of freedom and field of work. This article outlines a methodology of selecting optimal structure from a set of possible solutions. Optimization of a multi-drive machine, needs to take into account the interactions between cooperating mechanisms By introducing a certain quality criterion, a set of parameters optimized for the full range of motion is determined for each structure. Accordingly, each structure is assigned a value of the optimum quality index. The method was illustrated for a one-link crane with lever mechanisms, and comparison was made with ropes mechanisms. Optimization tasks were formulated assuming the ideal stiffness of the structure in quasi-static conditions. Effectiveness was verified under dynamic impact conditions, taking into account rope flexibility. Finding globally optimal design solution it comes to the best combination of different mechanisms allows the dynamic overload values to be significantly reduced at the stage of design of the steel structure.

[1] Stefan Chwastek, Ph.D.: Cracow University of Technology, Faculty of Mechanical Engineering, al. Jana Pawła II 37, Poland (PL), stefan.chwastek@mech.pk.edu.pl .

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: ENG137

The model of wheel-surface interaction for all terrain vehicle dynamics simulation

Tomasz Czapla, Mariusz Pawlak

Abstract: In this paper the new methodology of wheel-surface interaction numerical simulation is presented. The finite element method is combined with discrete element method, rigid body dynamics and advanced wheel-surface friction model. Compared to current state of art the novel approach is more realistic traction force application in the contact surface between wheel and soil. Rotation of non-driven wheel is the effect of axis movement and mentioned contact forces. Developed method allows to assess longitudinal and lateral forces for wide range of attack angle of the wheel. That is essential for skid-steered vehicles traction effort calculations. The paper presents current results of numerical calculation that are intended to complement the test results and develop the ground-tire interaction models. Therefore, the novel approach for traction effort for off-road vehicles is being developed through a combination of experimental laboratory and field tests with numerical calculation results. The proposed method will be implemented in the analysis software dedicated to fast calculation of traction effort for skid-steered off-road vehicles to optimize the transmission system. Based on the experimental research, a need appeared to create a numerical model and to describe the contact phenomenon between the wheel and the ground as faithfully as possible. In this publication, the novel approach is the manner of comparison of the experimental research results with a numerical simulation using the discrete and finite element methods in the LS-DYNA software.

[1] Tomasz Czapla, Ph.D.: Politechnika Śląska, Akademicka 2A, 44-100, Gliwice, Poland (PL), Tomasz.Czapla@polsl.pl .

[2] Mariusz Pawlak, Ph.D.: Politechnika Śląska, Akademicka 2A, 44-100, Gliwice, Poland (PL), Mariusz.Pawlak@polsl.pl .

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Dynamical Systems — Theory and Applications

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paper id: EXP136

Experimental identification of wheel-surface model parameters – various terrain conditions

Tomasz Czapla, Marcin Fice, Roman Niestrój

Abstract: The aim of the paper is to present the development of wheel-surface interaction model parameters estimation based on experiment results. Various terrain types are taken into account. Since the wheel interaction with a certain terrain cases (asphalt, concrete) are known and well described in case of straightforward motion and non-slip and slip cornering conditions, the skid-steered wheeled vehicles case needs to be analyzed. In case of described research various terrain types including snow, grass, asphalt and concrete are taken into account. Experimental stand designed and developed by authors allows to test the wheel-surface interaction for various terrain conditions and different driving directions. Test data were acquired for dry and wet sand, soil, grass and asphalt. Traction and side forces were acquired and used to identify the wheel-soil interaction model parameters.

[1] Tomasz Czapla, Ph.D.: Politechnika Śląska, Akademicka 2A, 44-100, Gliwice, Poland (PL), Tomasz.Czapla@polsl.pl .

[2] Marcin Fice, Ph.D.: Politechnika Śląska, Akademicka 2A, 44-100, Gliwice, Poland (PL), Marcin.Fice@polsl.pl .

[3] Roman Niestrój, Ph.D.: Politechnika Śląska, Akademicka 2A, 44-100, Gliwice, Poland (PL), Roman.Niestroj@polsl.pl .

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Dynamical Systems — Theory and Applications

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paper id: MTR124

Dynamic model of a remotely controlled swarm of robots

Jakub Deda, Tomasz Mirosław, Adam Zawadzki

Abstract: Drones and robots are getting more and more popular. We can buy DRONs in supermarkets. And see robots in factories or in service especially in military, security or rescuing application. Currently we are used to individual robot remotely controlled by an operator, but very soon we should expect teams of autonomous robots releasing their task or robots working as the swarm of robots. They can be used not only in military application but in rescuing actions, for instance collecting pollution or in ecological agriculture fighting with vermin. In this paper authors present the problem of control multi-element systems. In paper authors present the model of a swarm of robots as the one dynamically random reconfigurable body. To keep the system under control a new structure was proposed and analyzed with simulation. The method of swarm parameter evaluation is presented. Authors present the algorithm of system configuration and control in multilevel structure. The with proposition of further works and perspectives in this area.

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1) Jakub Deda, M.Sc. (Ph.D. student): Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), jakub.deda@pw.edu.pl .

2) Tomasz Mirosław, Ph.D.: Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), tomasz.miroslaw@pw.edu.pl .

3) Adam Zawadzki, M.Sc.: Warsaw University of Technology, Narbutta 84, 02-524 Warszawa, Poland (PL), adam.zawadzki@pw.edu.pl .

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paper id: STA110

Dynamics of circular plates under selected heat loadings: Finite element and analytical models

Simona Doneva, Jerzy Warminski, Emil Manoach

Abstract: The purpose of this paper is to study nonlinear oscillations of a heated plate subjected to dynamic loading. The response of moderately thick circular plates at elevated temperatures subjected to harmonic loading is analysed. A mathematical model of the plate is derived applying the geometrically nonlinear Reisner-Mindlin plate theory. The full coupled thermo-elastic model represented by a set of partial differential equations is reduced to three degree of freedom system by Galerkin orthogonalization method based on the first vibration mode. Two different approaches are used to study the problem: (a) the finite element method (FEM) and (b) the harmonic balance method applied to the reduced model taking into account the first vibration mode. In FEM, the clamped circular plate is discretized by four nodes finite element by using the commercial finite element package ANSYS. The numerical simulations are performed for the plate subjected to uniformly harmonic loading and different temperatures. The influence of the loading and elevated temperature on dynamic behaviour is studied for buckling and post buckling behaviour. In the second approach the obtained reduced nonlinear one degree of freedom model with cubic nonlinearity is studied by the harmonic balance method. The influence of the amplitude of the loading and the elevated temperature on the frequency response functions and selected bifurcation diagrams are computed and then compared with FEM.

[1] Simona Doneva, M.Sc. (Ph.D. student): Lublin University of Technology, Bulgarian Academy of Sciences, ul. Nadbystrzycka 38 D, 20 – 618 Lublin, Poland (PL), s.doneva@pollub.pl, s.doneva@imbm.bas.bg .

[2] Jerzy Warminski, Professor: Lublin University of Technology, ul. Nadbystrzycka 38 D 20 – 618 Lublin, Poland (PL), j.warminski@pollub.pl .

[3] Emil Manoach, Professor: Bulgarian Academy of Sciences, Bulgaria, Sofia, 1040 1 “15 November” Str., Bulgaria (BG), e.manoach@imbm.bas.bg .

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paper id: MAT344

Q-Ateb-functions and their properties

Ivanna Dronyuk

Abstract: Ateb-functions as inversion of Beta-functions are generalization of trigonometric functions. Ateb-functions can be expanded to all areas where there are the usual trigonometric functions. We constructed Ateb-transform as a special type of Fourier transform. Using the theory of generalized shift operators (GSO) the algebra under the Hilbert functional space was constructed. Algebra contains "addition" and "multiplication" operations. The addition is the usual addition of functions (correctness follows from the additivity of the addition), and multiplication is a convolution. As the periodic Ateb-functions are orthonormal, we can build a decomposition in a generalized Fourier series and can build for them a generalized harmonic analysis by analogy. We constructed hypergroup using GSO for Ateb -transforms and the corresponding convolution, completing within hypergroup algebra apparatus spectral and time analysis of functional spaces with the basis of Ateb-functions. The q-analog of Ateb-sine (q-Ateb-sine) and q-analog Ateb-cosine (q-Ateb-cosine) are defined as inversion of incomplete q-Beta-function. The properties of these functions are considered. The first interesting result of this investigation is that the constructed functions satisfy q-analog of ordinary differential equation system that ordinal Ateb-functions satisfy. The proof is given by a direct differentiation. The second main result of this investigation is that the main trigonometric identity are proven. The proof is based on q-hypergeometric function series.

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1) Ivanna Dronyuk, Associate Professor: Lviv Polytechnic National University, Bandery 12, 79013 Lviv, Ukraine (UA), ivanna.m.droniuk@lpnu.ua.

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paper id: CON288

Experimental investigation of wave propagation in light weight structures undergoing flexural vibration

Adriano Fabro, Daniely Amorim

Abstract: The wave approach in structural dynamics focus on local properties such as the dispersion relations, phase and group velocities, waves modes and energy transmission. This is in contrast to the modal approach, which typically focus in global properties such as the natural frequencies and modes shapes. Experimental technics for modal analysis are well stablished and have been successfully applied in the past decades unlike the experimental approaches for wave propagation. This paper aims to investigate experimental approaches for the identification of the wavenumber in light weight structures undergoing flexural vibration, such as metamaterial beams. Different estimation techniques are used, such as the Inhomogeneous Wave Correlation (IWC) and Discrete Fourier Transform (DFT) based approaches and the influence of measurement points distance, positioning along the structures are investigated. Upper and lower limits of the frequency bands for the analysis are given for light weight structures such as metamaterial beams produced from additive manufacturing with locally resonant band gaps. Results are compared to an available analytical and numerical solutions show good agreement.

[1] Adriano Fabro, Professor: Universidade de Brasília, University of Brasilia Campus Darcy Ribeiro, CEP 70.910-900, Brasilia, DF, Brazil, Brazil (BR), fabro@unb.com.

[2] Daniely Amorim, M.Sc. (Ph.D. student): Universidade de Brasília, University of Brasilia Campus Darcy Ribeiro, CEP 70.910-900, Brasilia, DF, Brazil, Brazil (BR), d.amorim.neves2@gmail.com.

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Dynamical Systems — Theory and Applications

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paper id: VIB131

Numerical investigation on pounding effects between two adjacent base-isolated building models under dynamic excitations

Tomasz Falborski, Natalia Lasowicz

Abstract: There are many different factors that can modify the dynamic response of a structure subjected to seismic excitations. Structural control methods (i.e. passive, active, or hybrid base isolation systems), pounding effects between adjacent buildings with insufficient in-between gap, or soil-structure interaction are counted among the most influential contributors which must not be neglected during detailed seismic analysis. Given that, the overall aim of the present paper is to conduct numerical investigation on dynamic response of two colliding building models with and without base isolation system (i.e. rubber bearings). Additionally, different in-between gap lengths will also be considered. Time history analysis plots will be presented. Results will be discussed.

[1] Tomasz Falborski, Ph.D.: Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, 11/12 Narutowicza St., 80-233 Gdańsk, Poland (PL), tomfalbo@pg.edu.pl .

[2] Natalia Lasowicz, Ph.D.: Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, 11/12 Narutowicza St., 80-233 Gdańsk, Poland (PL), natmajew@pg.edu.pl .

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paper id: EXP128

Fault detection of PTO with accurate MBS method

Hamed Farahmand, Reza Abdollahi

Abstract: In this paper a model – based fault detection method for detecting faults in power take-off (PTO) system of dump trucks is investigated. The main goal of this study is dedicated to describe the early mechanical faults detection of the system. PTO is modeled in a multi body simulation (MBS) environment. This interpreted simulation is well established based on the model of elastic bodies in Simpack 2018.1. Moreover, the simulation of gears is crucial to characterize the behavior of PTO in the whole system, especially in regards to acoustics, fatigue and wear.in this regard, gears work properly in the allowable clearance ranges if this ranges are not provided the gears faults are anticipated. In order to elucidate the fault detection of PTO, the influence of backlash geometrical and operational parameters for a rattling and a loaded gear pair are evaluated. The torque measurements are performed at input and output shafts, which carry gears, and results of two additional sensors in PTO are monitored. The results reveal the possibility of early fault detection by this method for PTO.

[1] Hamed Farahmand, Ph.D.: Department of Mechanical Engineering, Kerman Branch, Islamic Azad university, Kerman,Iran., Iran,Kerman,Valiasr Blvd. Postal code:7635131167, Iran (IR), hamed_1256@yahoo.com.

[2] Reza Abdollahi, B.A. (M.Sc. student): Department of Mechanical Engineering, Kerman Branch, Islamic Azad university, Kerman,Iran., Iran,Kerman,Valiasr Blvd. Postal code:7635131167, Iran (IR), rezaabd6593@gmail.com.

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paper id: CON71

Nonlinear dynamics and control of two tethered satellites: rigid body approach

André Fenili, Leonardo Monteiro Mazzariol

Abstract: A mathematical model for a two-dimensional nonlinear two tethered satellites is developed. This system comprises of a long cable (also known as tether) connecting two masses (satellites). Tethered satellites can be used in a variety of space applications such as electrodynamic propulsion, energy harvesting, momentum exchange, artificial gravity, etc. The cable connecting the satellites is approximated by two connecting rod-like rigid bodies. The satellites are modelled as two rigid bodies in the format of cubes. The set of ordinary differential governing equations of motion are obtained using the Lagrange´s equations approach. If the connecting rods are not aligned, it is assumed that the cable is not stretched (i.e. the cable is not under tension). This is an undesirable situation for this type of system. A nonlinear SDRE control is applied on the satellites propulsion system in order to drive the satellites into desired positions so that the rods may be maintained aligned as the whole tethered satellites system realizes manoeuvres in orbit.

[1] André Fenili, Associate Professor: Federal University of ABC, Av. dos Estados, 5001 - Bloco B / Sala 936 - Santo André/SP, Brazil (BR), andre.fenili@ufabc.edu.br .

[2] Leonardo Monteiro Mazzariol, Ph.D.: Federal University of ABC, Av. dos Estados, 5001, Bloco B / Sala 936 - Santo André/SP, Brazil (BR), leonardo.mazzariol@gmail.com .

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paper id: EXP279

Structural dynamic response of the coupling between transmission lines and tower under random excitation

Yanne Soares Fernandes, Marcela Machado, Maciej Dutkiewicz

Abstract: This work aims to present a model of an overhead power transmission line with the Spectral Element Method (SEM) to overcome the current limits of dynamic analysis in medium and high frequencies and verify the dynamic behaviour under random excitation. The numerical study performed through the computational implementation of the tower-cable coupled structure using SEM and the Finite Element Method (FEM) and investigated their dynamic response. Because SEM is an exact solution method, there is no need for discrete continuous elements which implies in low time processing. The vibration responses obtained by SEM and FEM are presented and compared. Transmission line system is usually exposed to several different uncertainty source vibration, which will affect its dynamic behaviour. Thus, this paper treats the problem of the vibrational response of the coupling structures modelled by the spectral element method under random excitation.

[1] Yanne Soares Fernandes, B.A. (M.Sc. student): University of Brasilia, 70910-900, Brazil (BR), yannemarcela@hotmail.com.

[2] Marcela Machado, Ph.D.: University of Brasilia, 70910-900, Brazil (BR), mromarcela@gmail.com.

[3] Maciej Dutkiewicz, Associate Professor: University of Science and Technology in Bydgoszcz, macdut@utp.edu.pl, Poland (PL), macdut@utp.edu.pl.

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The use of mechanical resonance for the reduction of torque pulsation and energy demand in machines with crankshaft systems

Wieslaw Fiebig

Abstract: In this paper the results of investigations concerning the use of mechanical resonance in crankshaft systems have been presented. In the crankshaft system the mass representing piston can be connected to the spring element and due to that the resonance occurs at a certain rotational speed. This speed is determined with the value of the mass attached to the spring and the spring stiffness. At resonance the inertia forces are compensated with the spring force. The energy supplied to the crankshaft system at resonance is used only to cover losses and work load. In the crankshaft system without spring the inertia forces are steady increasing by increase of the rotational speed, what cause higher amplitudes of the dynamical torque on the driving wheel of the motor. With use of mechanical resonance the amplitudes of the dynamical torque in the crankshaft systems can be significantly reduced. The influence of the resonance is similar to that by using a flywheel. The influence of the main parameters of the crankshaft system on the amplitudes of the dynamic torque has been shown. The experimental results have confirmed the reduction of the dynamic torque amplitudes and energy demand in the crankshaft system at the resonance conditions. Keywords: mechanical resonance, crankshaft system, dynamic forces, torque pulsation

[1] Wieslaw Fiebig, Professor: Wroclaw University of Science and Technology, Wybrzeże Wyspianskiego 27, 50-370 Wroclaw, Poland (PL), wieslaw.fiebig@pwr.edu.pl.

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paper id: NUM352

Influence of sliding bearing parameters on the dynamical behavior of external gear pumps

Wieslaw Fiebig, Piotr Kruczek

Abstract: Variable forces resulting from pressure as well as from the interlocking of teeth in the gearing are responsible for the vibration and noise development in gear pumps. These various forces are transmitted to the housing and cause it to vibrate, as well as surrounding elements like electric motor, valves, tank and piping system. With increasing speed and pressure the dynamic loads on the gears and the dynamic bearing forces increase accordingly. The resulting bearing forces are obtained by addition of the pressure force components and the teeth contact forces in the x and y-direction. In the paper the influence of excitation forces from the pressure on the vibration of gearwheels and dynamic loads in the external gear pumps have been evaluated by digital simulation. For the simulation of the dynamical model MatLab Simulink and LMS-VirtualLab have been used. In VirtualLab the combination of rigid body elements (gears) and elastic FE elements (gear wheels) have been considered. For the modeling of sliding bearings in the gear pump an elasto-hydrodynamic oil film model (EHD) has been used. The EHD model is able to completely describe the dynamic properties of the oil film in the lubrication gap of the bearings. The description is based on the solution of the Reynold’s differential equation and its coupling in the FE modeling.

[1] Wieslaw Fiebig, Professor: Wroclaw University of Science and Technology, Faculty of Mechanical Engineering, Lukasiewicza 7/9, 51-370 Wroclaw, Poland (PL), wieslaw.fiebig@pwr.edu.pl.

[2] Piotr Kruczek, M.Sc.: UTC Aerospace Systems, Bierutowska 65-67, 51-317 Wrocław, Poland (PL), piotr.kruczek@hs.utc.com>.

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Passenger distribution versus a light rail vehicle running behavior

Szymon Finke, Tomasz Staśkiewicz, Bartosz Firlik

Abstract: The paper deals with the influence of passenger distribution inside a multi section tram on its running behavior. Particular situations may contribute to an uneven distribution of passengers in the vehicle, such as a school trip packed in one car, occupying places mostly in air-conditioned section during summer time, some uncomfortable conditions repulsing people from one car to others or sitting place etc. Such behavior may change the carbodies inertia tensors substantially causing variable running behavior within the same track and speed conditions. The authors used a CAD software to calculate the inertia tensors of tram carbodies according to specified load scenarios and a multibody simulation tool to predict the vehicle dynamic response. Several arbitrary load scenarios were investigated to find the influence on vehicle dynamic behavior (derailment coefficients, ride index, ride comfort etc.). Additionally, scenarios including excitations from passengers jumping synchronously with several frequencies were also calculated and discussed

1) Szymon Finke, M.Sc. (Ph.D. student): Poznan University of Technology, pl. Marii Skłodowskiej-Curie 5 60-965 Poznań, Poland (PL), szymon.finke@put.poznan.pl.

2) Tomasz Staśkiewicz, M.Sc. (Ph.D. student): Poznan University of Technology, pl. Marii Skłodowskiej-Curie 5 60-965 Poznań, Poland (PL), tomasz.staskiewicz@put.poznan.pl.

3) Bartosz Firlik, Ph.D.: Poznan University of Technology, pl. Marii Skłodowskiej-Curie 5 60-965 Poznań, Poland (PL), bartosz.firlik@put.poznan.pl.

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paper id: ASY327

Analytical approach to vibro-impact dynamics of two coupled oscillators

Pawel Fritzkowski, Roman Starosta, Jan Awrejcewicz

Abstract: Most of approximate analytical methods for nonlinear problems can be used under the restriction of weak nonlinearities. However, recently some approaches to strongly nonlinear systems, including the vibro-impact ones, have been developed for certain types of motion. In what follows, the analytical technique based on a combination of the multiple time scales method and the saw-tooth function is used. A mechanical system composed of two weakly coupled oscillators under harmonic excitation is considered. The primary oscillator is linear, while the other one has a relatively small mass and is subjected to bilateral rigid barriers. The impacts are characterized by the restitution coefficient. Equations of motion for the system are derived and presented in a non-dimensional form. Periodic behaviour of the system with two impacts per cycle near 1:1 resonance is analyzed. The results have a semi-analytical character. Stability of the periodic motions is studied. In the unstable case, occurance of the strongly modulated response can be observed. The analytical solutions are compared with purely numerical results. The interplay between the model parameters is analyzed. Particularly, the effect of the distance between barriers on dynamics of the system is discussed.

[1] Pawel Fritzkowski, Ph.D.: Institute of Applied Mechanics, Poznan University of Technology, ul. Jana Pawła II 24, 60-965 Poznań, Poland (PL), pawel.fritzkowski@put.poznan.pl.

[2] Roman Starosta, Associate Professor: Institute of Applied Mechanics, Poznan University of Technology, ul. Jana Pawła II 24, 60-965 Poznań, Poland (PL), roman.starosta@put.poznan.pl.

[3] Jan Awrejcewicz, Professor: Department of Automatics and Biomechanics, Technical University of Łódź, ul. Stefanowskiego 1/15, 90-924 Łódź, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: LIF214

A biomechanical investigation of center of pressure velocity characteristics for scoliosis during walking

Lin Fu, Jan Awrejcewicz

Abstract: Background This study aimed to measure the spatial-temporal gait parameters characteristics of scoliosis subjects (I-observation and II-brace), including joint motion, Methods COP velocity and percentage of stance phase (heel strike, mid-stance, terminal stance). We measured spines of six subjects by using DIERS Formetric 4D, and divided them into two groups averagely, three for observation, and three for brace. The joint angle of ankle and hip was collected by VICON, and the COP velocity was calculated at each period of stance phase. Results We found II showed greater ankle dorsiflexion, hip extension and abduction than I. COP velocity of I presented larger than II during the mid-stance phase, but less during the heel strike phase. Conclusion Comparing to I, II showed greater ankle dorsiflexion, which was associated with ankle stability. Greater hip abduction may also cause low back pain, it could be a risk to obtain worse deformation of spine.

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1) Lin Fu, M.Sc. (Ph.D. student): Department of Automation, mechtronics and biomechanics, Faculty of mechanical engineering, Lodz University of Technology, 1/15 Stefanowskiego Str., building A22, 90-924 Lodz, Poland (PL), fulin023@126.com.

2) Jan Awrejcewicz, Professor: Department of Automation, mechtronics and biomechanics, Faculty of mechanical engineering, Lodz University of Technology, 1/15 Stefanowskiego Str., building A22, 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: OPT164

Approximate kinematic synthesis of the four-bar mechanism by two given positions of the links

Elena Gebel, Asylbek Jomartov

Abstract: Most of the algebraic methods for approximate kinematic synthesis of four-bar mechanisms are based on the well-known Freudenstein's equation. The distinctions in the big variety of these methods are due to the computational procedures that are used to find a proper solution. The Freudentein's equation provides very powerful possibilities for solving any approximate tasks because of its simplicity. The combination of Freudenstein's equation and function theory enlarges the possibilities of the dimensional synthesis of the four-bar mechanism and reduces the number of required initial data under a given accuracy of the numerical solution.

[1] Elena Gebel, Ph.D.: Omsk State Technical University, Mira avenue, 11, Omsk, 644050, Russia (RU), gebel_es@mail.ru.

[2] Asylbek Jomartov, Professor: Institute of Mechanics and Mechanical Engineering named after U. A. Dzholdasbekov, Kurmangazy St., 29, Almaty, 050010, Kazakhstan (KZ), legsert@mail.ru.

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paper id: ENG267

Deterministic chaos in a damage dynamics of the engineering (vibrating) structures under varying environmental and operational conditions

Alexander V. Glushkov, Vasily V. Buyadzhi, Alexander Mashkantsev, Alexey Lavrenko

Abstract: The work is devoted to problem of analysis, identification and prediction of the presence of damages, which above a certain level may present a serious threat to the engineering (vibrating) structures etc in result of the operational, environmental conditions, including the emergency accidents. We present and apply a novel computational approach to modelling, analysis of a chaotic behaviour of structural dynamic properties of the engineering structures, based on earlier developed chaos-geometric and vibration blind source monitoring approach. It includes a combined group of methods such as correlation integral approach, average mutual information, surrogate data, the Lyapunov's exponents and Kolmogorov entropy analysis, nonlinear prediction models etc (in versions [1-3]). We present the results of analysis and modelling chaotic elements in dynamical parameter time series for the experimental cantilever beam [3]. We list the data on the topological and dynamical invariants, namely, the correlation, embedding, Kaplan-Yorke dimensions, the Lyapunov's exponents and Kolmogorov entropy etc. References 1. Glushkov A.V., Methods of a Chaos Theory. Odessa: Astroprint, 2012. 2. Glushkov A.V., Khetselius O.Yu., Svinarenko A.A., Buyadzhi V.V., Methods of computational mathematics and mathematical physics, P.1. Odessa: TEC, 2015. 3. Tjirkallis A., Kyprianou A. Mech.l Syst. Signal Process. 66-67, 282 (2016).

1) Alexander V. Glushkov, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), glushkovav@gmail.com.

2) Vasily V. Buyadzhi, Associate Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), buyadzhivv@gmail.com.

3) Alexander Mashkantsev, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), mashkantsevaa@rambler.ru.

4) Alexey Lavrenko, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), lavrodessa@rambler.ru.

paper id: MAT269

Nonlinear dynamics of atomic and molecular systems in an electromagnetic field: Deterministic chaos and strange attractors

Alexander V. Glushkov, Anna Ignatenko, Anna Kuznetsova, Anna Buyadzhi

Abstract: We present an effective mathematical approach to studying a deterministic chaos and strange attractors in dynamics of nonlinear processes in the quantum (Rydberg atomic and molecular) systems interacting with a resonant electromagnetic field. We have elaborated an effective computational approach that includes new quantum-dynamic model for atomic and diatomic molecule in an electromagnetic field (based on the finite-difference solution of the Schrödinger equation, optimized operator perturbation theory and realistic model potential method) [1] and advanced chaos-geometric approach (e.g.[2,3]). The dynamical and topological invariants such as the correlation and embedding dimensions, the Kaplan-Yorke dimension, Lyapunov's exponents and Kolmogorov entropy etc for different parameters of a field are computed. It is shown that a low-dimensional chaos is realized in dynamics of diatomic molecules interacting with a resonant linearly polarized field. 1. Glushkov A.V., Advanced Relativistic Energy Approach to Radiative Decay Processes in Multielectron Atoms and Multicharged Ions. In: Nishikawa K., Maruani J., Brändas E., Delgado-Barrio G., Piecuch P. (eds) Quantum Systems in Chemistry and Physics. vol 26. Springer, Dordrecht. 2012. pp 231-252. 2. Glushkov A.V., Methods of a Chaos Theory. Odessa: Astroprint, 2012. 3. Glushkov A.V., Kuzakon V.M., Ternovsky V.B., Buyadzhi V.V., Dynamical Systems Theory Eds. J. Awrejcewicz, M. Kazmierczak, P. Olejnik, J, Mrozowski (Lodz). Vol.T1. P.461-466 (2013).

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[1] Alexander V. Glushkov, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), glushkovav@gmail.com.

[2] Anna Ignatenko, Associate Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), ignatenkoav13@gmail.com.

[3] Anna Kuznetsova, Associate Professor: Odessa National Maritime Academy, Didrikhsona str., 4, Odessa, 65000, Ukraine (UA), kuznetsovaa232@gmail.com.

[4] Anna Buyadzhi, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), buyadzhiaa@gmail.com.

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Dynamical Systems — Theory and Applications

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paper id: ENG316

An influence of the external electric field and internal imperfections on the reflectance and transmittance of light propagated in liquid crystals

Dariusz Grzelczyk, Jan Awrejcewicz

Abstract: Electric fields acting on the molecules of the liquid crystals generate additional torques determining its internal structure, i.e. distribution of the optical axis. On the other hand, some disturbances in the distribution of the optical axis may be caused by internal imperfections of the liquid crystal structure or may depend on the boundary conditions between the investigated optical medium and the bounded glass. In this paper we investigated numerically the influence of the changes in the direction of the optical axis of the liquid crystals on the reflectance and transmittance of light propagated inside the mentioned optical birefringent networks. In order to model optical phenomena in the considered systems, we employed an exact 4×4 matrix method. Interesting reflectance and transmittance spectra and plots for different system parameters and arbitrary incident monochromatic light were obtained and reported. The presented results can be useful for understanding various birefringent optical systems, especially liquid crystal displays.

[1] Dariusz Grzelczyk, Ph.D.: Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowskiego Street, 90-924 Lodz, POLAND, Poland (PL), dariusz.grzelczyk@p.lodz.pl.

[2] Jan Awrejcewicz, Professor: Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowskiego Street, 90-924 Lodz, POLAND, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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Dynamical Systems — Theory and Applications

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paper id: MTR314

Stability and control of a hybrid walking robot on vibrating and unstable terrain

Dariusz Grzelczyk, Jan Awrejcewicz

Abstract: In this study we developed and investigated a general dynamic model of a hybrid robot consisting both crab-like and mammal-like legs. A relatively simple and efficient model of gait as well as an algorithm responsible for the initial, rhythmic and terminal phases of the robot gait were employed and tested. The simulation model implemented in Mathematica allowed us for virtual experiments of the visualization process of the robot's locomotion. The obtained numerical results proved advantages of the used control method, including dynamic stability margin of the robot during walking. However, in this paper we especially considered more precisely control possibility the position of the robot during walking in different directions. The presented control algorithm can be used to simultaneous control of all robot's legs in order to control of all six spatial degrees-of-freedom of the robot's body, i.e. three rotations and three deviations, respectively. Especially, this method can be successfully used to coordination and control all robot's legs on planar, vibrating and unstable ground, for instance during stabilization of the robot's spatial position. Since the used version of the Mathematica computer program allows to communicate with different modern microcontrollers, the developed control algorithm can be simply adopted to control real constructions of different multi-legged robots.
Acknowledgment: The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700.

[1] Dariusz Grzelczyk, Ph.D.: Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowskiego Street, 90-924 Lodz, POLAND, Poland (PL), dariusz.grzelczyk@p.lodz.pl.

[2] Jan Awrejcewicz, Professor: Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowskiego Street, 90-924 Lodz, POLAND, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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Dynamical Systems — Theory and Applications

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paper id: LIF315

Modelling and control of a lower limb exoskeleton driven by linear actuators

Dariusz Grzelczyk, Olga Jarzyna, Jan Awrejcewicz

Abstract: This paper presents novel design of a lower limb exoskeleton driven by linear electric actuators. To better investigate the crucial kinematic parameters of the device, we created a general, three-dimensional simulation model of the studied exoskeleton in Mathematica software. Both in the presented design and the developed simulation model, biocompatibility aspects of the simulated walking machines were also considered. As the articulated variables in the individual joints of the exoskeleton, we employed time histories of human joint angles obtained by a motion capture system. A new gait generator was developed and tested. It can be used to produce rhythmic movements in hip and knee joints. Finally, we verified the possibility of implementing the proposed control method by using the constructed prototype of a single limb of an exoskeleton, controlled by a popular Arduino Uno microcontroller. The carried out experimental tests gave promising results regarding the applied control possibilities. Acknowledgment: The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700.

[1] Dariusz Grzelczyk, Ph.D.: Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowskiego Street, 90-924 Lodz, POLAND, Poland (PL), dariusz.grzelczyk@p.lodz.pl.

[2] Olga Jarzyna, M.Sc. (Ph.D. student): Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowskiego Street, 90-924 Lodz, POLAND, Poland (PL), olga.jarzyna@edu.p.lodz.pl.

[3] Jan Awrejcewicz, Professor: Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowskiego Street, 90-924 Lodz, POLAND, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: EXP232

Application of the Unscented Kalman Filter to experimental estimation of states and parameters of synchronous generators

Jose Mario Vicensi Grzybowski, Cassio Luciano Baratieri

Abstract: This paper presents an experimental study of the Unscented Kalman Filter (UKF) and Extended Kalman Filter (EKF) for estimation of states and parameters of synchronous generators. The research aims at testing the suitability of the filter in an experimental environment where process noise, measurement noise and harmonics are present in the voltage and current signals. Estimates of states and parameters are obtained from the noisy measurements of input voltages, output currents and rotor angle. While the EKF is currently the leading nonlinear filtering technique in industrial applications, the results show that the estimates provided by the UKF are better in the sense that the parameter estimates feature tighter convergence to the actual values, i.e., those obtained by means of bench measurements.

[1] Jose Mario Vicensi Grzybowski, Ph.D.: Federal University of Fronteira Sul, Rodovia RS 135 km 72 CEP 99700-000 Erechim-RS, Brazil (BR), jose.grzybowski@uffs.edu.br.

[2] Cassio Luciano Baratieri, Ph.D.: Universidade Regional Integrada do Alto Uruguai e das Missoes, Rodovia RS 331 CEP 99700-000 Erechim - RS, Brazil (BR), cassiobaratieri@uricer.edu.br.

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paper id: EXP88

A rotational energy harvester for propulsion systems: design and experimental validation

Ben Gunn, Stephanos Theodossiades, Steve Rothberg

Abstract: Modern control systems in propulsion applications can ensure the smooth and efficient operation and assist in detecting failures at early stages. The implementation of these control systems is restricted by the availability of sensor data, such as the stress experienced by a rotating shaft. Wireless sensor technology could be mounted to rotating components but nevertheless powering these sensors is a technical challenge. Traditionally batteries or slip rings would be used but these have a relatively short service life, which could lead to unacceptable maintenance demands. Energy harvesters may solve this issue by utilising vibration energy and converting it to useable electrical energy. In the present work, the prototype of a duffing-type rotational electromagnetic energy harvester is designed and tested, based on a previously published model of the authors. The harvester takes energy from the torsional speed fluctuations of a rotating shaft, commonly found in propulsion systems. The experimental results show a broadband response of the energy harvester to achieve useful power generation across a wide range of shaft speeds, which agrees well with the numerical model predictions.

1) Ben Gunn, M.Sc. (Ph.D. student): Loughborough University, Wolfson School, Loughborough University, Ashby Road, Loughborough, LE11 3TU, England (GB), B.E.Gunn@lboro.ac.uk .

2) Stephanos Theodossiades, Professor: Loughborough University, Wolfson School, Loughborough University, Ashby Road, Loughborough, LE11 3TU, England (GB), S.Theodossiades@lboro.ac.uk .

3) Steve Rothberg, Professor: Loughborough University, Wolfson School, Loughborough University, Ashby Road, Loughborough, LE11 3TU, England (GB), S.J.Rothberg@lboro.ac.uk .

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Dynamical Systems — Theory and Applications

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paper id: MAT174

A new analytical approach to nonlinear free vibration of microtubes

Nicolae Herisanu, Vasile Marinca

Abstract: In this paper, the microfluid-induced nonlinear free vibration of microtubes is studied by means of a new analytical technique, namely the Optimal Auxiliary Functions Method (OAFM). The the nonlinear equation of motion is obtained after some developments based on Hamilton's principle and a modified couple stress theory. Explicit and accurate approximate analytical solutions are obtained using the proposed technique. The influence of internal material length scale parameter, outer diameter and flow velocity on the dynamic behaviour is presented.

1) Nicolae Herisanu, Professor: University Politehnica Timisoara, Bd.Mihai Viteazu 1, Romania (RO), n_herisanu@yahoo.co.uk.

2) Vasile Marinca, Professor: University Politehnica Timisoara, Bd.Mihai Viteazu 1, Romania (RO), v_marinca@yahoo.co.uk.

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paper id: MAT179

Nonlinear vibration of Bernoulli-Euler beam resting on a Winkler elastic foundation

Nicolae Herisanu, Vasile Marinca

Abstract: In this paper, a Bernoulli-Euler beam resting on a Winkler elastic foundation is studied. The considered beam is assumed to be pinned–pinned with a linear torsional spring at one end and the effect of the axial force induced by mid-plane stretching is considered in the investigation of the nonlinear dynamic behavior of the beam. The governing partial differential equation is discretized using Galerkin method and the nonlinear differential equation is analytically solved. The proposed procedure is independent on the presence of small or large parameters in the equation under study and the approximate analytical solution obtained after the first iteration is very accurate, which prove the reliability and effectivenes of the proposed approach.

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[1] Nicolae Herisanu, Professor: University Politehnica Timisoara, Bd.Mihai Viteazu 1, Romania (RO), n_herisanu@yahoo.co.uk .

[2] Vasile Marinca, Professor: University Politehnica Timisoara, Bd.Mihai Viteazu 1, Romania (RO), v_marinca@yahoo.co.uk .

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paper id: EXP330

Harmonic transfer path analysis of a wine refrigerator

Wolfgang Hörtnagel, Stefan Plagg, Fadi Dohnal

Abstract: Transfer path analysis (TPA) is increasingly being applied in the industry when it comes to a new product generation of lightweight and therefore highly flexible structures. TPA helps identifying critical locations and components of the overall structure that contribute to specific vibration observations. Typically TPA needs to be balanced between needed accuracy and time efficiency/cost. Several TPA methodologies exist and need to be adapted to the specific system under consideration. We develop a robust algorithm for the estimation of the frequency response functions of a complex, flexible structure like a commercial wine refrigerator. These lead to an improved TPA of the overall system and help optimizing future designs by defining desirable characteristics of critical locations.

1) Wolfgang Hörtnagel, M.Sc. (Ph.D. student): UMIT, Linker Iselweg 21, 9900 Lienz, Austria (AT), wolfgang.hoertnagel@umit.at.

2) Stefan Plagg, M.Sc.: Liebherr-Hausgeräte Lienz, Dr.-Hans-Liebherr-Straße 1, Austria (AT), stefan.plagg@liebherr.com.

3) Fadi Dohnal, Professor: UMIT, Linker Iselweg 21, 9900 Lienz, Austria (AT), fadi.dohnal@umit.at.

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paper id: NON106

Optimal dynamic vibration absorber for friction-induced vibration mitigation

Jia Lin Hu, Giuseppe Habib

Abstract: Friction-induced vibrations appear in diverse fields of science, ranging from squeal of braking vehicles and earthquakes, to musical instruments such as violins. In engineering systems they are generally undesired and designers try to mitigate them whenever possible. In this work, we aim at suppressing friction-induced vibrations of a host mechanical system by adopting a passive dynamic vibration absorber. The host structure consists of a single degree-of-freedom oscillator in contact with a moving belt (usually referred to as mass-on-belt), while the vibration absorber is attached to the mass through a spring and a damper. Two different aspects are considered for the optimization of the absorber. First, the stable region of the trivial solution of the system, with respect to the belt velocity, is maximized. A fully analytical approach enables us to identify the optimal absorber parameters for obtaining the largest possible stable region. These are expressed in practical compact formulas. Then, adopting a mixed analytical-numerical approach, the nonlinear parameters of the absorber are tuned in order to narrow the so-called bistable region of the system and to reduced vibration amplitude when full suppression is not reachable.

[1] Jia Lin Hu, B.A. (M.Sc. student): Dept. of Applied Mechanics - Budapest University of Technology and Economics, 1111 Budapest Műegyetem rkp. 5., Hungary (HU), hujialin1995@gmail.com.

[2] Giuseppe Habib, Ph.D.: Dept. of Applied Mechanics - Budapest University of Technology and Economics, 1111 Budapest Műegyetem rkp. 5., Hungary (HU), habib@mm.bme.hu.

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paper id: VIB255

Dynamics of the microresonator in the regime of supercritical compression

Vasilisa Igumnova, Lev Shtukin, Aleksei Lukin, Ivan Popov

Abstract: In this work we research microresonator consisting of an elastic element in the form of a beam located between stationary electrodes. One end of the beam is rigidly clamped, and the other one is elastically fixed in the longitudinal direction. Longitudinal movement of the elastic fastening creates a longitudinal force in the elastic element of the microresonator. Equilibrium positions depending on the longitudinal displacement of the elastic fastening mechanism are obtained in the presence of a longitudinal compressive force and one or two sources of constant electromotive force. With different switched on sources of constant electromotive force either two or three critical values of the force are possible, which differ from the Euler force. In the formulation of free oscillations phase portraits of the system were constructed for various field inclusions. The forced oscillations of the resonator with supercritical longitudinal compressive loads in different regimes are considered. Resonance curves were constructed with characteristic jump phenomena during the transition from one regime to another. A comparison of the results of the multi-scale solution with the numerical integration in the MATCONT software package has been carried out. A positive feedback scheme for the excitation of self-oscillatory modes was proposed. A numerical experiment demonstrating the possibility of the occurrence of a self-oscillatory regime was carried out and the effect of various parameters on the frequency and amplitude of self-oscillations was investigated.

[1] Vasilisa Igumnova, B.A.: Peter the Great St.Petersburg Polytechnic University (SPbPU), St. Petersburg, Kollontai st, 21/3, 193231, Russia (RU), igumnovavs@mail.ru.

[2] Lev Shtukin, Ph.D.: Peter the Great St.Petersburg Polytechnic University (SPbPU), St.Petersburg, Polytechnicheskaya, 29, 195251, Russia (RU), lvtvsh4749@gmail.com.

[3] Aleksei Lukin, Ph.D.: Peter the Great St.Petersburg Polytechnic University (SPbPU), St.Petersburg, Polytechnicheskaya, 29, 195251, Russia (RU), lukin_av@spbstu.ru.

[4] Ivan Popov, Ph.D.: Peter the Great St.Petersburg Polytechnic University (SPbPU), St.Petersburg, Polytechnicheskaya, 29, 195251, Russia (RU), popov_ia@spbstu.ru.

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paper id: OPT54

Optimization of mitigation strategy for Under-Body Blast load to minimize injury of spine

Artur Iluk

Abstract: In the paper, the mitigation strategy of the seat support system in case of Under–Body Blast (UBB) was investigated. For the UBB, the vehicle body is accelerated vertically, and the main goal was a minimization of the vertical space inside a vehicle required to accelerate the human body without injury of spine. As a biomechanical injury criterion, the Dynamic Response Index (DRIz) was used in connection with other limitations discussed in the paper. In the first stage, simply analytical models were used to evaluate response of the human body and to find optimal loading profile for no-injury conditions. The optimal profile of the acceleration was discussed. In the second stage, the more realistic numerical model based on Hybrid III Anthropomorphic Test Device (ATD) and real structure of the blast attenuating seat was investigated in simplified UBB conditions. The axial force acting on spine and corresponding DRIz profiles were calculated. The limitations of presented mitigation strategy and the DRIz model as a biomechanical criterion for UBB events were discussed.

1) Artur Iluk, Associate Professor: Wrocław University of Science and Technology, Lukasiewicza 7/9, Poland (PL), artur.iluk@pwr.edu.pl.

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paper id: CON166

Controlled dynamical system for leveling vibrations of longitudinal forces in railway couplers of multi-part rail vehicles

Jacek Jackieiwcz

Abstract: The work presents a technical solution designed for modern, multi-section rail-vehicles, which move at high speeds and have one low-floor to increase the comfort of travelers. In the multi-part rail vehicle without an appropriate control system, braking forces, as well as tractive forces of each unit of this vehicle can not appear at the same time. In most cases, it can be a source of the generation of unfavorable braking and acceleration waves. Therefore, the proposed solution uses cruise control, coupled with active eliminators of longitudinal vibrations of the rail vehicle. Moreover, during braking, the action of the energy recovery system of the rail vehicle is under the simultaneous influence of cruise control.

[1)] Jacek Jackieiwcz, Associate Professor: Faculty of Mathematics, Physics & Technical Sciences, Kazimierz Wielki University, ul. Chodkiewicza 30, 85–064 Bydgoszcz, Poland, Poland (PL), jacek.jackiewicz@ukw.edu.pl .

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paper id: LIF326

A simple pattern generator for biped walking

Olga Jarzyna, Dariusz Grzelczyk, Jan Awrejcewicz

Abstract: The paper proposes a simple model of a central pattern generator for bipedal walking. The model approximates the angular positions of hip, knee and ankle joints during walking considered in the sagittal plane. The proposed mathematical representation of the walking pattern generator is based on experimental observations of healthy volunteer's gait. It consists of three piecewise-defined continuous and smooth sine-squared-based functions approximating the angular positions of particular joints within a gait cycle. The model can be potentially employed to generate signals controlling motion of an exoskeleton for rehabilitation of lower limbs. It can be easily modified by changing the values of model parameters. The proposed model can be also potentially implemented in control of bipedal robots in the future. Acknowledgment: The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700.

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[1] Olga Jarzyna, M.Sc. (Ph.D. student): Lodz University of Technology, 1/15 Stefanowskiego St., 90-924 Łódź, Poland (PL), olga.jarzyna@edu.p.lodz.pl.

[2] Dariusz Grzelczyk, Ph.D.: Lodz University of Technology, 1/15 Stefanowskiego St., 90-924 Łódź, Poland (PL), dariusz.grzelczyk@p.lodz.pl.

[3] Jan Awrejcewicz, Professor: Lodz University of Technology, 1/15 Stefanowskiego St., 90-924 Łódź, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: EXP242

Motion cases analysis of the mobile platform with four-wheel drive under slippage conditions

Anna Jaskot, Bogdan Posiadała, Szczepan Śpiewak

Abstract: The cases of motion of the prototype of mobile platform equipped with four drive modules are considered. The prototype has been developed by the author's construction assumptions that allows to realize the motion of the platform in a various configurations of wheel drives, including control of the active forces and the direction of their settings while driving. The model of the platform's dynamics has been proposed in previous works of the authors. In the proposed model the relations between active and friction forces in longitudinal and transverse directions have been considered. The solution of the initial problems in relation to selected cases of platform motion have been obtained numerically using the Runge-Kutta method of the fourth order. The results presented in the work have been chosen to represent the behavior of the platform during its motion when the wheels slip and in the circumstances to refrain the platform from falling into the skid. On the basis of the model and calculation program it is possible to create the calculation models for other cases by introducing the other elements of the real object and the interaction of its elements with the ground to the mathematical description and numerical procedure.

[1] Anna Jaskot, M.Sc. (Ph.D. student): Czestochowa University of Technology, Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), jaskot@imipkm.pcz.pl.

[2] Bogdan Posiadała, Professor: Czestochowa University of Technology, Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), bogdan.p@imipkm.pcz.pl.

[3] Szczepan Śpiewak, Ph.D.: Czestochowa University of Technology, Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), spiewak@imipkm.pcz.pl.

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paper id: CON263

Adaptive, nonlinear synchronization of a Duffing oscillator with unknown parameters

Jacek Kabziński

Abstract: For many years, the Duffing oscillator was investigated intensively as a benchmark of a chaotic system which is able to demonstrate all phenomena of chaos. Contemporarily oscillating systems that exhibit Duffing-like behavior are present in many areas: MEMS, laser technique, wireless power harvesters and many others. Therefore, the problem of controlling a Duffing system becomes more and more practical. A general tracking control problem is solved for a chaotic system (Duffing oscillator) with unknown parameters. We consider additional requirement that the tracking error must remain inside an imposed hard constraint. We compare several techniques like barrier Lyapunov functions or nonlinear state transformation applied in the adaptive backstepping scheme. Several system properties are investigated and benefits coming from state variable constraints are discussed. The same approach may be used for chaos synchronization and chaotification.

[1)] Jacek Kabziński, Professor: Institute of Automatic Control, Lodz University of Technology, Stefanowskiego 18 22, Lodz, Poland (PL), jacek.kabzinski@p.lodz.pl.

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paper id: EXP215

Optimization of the spindle speed during milling of high-dimensional structures with the use of technique of Experiment-Aided Virtual Prototyping

Krzysztof J. Kaliński, Marek Galewski, Michał Mazur, Natalia Morawska

Abstract: In the paper are presented considerations concerning vibration suppression problems during milling of large-sized workpieces with the use of innovative method of matching the spindle speed of cutting tool. It depends on repeatable change of the basic value of spindle speed as soon as the optimal vibration state of the workpiece approaches. The values of dominant "peaks" in the frequency spectra and the Root Mean Square (RMS) values of time domain displacements are evaluated. The efficiency of the proposed approach is evidenced by chosen mechatronic design technique, called Experiment-Aided Virtual Prototyping (E-AVP). Thanks to the results of the identification of the modal subsystem obtained by the ERA method, it can be stated that the parameters obtained from the experiment and delivered from the computational model have been correctly determined and constitute reliable process data for the simulation tests.

[1] Krzysztof J. Kaliński, Professor: Gdansk University of Technology, ul. Gabriela Narutowicza 11/12, Poland (PL), kkalinsk@o2.pl.

[2] Marek Galewski, Associate Professor: Gdansk University of Technology, ul. Gabriela Narutowicza 11/12, Poland (PL), marek.galewski@pg.edu.pl.

[3] Michał Mazur, Ph.D.: Gdansk University of Technology, ul. Gabriela Narutowicza 11/12, Poland (PL), michal.mazur@pg.edu.pl.

[4] Natalia Morawska, M.Sc. (Ph.D. student): Gdansk University of Technology, ul. Gabriela Narutowicza 11/12, Poland (PL), natalia.morawska@pg.edu.pl.

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paper id: STA345

Nonlinear study of a Pneumatic Artificial Muscle (PAM) under superharmonic resonance condition using method of multiple scales

Bhaben Kalita, Santosha K. Dwivedy

Abstract: In this work, the nonlinear behaviour exhibit in the Pneumatic artificial muscle (PAM) has been studied. For the analysis, a single degree of freedom system is considered where the nonlinear Pneumatic Artificial Muscle (PAM) is attached with an external spring to provide additional support the system. The nonlinear equation of motion is solved with the help of the method of multiple scales to find out the reduced equations for superharmonic resonance condition. The dynamic stability and bifurcation of the system have been studied from the reduced equations. The frequency responses have been plotted to understand the effect of the different parameters on the system amplitude. Basin of attraction also have been plotted to verify the frequency plots. Finally, with the help of this work, the designers and researchers working in this field will get an idea to know about the safe range of various system parameters to operate for different applications of PAMs.

[1] Bhaben Kalita, Ph.D.: Indian Institute of Technology Guwahati, Mechanical Engineering Department, IIT Guwahati, India, 781039, India (IN), k.bhaben@iitg.ac.in.

[2] Santosha K. Dwivedy, Professor: Indian Institute of Technology Guwahati, NORTH GUWAHATI, GUWAHATI, India (IN), dwivedy@iitg.ac.in.

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paper id: ASY341

The influence of asymmetric electrodes on the non-planar dynamics of a parametrically excited nonlinear microbeam

Prashant Kambali, Tova Mintz, Karin Mora, Eyal Buks, Oded Gottlieb

Abstract: Electrodynamically excited nano- and micro-mechanical resonators consist of configurations and structural elements which make use of one of their resonance frequencies. Their applications include atomic force microscopy, mass sensing etc. Majority of theoretical studies in literature assume that electrodes and beams are symmetrically spaced for both single and multi-element arrays. Thus in this work we study the influence of an imperfect configuration with asymmetric gaps between the electrodes and investigate the bifurcation structure resulting from spatio-temporal effects of the asymmetrical gap configuration on a non-planar, nonlinear micro-beam-string response. An initial-boundary value problem describing the three dimensional motion of a parametrically excited nonlinear microbeam in an asymmetric dual gap configuration is investigated asymptotically and numerically to study the influence of imperfections on its spatio-temporal dynamics. The analytical and numerical investigation of the non-planar dynamics reveals coexisting period doubled and quasiperiodic solutions corresponding to saddle-node and secondary Hopf instabilities in the slowly varying evaluation equations. The results are also compared with measurements from an experiment with asymmetric electrode gaps demonstrating that a planar model with parametric excitation cannot predict the documented bias in the observed frequency response of a nonlinear microbeam with an imperfect electrode configuration.

[1] Prashant Kambali, Ph.D.: Technion, Israel Institute of Technology, Haifa, Israel, Technion, Israel (IL), kprashant@campus.technion.ac.il.

[2] Tova Mintz, M.Sc.: Technion, Israel Institute of Technology, Haifa, Israel, Technion, Israel (IL), kprashant@campus.technion.ac.il.

[3] Karin Mora, Ph.D.: University of Paderborn, Paderborn, Germany (DE), oded@technion.ac.il.

[4] Eyal Buks, Professor: Technion, Israel Institute of Technology, Haifa, Israel, Technion, Hiafa, Israel (IL), eyal@ee.technion.ac.il.

[5] Oded Gottlieb, Professor: Technion, Israel Institute of Technology, Haifa, Israel, Technion, Hiafa, Israel (IL), oded@technion.ac.il.

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paper id: CON182

Dynamics of a spherical robot in cases of periodical control actions and oscillations of the underlying surface

Yury Karavaev, Alexander Kilin, Alexey Borisov

Abstract: The dynamics of a spherical robot of combined type is investigated. The spherical robot is set in motion by moving the position of the center of mass and by generating variable gyrostatic momentum. Problems of stabilizing the rolling of the spherical robot using periodic control actions are considered within the framework of a nonholonomic model. A mathematical model is presented which describes the movement of the spherical robot on an oscillating flat surface. The results of numerical modeling of the motion of the spherical robot for various combinations of control actions and parameters of plane oscillations are discussed.

[1)] Yury Karavaev, Ph.D.: Kalashnikov Izhevsk State Technical University, Studencheskaya str,, 7, Izhevsk, 426069, Russia (RU), karavaev_yury@istu.ru .

[2)] Alexander Kilin, Professor: Udmurt State University, ul. Universitetskaya 1, Izhevsk, 426034, Russia (RU), aka@rcd.ru .

[3)] Alexey Borisov, Professor: Moscow Institute of Physics and Technology, Institutskii per. 9, Dolgoprudnyi, 141700, Russia (RU), borisov@rcd.ru .

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paper id: ENG227

Ultrasensitive mass sensing using a single cantilever coupled with a computational cantilever

Yuki Kasai, Hiroshi Yabuno, Takeshi Ishine, Yasuyuki Yamamoto, Sohei Matsumoto

Abstract: Mass sensing based on the eigenmode shift of coupled cantilevers achieves very high sensitivity. In this method, identical cantilevers and the weaker coupling stiffness between them enable higher sensitivity. However, the sensitivity is restricted because the identity of cantilevers and the coupling stiffness depend on machining accuracy. To maximize the sensitivity, we propose completely identical weakly coupled cantilevers using a single cantilever and a digital computer. The digital computer calculates the dynamics of one of the conventional coupled cantilevers and the effect of coupling. Then, the calculated effect of coupling moves the single cantilever's supporting point. The system enables us to set the physical parameters of the cantilever whose dynamics is calculated and the coupling stiffness appropriately. In addition, to use even in viscosity environments, we apply the self-excited oscillation with a steady-state amplitude proposed in our previous work to the coupled cantilevers. We realized the identical coupled cantilevers and their arbitrary coupling stiffness in the experiment using the prototype system with a macrocantilever. Furthermore, we achieved ultrasensitive mass sensing.

[1] Yuki Kasai, B.A. (M.Sc. student): Graduate School of System and Information Engineering, University of Tsukuba, 1-1-1, Tennodai, Tsukuba, Ibaraki, Japan (JP), s1920782@s.tsukuba.ac.jp.

[2] Hiroshi Yabuno, Professor: Graduate School of System and Information Engineering, University of Tsukuba, 1-1-1, Tennodai, Tsukuba, Ibaraki, Japan (JP), yabuno@esys.tsukuba.ac.jp.

[3] Takeshi Ishine, B.A.: School of Science and Engineering, University of Tsukuba, 1-1-1, Tennodai, Tsukuba, Ibaraki, Japan (JP), it3939241084@gmail.com.

[4] Yasuyuki Yamamoto, Ph.D.: Fluid Property Standards Group, Research Institute for Engineering Measurement, National Metrology Institute of Japan(NMIJ), National Institute of Advanced Industrial Science and Technology(AIST), 1-1-1 Umezono, Tsukuba, Ibaraki, Japan (JP), yamamoto-yasu@aist.go.jp.

[5] Sohei Matsumoto, Ph.D.: Research Center for Ubiquitous MEMS and Micro Engineering, National Institute of Advanced Industrial Science and Technology (AIST), 1-2-1 Namiki, Tsukuba, Ibaraki, Japan (JP), sohei.matsumoto@aist.go.jp.

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Dynamical Systems — Theory and Applications

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paper id: MAT63

Uncertainties in the movement and measurement of a hexapod robot

István Kecskés, Ákos Odry, Péter Odry

Abstract: The uncertainties can be defined using the simulation model and real values, and, thus, practically represent the model's accuracy. All differences between the simulation and the reality create inaccuracy and uncertainty. Our previous research presented numerically these inaccuracies and point out some structure imperfections of the Szabad(ka)-II hexapod robot. Uncertainty variables can be divided into three groups in a optimization problem: physical, design, and scenario uncertainties. The physical uncertainties occur in the parts of the model where the model has estimated or approximate solutions. The scenario uncertainties are related to the scenario parameters in a multi-scenario approach, whereas the optimized (design) variables carry the design uncertainties. The sequential and parallel measurement made on Szabad(ka)-II robot shows more or less uncertainties between the left and right side, between front and rear legs, between current and voltage sensors and repetition of same walking scenario. The differences observed from same scenario are compared difference between different scenarios. There are also deviation in the first walking step compared to the rest steps. The 6-axis accelerometer signals are analyzed both in time and frequency domain. Before optimize any kind of robot motion and structural quality the measurement errors and uncertainties should be estimated. It is also necessary to define the expected quality optimum, and interpret correctly the simulation results and imperfections.

[1] István Kecskés, Ph.D.: University of Dunaújváros, Jasenovacka 16, Subotica 24000, Serbia (RS), kecskes.istvan@gmail.com.

[2] Ákos Odry, M.Sc. (Ph.D. student): University of Dunaújváros, 24000 Subotica, Serbia (RS), odrya@uniduna.hu.

[3] Péter Odry, Professor: University of Dunaújváros, 24413 Palic, Serbia (RS), PODRY@uniduna.hu.

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paper id: MAT270

New generalized chaos-geometric and neural networks approach to nonlinear modeling of complex chaotic dynamical systems

Olga Khetselius, Andrey Svinarenko, Anna Ignatenko

Abstract: We present a new generalized approach to modelling nonlinear processes of chaotic systems based on the known concept of compact geometric attractors (CGA), chaos theory methods plus implemented neural networks (NNW) simulation algorithm. The basic idea of the construction of prediction approach to chaotic properties of complex systems is in the use of the traditional concept of a CGA in which evolves the measurement data, plus the NNW quantum algorithm implementation. In terms of the neuro-informatics and neural networks theory the process of modelling the evolution of the system can be generalized to describe some evolutionary quantum dynamic neuro-equations. The main blocks of the combined approach (technology) are as follows (in [1,2]): I. General analysis and evolutionary differential equations treatment; II. Study of presence of chaos (Test by Gottwald-Melbourne. Fourier decompositions. Spectral analysis; III. The geometry of the phase space. Multi-fractal spectra. Wavelet analysis; IV. Processing and Prediction methods and algorithms (nonlinear parameterized function; optimized trajectories (propagators) algorithms; Neural Networks algorithms (technology).
References. [1] Glushkov A.V.: Methods of a chaos theory , Odessa, Astroprint (2012). [2] Khetselius O.Yu.: Forecasting evolutionary dynamics of chaotic systems using advanced non-linear prediction method. In: Dynamical Systems Applications, Eds.: J. Awrejcewicz, M. Kazmierczak, P. Olejnik, J. Mrozowski (Lodz, Poland) 2013. Vol. T2, 145-152.

1) Olga Khetselius, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), okhetsel@gmail.com.

2) Andrey Svinarenko, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), svinarenkoaa@gmail.com.

3) Anna Ignatenko, Associate Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), ignatenkoav13@gmail.com.

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Dynamical Systems — Theory and Applications

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paper id: LIF266

Chaos-geometric approach to analysis and forecasting evolutionary dynamics of complex systems: atmospheric pollutants dynamics

Olga Khetselius, Andrey Svinarenko, Yuliya Bunyakova, Iryna Buchko

Abstract: An effective computational complex approach to analysis, modelling and forecasting evolutionary chaotic dynamics of complex nonlinear geosystems (atmospheric pollutants dynamics) is presented. The approach is based on the combined using dynamical geosystem models and non-linear analysis and chaos theory methods such as the autocorrelation function method, multi-fractal formalism, wavelet analysis, mutual information approach, correlation integral analysis, false nearest neighbour algorithm, Lyapunov exponent's analysis, surrogate data method, stochastic propagators method, memory and Green's functions approaches etc (in [1-3]). The results of numerical studying the deterministic chaos elements in the pollutant concentration (dioxide of nitrogen etc in atmosphere of industrial cities of the Odessa and Gdansk regions) time series are presented. References. [1] Khetselius O., BunyakovaY.: Proc.of 8th Int. Carbon Dioxide Conf.-Jena, Germany, 2009. [2] Glushkov A.V.: Methods of a Chaos Theory. Odessa: Astroprint, 2012. [3] Glushkov A.V., Khetselius O.Yu., Svinarenko A.A., Buyadzhi V.V.: Methods of computational mathematics and mathematical physics, P.1. Odessa: TEC, 2015.

[1] Olga Khetselius, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), okhetsel@gmail.com.

[2] Andrey Svinarenko, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), svinarenkoaa@gmail.com.

[3] Yuliya Bunyakova, Ph.D.: Department of Environmental Economics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), bunyakovayy@gmail.com.

[4] Iryna Buchko, B.A. (M.Sc. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), bunyakovayy@gmail.com.

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paper id: EXP20

An experimental observation of the spatial motions of strings in resonance points under the planar excitation

Sungyeup Kim

Abstract: In general, strings are resonated when the excitation frequency is in the neighborhood of natural frequency by planar excitation. It is a primary resonant phenomenon. And they are also resonated by three times frequency of the natural one under the external excitation. This phenomenon is called superharmonic resonance. In this study, we consider the case when the lower end of a string is excited periodically by shaker in a direction which is perpendicular to the longitudinal one and the other upper end is fixed. Then, we show experimentally nonlinear phenomena in strings by frequency response curves. As a result, we found out that spatial motion can occur by superharmonic resonance. Finally, we observe the occurrence of the out of plane or spatial motions through the experiments. These phenomena are caused by the coupling effect of the stiffness due to the characteristic of the geometrical cubic nonlinear restoring force in strings.

[1)] Sungyeup Kim, M.Sc. (Ph.D. student): Graduate School of Systems and Information Engineering, University of Tsukuba, 1-1-1, Tennodai, Tsukuba, Ibaraki, 305-8573, Japan (JP), white10040201@hotmail.com .

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Dynamical Systems — Theory and Applications

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paper id: VIB53

Electromechanical impedance tomography for strand breakage localization in multi-strands anchorage

Jeong-Tae Kim, Ngoc-Loi Dang

Abstract: So far, vibration-based damage detection studies have focused mostly on globally assessing the prestress loss in tendon-anchorage system. For the tendon-anchorage with multi-strands, damage can occur at any local strands. Thus, the localization of damaged strands should be accurately estimated for the integrity of the entire system. As a local vibration approach, in this study, an electromechanical impedance-based method is presented for strand breakage detection in multi-strand anchorage systems. Firstly, stress fields of a multi-strand anchorage are analyzed to examine anchorage's responses sensitive to local strand breakage. Secondly, an impedance-based stress monitoring technique via the PZT interface which is designed for the multi-strand anchorage to monitor stress variations induced by the strand breakage. Local dynamic responses of the hoop-type PZT interface are analyzed to predetermine the effective frequency ranges. Finally, the feasibility of the proposed method is verified for a 9-strands anchorage system under various strand breakage cases. Variations in impedance responses are quantified, and broken strands are localized by linear tomography analysis of damage indices.

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[1] Jeong-Tae Kim, Professor: Pukyong National University, B14-304, 599-1 Daeyon-3dong, Nam-gu, Busan, South Korea (KR), idis@pknu.ac.kr.

[2] Ngoc-Loi Dang, M.Sc. (Ph.D. student): Pukyong National University, B14-320, 599-1 Daeyon-3dong, Nam-gu, Busan, South Korea (KR), loi.ngocdang@gmail.com.

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paper id: OPT140

Rapid vibro-acoustic optimisation of laminated composites

Matthias Klaerner, Lothar Kroll, Steffen Marburg

Abstract: Light and stiff composites such as fibre-reinforced plastics are sensitive to propagate structure borne sound but simultaneously offer a wide range of adjusting the material behaviour. Thereby, stiffness and damping of such composites are contradictory material properties related to the fibre orientation. Commonly, the composite design is based on FEA simulations requiring special modelling efforts. In contrast, the multi-dimensional optimisation of a laminate with numerous layers of different materials and orientations requires very fast numerical solutions for numerous repetitions. In this study, a complex but efficient vibro-acoustic model is presented. The FEA is extended by a strain energy based modal damping approach for the layerwise accumulation of the anisotropic damping. In addition, the radiated sound power is determined by a velocity based approach directly on steady state simulations of the structure only avoiding a complex multi-physical modelling. Moreover, the frequency dependent radiation is consolidated to a single scalar optimisation objective using a fast and efficient semi-analytic approach. Therefore, analytical formulations of amplification factors of the modal power contributions are introduced. This efficient simulation methodology is further applied to design a vibro-acoustically optimised composite part. The achieved results emerge the vibro-acoustic optimisation potential of thermoplastic composites compared to a steel reference case by material substitution only as well as an additional laminate optimisation.

[1] Matthias Klaerner, M.Sc. (Ph.D. student): Chemnitz University of Technology, Reichenhainer Str. 31-33, 09126 Chemnitz, Germany, Germany (DE), matthias.klaerner@mb.tu-chemnitz.de .

[2] Lothar Kroll, Professor: Chemnitz University of Technology, Reichenhainer Str. 31-33, 09126 Chemnitz, Germany, Germany (DE), matthias.klaerner@mb.tu-chemnitz.de .

[3] Steffen Marburg, Professor: Technical University Munich, Boltzmannstr. 15, 85748 Garching, Germany (DE), steffen.marburg@tum.de .

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paper id: NUM190

Impact wave propagation in a thin elastic isotropic plate

František Klimenda, Josef Soukup, Lenka Rychlíková

Abstract: Abstract: The paper deals with the theory of solution of transverse shock wave propagation in thin plane elastic isotropic plate. The solution is made for various material and geometric models of the plate. The calculation is performed analytically for Kirchhoff and Rayleigh geometric models. The plate is fixed around its perimeter. The plate is loaded continuously or by the solitary force acting on the upper facial surface in the perpendicular direction to the midline surface of the unloaded plate. The paper presents the relations and results for transverse displacement, velocity and voltage. Analytical results are compared with the experiment.

[1] František Klimenda, Ph.D.: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), frantisek.klimenda@ujep.cz.

[2] Josef Soukup, Associate Professor: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), josef.soukup@ujep.cz.

[3] Lenka Rychlíková, M.Sc. (Ph.D. student): University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), lenka.rychlikova@ujep.cz.

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paper id: ENG193

Convergence of dual infinity series

František Klimenda, Josef Soukup, Blanka Skočilasová, Lenka Rychlíková

Abstract: The solution of the system of the partial differential motion equations describing the movement of plate element by Fourier's series is presented in the article. The investigated function is expressed by product of three or four functions of the particular variables. These functions are demanded relation for the calculation of the displacement components, rotation components and stress components. These functions are defined in the form of the dual infinite series. The sum of these functions is necessary to perform by the numerical summarization element by element. The convergence of these series has to be proved before, namely in the equations of stresses.

[1] František Klimenda, Ph.D.: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), frantisek.klimenda@ujep.cz.

[2] Josef Soukup, Associate Professor: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), josef.soukup@ujep.cz.

[3] Blanka Skočilasová, Ph.D.: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), blanka.skocilasova@ujep.cz.

[4] Lenka Rychlíková, M.Sc. (Ph.D. student): University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), lenka.rychlikova@ujep.cz.

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Nonlinear dynamics of a planar beam–spring system: a 2:1 internal transversal-axial resonance

Łukasz Kłoda, Stefano Lenci, Jerzy Warmiński

Abstract: The nonlinear dynamics of a planar system consisting of a hinged simply supported beam with an embedded spring along the axis are investigated. Attention is focused on coupled axial-transversal oscillations, where double of a natural frequency of bending mode is tuned by axial spring to be close to the longitudinal natural frequency, thus realizing a 2:1 internal resonance. The effect of the spring on forced-damped vibrations of the system is investigated analytically by the multiple time scales method. The approximate frequency response curve is obtained, and for selected cases numerical validation by explicit finite element method is provided.
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[1] Łukasz Kłoda, M.Sc. (Ph.D. student): Lublin University of Technology, Department of Applied Mechanics & Polytechnic University of Marche, Department of Civil and Building Engineering, and Architecture, ul. Nadbystrzycka 36 20-618 Lublin, Poland, Poland (PL), l.kloda@pollub.pl.

[2] Stefano Lenci, Professor: Polytechnic University of Marche, Department of Civil and Building Engineering, and Architecture., Via Brecce Bianche, 60131 Ancona, Italy, Italy (IT), s.lenci@univpm.it.

[3] Jerzy Warmiński, Professor: Lublin University of Technology, Department of Applied Mechanics, ul. Nadbystrzycka 36 20-618 Lublin, Poland, Poland (PL), j.warminski@pollub.pl.

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System-level modelling of resonant MEMS inertial sensors

Petr Koludarov, Alexey Lukin, Ivan Popov

Abstract: System-level Modelling of Resonant MEMS Inertial Sensors Koludarov P.Y. (Peter the Great St.Petersburg Polytechnic University, Institute of Applied Mathematics and Mechanics, “Mechanics and Control Processes” department), Lukin A.V. (Peter the Great St.Petersburg Polytechnic University, Institute of Applied Mathematics and Mechanics, “Mechanics and Control Processes” department), Popov I.A. (Peter the Great St.Petersburg Polytechnic University, Institute of Applied Mathematics and Mechanics, “Mechanics and Control Processes” department; IPME RAS) In this article a verified methodology of MEMS modelling is presented. The methodology is validated on micro resonator beam with comparison to analytical studies of its dynamics. Different resonant MEMS sensors can be created using this methodology. In this study dynamics of torsional micro-vibratory gyroscope is being investigated and system level model is being created. In this work Reduced Order Modelling approach to coupled nonlinear mechanical systems is utilized to consider complex geometry as well as multidomain physics for system level modelling. Finite element model is reduced to a system of differential equations of lower orders allowing model to be fast to simulate and effortless to implement in control schemes. An analytical model of reduced order gyroscope mechanical system is created and analyzed using asymptotic methods of nonlinear mechanics and numerical parameter continuation, which allows for performing parametric analyses obtaining essential mechanical characteristics such as frequency response.

[1] Petr Koludarov, M.Sc.: Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), mrpetrkol@gmail.com.

[2] Alexey Lukin, Ph.D.: Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), lukin_av@spbstu.ru.

[3] Ivan Popov, Ph.D.: Peter the Great St.Petersburg Polytechnic University, 195251, Russia (RU), popov_ia@spbstu.ru.

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Control of the gyroscopic observation and tracking system on deck of the quadrotor unmanned aerial vehicle in the conditions of random interference impact

Zbigniew Koruba, Izabela Krzysztofik

Abstract: The paper presents the method control of the gyroscopic observation and tracking system located on the Quadrotor Unmanned Aerial Vehicle (QUAV), whose task is to track and laser illumination of the ground target. Taking into account the maneuvers performed by QUAV and the vibration of its deck as well as the occurrence of both process and measurement noise, it is necessary to restore state variables and filtering measurement data. Therefore, in the said gyroscopic system, an extended Kalman filter was used, along with a modified LQR regulator. As a result of such a synthesis, an LQG regulator (using Jacobian instead of a state matrix) was used, which ensures precision of tracking and illumination of the target. Some results of numerical simulation tests are presented in a graphical form.

[1] Zbigniew Koruba, Professor: Kielce University of Technology, Tysiąclecia Państwa Polskiego 7, 25-314 Kielce, Poland (PL), ksmzko@tu.kielce.pl.

[2] Izabela Krzysztofik, Associate Professor: Kielce University of Technology, Tysiąclecia Państwa Polskiego 7, 25-314 Kielce, Poland (PL), pssik@tu.kielce.pl.

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Assessment of implementation of neural networks in on-board dynamic payload weighing systems

Andrzej Kosiara, Aleksander Skurjat, Jakub Chołodowski

Abstract: While loading loose materials onto dump trucks, freight wagons or any other vehicles, a crucial issue is not to exceed their maximum permissible load capacity. Very efficient tools for monitoring weight of the loaded material are the on-board payload weighing systems which are usually installed on earthmoving machinery such as single bucket excavators and loaders. Operation of conventional systems of this type is typically based on computational models deriving from equations of dynamic equilibrium of machine and its manipulator. However, identification of parameters of these models might bring certain difficulties. The following paper presents a discussion on substitution of the conventional models implemented in payload weighing systems with the ones based on neural networks. A number of payload weighing systems involving neural networks varying in terms of inputs, structure and neuron types were designed by the author and implemented in an exemplary machine. Performance of these systems will be compared in the article. The influence of size of training dataset on the accuracy of the weighing system will be also discussed.

[1] Andrzej Kosiara, Ph.D.: Wrocław Univeristy of Science and Technology, 50-370 Wrocław, Wybrzeże Wyspiańskiego 27, Poland (PL), andrzej.kosiara@pwr.edu.pl.

[2] Aleksander Skurjat, Ph.D.: Wrocław Univeristy of Science and Technology, 50-370 Wrocław, Wybrzeże Wyspiańskiego 27, Poland (PL), aleksander.skurjat@pwr.edu.pl.

[3] Jakub Chołodowski, M.Sc. (Ph.D. student): Wrocław University of Science and Technology, 50-370 Wrocław, Wybrzeże Wyspiańskiego 27, Poland (PL), jakub.cholodowski@pwr.edu.pl.

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Some special properties of dynamical system caused by non-linear eigenvalue problem

Jan Kozanek

Abstract: Some special properties of dynamical system caused by non-linear eigenvalue problem Authors: Kozanek Jan, Zapomel Jaroslav The dynamical systems are defined by real mass, stiffness and viscous damping matrices and are described by the system of second-order ordinary differential equations. Corresponding eigenvalue problem is in general case of damping matrix non-linear – the so called lambda matrix problem. The steady-state response of dynamical system on harmonic excitation can be expressed in resolvent form as the linear combination of eigenvectors. Normally, the eigenvectors corresponding to the different eigenvalues are considered linearly independent. For special dynamical systems there are some pathological cases, studied in this paper, where the same eigenvector corresponds to the different eigenvalues. From a mathematical point of view, this property is known, but in dynamical systems and in particular in modal identification domains this property is somewhat surprising. We recall that in the earlier publications in connection with the eigen-solution of the lambda matrix problem it is used to name a latent vector instead of eigenvector.

[1] Jan Kozanek, Ph.D.: Institute of Thermomechanics of the Czech Academy of Sciences, Dolejskova 5, 182 00 Prague 8, Czech Republic (CZ), kozanek@it.cas.cz.

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paper id: MAT84

On the theory of wave gravitational field arising under orbital motion of a gravitating body

Alexander Krot

Abstract: This work investigates wave processes in orbital motion of a body under its gravitational interaction with a central body based on the statistical theory as well as the theory of retarded gravitational potentials. The statistical theory for a cosmogonical body forming (so-called spheroidal body) has been proposed in our previous works. It predicts statistical oscillations of orbital motion of planets around stars. Indeed, as known, the Alfvén–Arrhenius's radial and axial oscillations modify the forms of planetary orbits. Here we explain how the stability of orbital body (a planet) moving around central gravitating body (a star) is reached by the wave gravitational interaction between them. Using the statistical theory of cosmogonical body formation we find that periodic temporal deviation of the gravitational compression function of a spherically symmetric spheroidal body (under the condition of mechanical quasi-equilibrium) induces an additional periodic force of Alfvén–Arrhenius. Within framework of the developed theory of retarded gravitational potentials the formula of additional periodic force (as well as the wave gravitational potential relation) is also derived. We show that energetic wave exchanges between the central gravitating body and the orbital moving body seem be effected in the different spectral domains. Therefore, the orbital motion of body should be considered in a fast oscillating wave gravitational field.

[1)] Alexander Krot, Professor: Head of Laboratory of Self-Organization System Modeling at United Institute of Informatics Problems of National Academy of Sciences of Belarus, 6, Surganov str., Minsk 220012, Belarus (BY), alxkrot@newman.bas-net.by .

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paper id: NON65

String lattices vibrating near limiters

Vitaly Krupenin

Abstract: Lattice structures are widely used in various branches of mechanics and engineering. Of great model interest are string lattices, which are stretched intersecting strings with massive knots, in which there are solids. Such lattices can simulate two-dimensional objects, for example, membranes, and when adopting additional hypotheses, plates, various types of panels, etc. The report gives a brief overview of the dynamics of lattices with different types of cells (square, rectangular and hexagonal), the process of wave propagation with transverse oscillations of nodes is considered. Diverse non-linear effects manifest themselves when vibrations of string lattices, whose nodes collide with obstacles. In the corresponding vibro-impact systems with many shock pairs, various dynamic phenomena are described, such as impacts synchronization in remote shock pairs, nonlinear resonance effects inherent in the simplest impact oscillator, and others. The results of analytical studies obtained using time-frequency methods are presented. In the case of random oscillations, methods of diffusive Markov processes are used. A review of a large number of experimental data obtained at the facility developed at the Mechanical Engineering Research Institute of the Russian Academy of Sciences is given.

[1] Vitaly Krupenin, Professor: Mechanical Engineering Research Institute of the Russian Academy of Sciences; IMASH RAN, IMASH RAN: 4, M. Kharitonyevskiy Pereulok, 101990 Moscow, the Russian Federation., Russia (RU), krupeninster@gmail.com .

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Nonlinear dynamics of flexible mesh cylindrical panels in the white noise's field

Ekaterina Krylova, Jan Awrejcewicz, Irina Papkova, Vadim Krysko

Abstract: The mathematical model of the nonlinear dynamics of flexible mesh cylindrical panels in the additive white noise's field is constructed in this paper. To account for size-dependent behavior, a nonclassical continual model based on a Cosserat medium is considered. Thus, along with the classical stress field, the moment voltages are also taken into account. It is also assumed that the fields of displacements and rotations are not independent. The equilibrium equations for the plate element and the boundary conditions are obtained from the Ostrogradskyi-Gamilton variation principle on the basis of Kirchhoff-Lov's kinematic hypothesesand Karman's geometric nonlinearity.In accordance with a continual model, a mesh panel consisting of a regular system of often located same material's edges is replaced by an equivalent continuous layer having some averaged stiffness depending on the layout of the edges and their stiffness.The system of differential equations in partial derivatives is reduced to a system of ODE using the finite difference method of the second order of accuracy. The resulting system is solved by the fourth-order Runge-Kutta methods. The work was supported by the RFBR, № 18-01-00351a

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[1] Ekaterina Krylova, Associate Professor: Department of Mathematics and computer modelling Saratov State University, Str. Astrakhanskaya, 83 Saratov, Russian Federation, Russia (RU), kat.krylova@bk.ru.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, Faculty of Mechanical Engineering, Department of Automation, Biomechanics and Mechatronics,, 1/15 Stefanowskego Str., 90-924 Lodz, Poland, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[3] Irina Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russian Federati, Russia (RU), ikravzova@mail.ru.

[4] Vadim Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russian Federation, Russia (RU), tak@san.ru.

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Oscillations of flexible orthotropic meshed micropolar Timoshenko's plate

Ekaterina Krylova, Jan Awrejcewicz, Irina Papkova, Vadim Krysko

Abstract: The oscillation's theory of a geometrically nonlinear micropolar orthotropic meshed plate under the action of a normal distributed load is constructed in this paper. The plate's material as a Cosserat continuum with constrained particle rotation (pseudocontinuum). As a result, an additional independent parameter of length l associated with the symmetric bending-torsion tensor will appear in the model. The panel consists of n sets of identical edges, what allows to apply the continuous G. I. Pshenichnov's model. The equilibrium equations for the plate element and the boundary conditions are obtained from the Ostrogradskyi-Gamilton variation principle on the basis of S. P. Timoshenko's kinematic hypotheses. Geometric nonlinearity is taken into account according to the Theodore von Karman model. The system of differential equations in partial derivatives is reduced to a system of ODE using the finite difference method of the second order of accuracy. The resulting system is solved by the fourth-order Runge-Kutta methods. The influence of the normal load, an additional length's parameter l, and mesh's geometry on the orthotropic plate's oscillations consisting of two families of mutually orthogonal edges has been studied. The work was supported by the RFBR, № 18-01-00351a

[1] Ekaterina Krylova, Ph.D.: Saratov State University, Str. Astrakhanskaya, 83, Russia (RU), kat.krylova@bk.ru.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, Faculty of Mechanical Engineering, Department of Automation, Biomechanics and Mechatronics,, 1/15 Stefanowskego Str., 90-924 Lodz, Poland, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[3] Irina Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russian Federation, Russia (RU), ikravzova@mail.ru.

[4] Vadim Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russian Federation, Russia (RU), tak@san.ru.

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Analysis of human EEG to identify pathological conditions using nonlinear dynamics methods

Anton V. Krysko, Maxim V. Zhigalov, Sergey P. Pavlov, Olga A. Saltykova, Irina V. Papkova, Tatyana Y. Yaroshenko, Tatyana V. Yakovleva, Vitalyi V. Dobriyan, Ilya E. Kutepov, Nikolai P. Erofeev, Jan Awrejcewicz, Vadim A. Krysko

Abstract: The paper proposes a methodology for the study of human electroencephalograms (EEG) on the basis of mathematical methods of nonlinear dynamics and statistical data processing for the detection and classification of pathological conditions such as schizophrenia or epilepsy. The applicability of various methods of EEG signal purification and their combinations for optimal results is studied. As cleaning methods are used: principal component analysis (PCA), the empirical mode decomposition method, the method of cleaning on the basis of the wavelet transformation. To determine the degree of chaotization of signals, the values of the largest Lyapunov exponent are calculated using the Wolf and Rosenstein algorithms, entropy as well as the spectral power density of the signals are also calculated. The described methods have been successfully tested on the basis of data of patients with schizophrenia of the Moscow State University and the characteristics of signals corresponding to the normal and pathological condition of a conditionally healthy and conditionally sick person have been determined.

[1] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

[2] Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[3] Sergey P. Pavlov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), pspsar@yandex.ru.

[4] Olga A. Saltykova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), olga_a_saltykova@mail.ru.

[5] Irina V. Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), ikravzova@mail.ru.

[6] Tatyana Y. Yaroshenko, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tyyaroshenko@gmail.com.

[7] Tatyana V. Yakovleva, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), yan-tan1987@mail.ru.

[8)] Vitalyi V. Dobriyan, M.Sc. (Ph.D. student): Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), dobriy88@yandex.ru.

[9)] Ilya E. Kutepov, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), iekutepov@gmail.com.

[10)] Nikolai P. Erofeev, M.Sc. (Ph.D. student): Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), erofeevnp@mail.ru.

[11)] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

[12)] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Dynamics of the size-dependent plates based on reduction of the problem dimension

Anton V. Krysko, Jan Awrejcewicz, Igor A. Kopnin, Maxim V. Zhigalov, Vadim A. Krysko

Abstract: We are aimed on reduction of the solution of the partial differential equation to the solution of an ordinary differential equation. One of the possible approach is a method based on the Bubnov-Galerkin procedure, which is aimed on reduction of the iterative procedure for independent variables of the problem, and the solution of the partial differential equation to the solution of ordinary differential equations. In the Russian scientific literature the latter method was called the method of variational iterations (MVI). MVI was widely used by many researchers in solving problems of the theory of shells and plates. The authors of this work, since the 70s of the last century, has been used this method to solve geometrically, physically nonlinear and contact problems of the theory of plates and shells for full-size systems. In a number of their works, the authors give a justification of this method for a class of equations described by positive definite operators. In the presented paper, MVI is used in plate nanomechanics problems and a proof of MVI convergence for the problems under consideration is given. It should be noted the following advantages of MVI. When implementing the MVI procedure, there is no need to construct an initial approximation that satisfies, for example, the boundary conditions of the task. MVI allows to obtain the symmetry of the approximate solution, if it is inherent in the exact solution of the problem.

[1] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[3] Igor A. Kopnin, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), igor.kopnin@gmail.com.

[4] Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[5] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Nonlinear dynamics of NEMS resonators in temperature fields

Anton V. Krysko, Jan Awrejcewicz, Ilya E. Kutepov, Vadim A. Krysko

Abstract: Regular and chaotic dynamics of a curvilinear nanobeam governed by the first-order approximation kinematic model (Bernoulli-Euler) in a stationary field is studied. Geometrical nonlinearity follows the von Kármán model, whereas the influence of the temperature field obeys the Duhamel-Neumann theory. PDEs of motion of flexible beam are yielded by Hamilton's principle taking the account of the couple stress theory. The obtained PDEs with respect to displacements are reduced to the counterpart Cauchy problem by the FDM of the second-order approximation, and the obtained nonlinear ODEs are solved by the 4th order Runge-Kutta method. Realibility of the numerical results is quantified based on the Runge-Kutta principle. Both chaotic and regular nonlinear dynamics were investigated with respect to reliability (true results) by using qualitatively different methods of theories of dynamical systems and differential equations based on the Fourier and wavelet power spectra, phase portraits, and Poincaré sections. In order to get results reliable (convergent) with respect to chaotic regimes, the sign of the largest Lyapunov exponent is estimated, whereas the power of chaotic dynamics is measured by a spectrum of the Lyapunov exponents. The reliability of computation of the sign of the largest Lyapunov exponent is validated by the Wolf, Rosenstein, Kantz, and the modified neural network methods.

[1] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

[3] Ilya E. Kutepov, Ph.D.: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), iekutepov@gmail.com.

[4] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Complex vibrations of flexible beam NEMS elements, taking into account Casimir's forces in additive white noise

Vadim A. Krysko, Jan Awrejcewicz, Irina V. Papkova, Anton V. Krysko

Abstract: The equations of motion for partial derivatives of the structural members of the NEMS in the form of a beam element of the beams, the boundary and initial conditions, taking into account the Euler-Bernoulli hypotheses and geometric nonlinearity in the form of T. von Karman, were obtained. Hamilton's energy principle has been applied. The system of nonlinear partial differential equations is reduced to the Cauchy problem by the second-order finite difference method. The Cauchy problem by the fourth-order Runge-Kutta method was solved. The analysis of the results is carried out by the methods of nonlinear dynamics and the qualitative theory of differential equations. The effect of Casimir force and additive white noise on the nonlinear dynamics of the beam element of the NEMS was studied.

[1)] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

[2)] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[3)] Irina V. Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), ikravzova@mail.ru.

[4)] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

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Nonlinear dynamics of flexible nanoplates resting on an elastic foundation in a stationary temperature field

Vadim A. Krysko-jr, Jan Awrejcewicz, Irina V. Papkova

Abstract: Microsystem technology (MST) as well as nanotechnology (NT) are considered revolutionary technologies that determine the direction of the development of strategically important branches of mechanical engineering including space, military, medical and IT technologies, instrumentation for scientific research as well as micro-robotics. In this study, a mathematical model of a flexible nanoplate resting on an elastic foundation and subjected to the temperature field and transverse alternating loads is constructed. Main hypotheses: the body is elastic and isotropic; the hypothesis of the first approximation (Kirchhoff) is taken; geometric nonlinearity is introduced using the von Karman model; nanostructures are described by the modified couple stress theory of elasticity; temperature field model is based on the Duhamel-Neumann assumptions. Nanoplates governing equations of motion are yielded by the Hamilton's principle. As a method of reduction to the Cauchy problem, the method of finite differences in the spatial coordinate of the second order of accuracy is adopted. To determine the stationary temperature field, methods of variational iterations and the generalization of the Galerkin method are employed. The 3D heat equation is solved for the boundary conditions of the first/second/third kind. The Cauchy problem is solved by one of the Runge-Kutta type methods. We study the convergence of the solution depending on the number of partitions of the domain of integration versus a number of values of the size-dependent parameter.

[1] Vadim A. Krysko-jr, M.Sc. (Ph.D. student): Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), vadimakrysko@gmail.com.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

[3] Irina V. Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), ikravzova@mail.ru.

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paper id: CON239

Sensitivity research of the gyro system tracking the ground target from the quadrotor in conditions of external disturbances impact

Izabela Krzysztofik, Zbigniew Koruba

Abstract: One of the most important elements of equipment for a Quadrotor Unmanned Aerial Vehicle (QUAV) is the observation head. It is used for automatic searching and tracking of ground targets, both mobile and stationary. Its task is to determine the position of the Target Line of Sight (TLOS). A Gyroscopic System (GS) was proposed as a control and stabilizing TLOS device. An important issue in this type of device is the problem of its control in the conditions of disturbances from the side of the maneuvering deck QUAV. In the paper was investigated the sensitivity (robustness) of the gyro system tracking the ground target from the quadrotor's deck on changing the parameters of its regulator, in the conditions of disturbances impact. It was shown which elements of the gain matrix are the most sensitive – their even slight deviation from the optimal values can lead to reduced effectiveness of target tracking and even loss of stability of the control system. The simulation tests of dynamics controlled GS were carried out in the Matlab/Simulink environment. Selected test results are presented in a graphical form.

[1] Izabela Krzysztofik, Associate Professor: Kielce University of Technology, Aleja Tysiąclecia PP 7, Poland (PL), pssik@tu.kielce.pl.

[2] Zbigniew Koruba, Professor: Kielce University of Technology, Aleja Tysiąclecia PP 7, Poland (PL), ksmzko@tu.kielce.pl.

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Dynamical Systems — Theory and Applications

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paper id: EXP55

Experimental validation of valve solenoid numerical model

Jakub Lagodzinski, Eliza Tkacz

Abstract: Computer Aided Engineering (CAE) is often used in modern design processes. In this method, a trustworthy model is developed and used for determination of the design behavior. The level of complexity of the model depends on the required precision on the one hand and available CPU time on the other. These are conflicting criteria and the compromise is to build a model of moderate complexity, which requires relatively low computational time. In any case, we need to verify the accuracy of the model and the best way to do so is to compare the obtained numerical data with experimental results. In this paper, the considered solenoid valve is of a fast reacting type, with a specified stroke length. Two different Finite Element Method (FEM) models of the valve solenoid are described – an axisymmetric model and a full 3D one. For the sake of models validation a valve mockup has been built. Then, the experimental static characteristics of the coil attractive force vs. the valve stroke for given current intensities are compared with simulation results in order to prove the accuracy and reliability of both developed models.

[1] Jakub Lagodzinski, Ph.D.: Lodz University of Technology, 219/223 Wolczanska St, Poland (PL), jakub.lagodzinski@p.lodz.pl .

[2] Eliza Tkacz, Ph.D.: Lodz University of Technology, 219/223 Wolczanska St, Poland (PL), eliza.tkacz@p.lodz.pl .

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paper id: VIB130

Dynamic analysis of a steel temporary grandstand subjected to human-induced excitations due to jumping

Natalia Lasowicz, Tomasz Falborski

Abstract: Steel grandstands are structures that are frequently used during sport games and many other non-sporting events such as festivals, music concerts, or even politicians rallies, where large number of attendees is also observed. Unfortunately, the presence of unexpected excessive dynamic loads due to unpredictable spectators behaviour (e.g. synchronized harmonic jumping or swaying), may lead to a structural damage or even total collapse of a structure, which was already observed in the past. Given that, steel grandstands should be designed so as to withstand the unexpected dynamic loads and, therefore, ensure maximum safety of all participants. Building codes, however, present different approaches. According to the Polish Standard an additional horizontal load equal to 6% of the total vertical load acting on a grandstand has to be consider at the design level. The British Standard, on the other hand, specifies a slightly higher value of horizontal load (i.e. 10% of the total vertical load) that should be taken into account. Therefore, the overall aim of the present paper is to conduct a dynamic numerical investigation focused on the response of a steel temporary grandstand subjected to human-induced vibrations due to jumping with two different values of horizontal load (6% and 10% of the total vertical load). The results will be discussed.

[1] Natalia Lasowicz, Ph.D.: Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, 11/12 Narutowicza St., 80-233 Gdańsk, Poland (PL), natmajew@pg.edu.pl .

[2] Tomasz Falborski, Ph.D.: Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, 11/12 Narutowicza St., 80-233 Gdańsk, Poland (PL), tomfalbo@pg.edu.pl .

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Discrete-time model reference sliding mode control using an exponential reaching law

Paweł Latosiński, Andrzej Bartoszewicz

Abstract: Discrete time reaching law based sliding mode control is well known to ensure good robustness of the controlled system with respect to any bounded uncertainties. In principle, reaching law methodology involves a priori specifying the desired evolution of the system representative point and obtaining a control signal which ensures this evolution. However, since the plant is subject to uncertainties at each time instant, the desired state trajectory specified by the reaching law can get gradually distorted during the control process. This in turn can negatively alter the length of the reaching phase or increase quasi-sliding mode band width. Motivated by this problem, in this paper we describe a novel model reference approach to discrete-time sliding mode controller design. In this approach, a reaching law based control strategy is first applied to a reference model of the plant with the aim of obtaining a desirable state trajectory. Then, a secondary controller is applied to the original plant to drive its state alongside that of the model, thus eliminating the residual effect of disturbance on quasi-sliding motion of the system. In particular, in this paper a non-switching reaching law using an exponential function of the sliding variable has been applied to the model with the aim of obtaining favorable properties of its quasi-sliding motion. It has been demonstrated that, with the use of the proposed model reference approach, these properties are then carried over to the original plant even in the continued presence of uncertainties.

[1] Paweł Latosiński, Ph.D.: Lodz University of Technology, 18/22 B. Stefanowskiego St., 90-924 Lodz, Poland (PL), pawel.latosinski@p.lodz.pl.

[2] Andrzej Bartoszewicz, Professor: Lodz University of Technology, 18/22 B. Stefanowskiego St., 90-924 Lodz, Poland (PL), andrzej.bartoszewicz@p.lodz.pl.

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Dynamical Systems — Theory and Applications

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Nanoparticle mass detection using suspended microchannel resonator with account for internal fluid flow

Yulia Ledovskaya

Abstract: In this paper, we construct and study a mathematical model of a suspended microchannel resonator (SMR) resonator with an electrostatic principle of actuation, designed to determine the mass of nanoparticles located in the fluid flowing through the channel of the resonator. The problem of small oscillations of a resonator in the vicinity of a non-trivial equilibrium state is investigated. The dependence of the natural frequencies of the resonator on the flow rate of the liquid, the magnitude and location of the nanoparticle in the channel, the strength of the electric field is determined. The problem of elastic stability of a resonator is investigated in the presence of non-conservative forces. An algorithm is proposed for determining the mass of a nanoparticle from the recorded changes in the spectral properties of the system.

[1)] Yulia Ledovskaya, B.A. (M.Sc. student): Peter the Great St.Petersburg Polytechnic University, ledovskaja.julia@yandex.ru, Russia (RU), ledovskaja.julia@yandex.ru.

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paper id: CON152

Kinematic analysis of the rolling locomotion of mobile robots based on tensegrity structures with spatially curved compressed members

Einrique Roberto Carrillo Li, Philipp Schorr, Tobias Kaufhold, Jorge Antonio Hernandez Rodrigez, Lena Zentner, Klaus Zimmermann, Valter Böhm

Abstract: The use of mechanically compliant tensegrity structures in mobile robots is an attractive research topic, due to the possibility to adjust their mechanical properties reversibly during locomotion. In this paper rolling locomotion of mobile robots based on simple tensegrity structures, consisting of three or more compressed spatially curved members connected to a continuous net of prestressed tensional members, is discussed. Planar locomotion of these robots is induced by the movement of internal masses. The movement direction can be changed by changing the robot's shape between a cylinder and a truncated cone. The paper focuses on the description of the kinematics of these systems with respect to the shape change.

[1] Einrique Roberto Carrillo Li, M.Sc.: Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel 15088, Peru, Peru (PE), ecarrillol@pucp.pe .

[2] Philipp Schorr, M.Sc.: Ilmenau University of Technology, Faculty of Mechanical Engineering, Max-Planck-Ring 12, D-98693, Ilmenau, Germany (DE), philipp.schorr@tu-ilmenau.de .

[3] Tobias Kaufhold, Ph.D.: Ilmenau University of Technology, Max-Planck-Ring 12, D-98693 Ilmenau, Germany (DE), tobias.kaufhold@tu-ilmenau.de .

[4] Jorge Antonio Hernandez Rodrigez, Professor: Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel 15088, Peru, Peru (PE), crodrig@pucp.edu.pe .

[5] Lena Zentner, Professor: Ilmenau University of Technology, Faculty of Mechanical Engineering, Max-Planck-Ring 12, D-98693 Ilmenau, Germany (DE), lena.zentner@tu-ilmenau.de .

[6] Klaus Zimmermann, Professor: Ilmenau University of Technology, Faculty of Mechanical Engineering, Max-Plack-Ring 12, D-98693 Ilmenau, Germany (DE), klaus.zimmermann@tu-ilmenau.de .

[7] Valter Böhm, Professor: Ostbayerische Technische Hochschule Regensburg, Galgenbergstr. 30, D-93053 Regensburg, Germany (DE), valter.boehm@oth-regensburg.de .

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Dynamical Systems — Theory and Applications

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paper id: CON236

Experimental validity of highly sensitive atomic force microscope (AFM)

Yubo Lin, Hiroshi Yabuno, Xuan Liu

Abstract: In conventional AFM based on eigenfrequency shift of a single cantilever, the enhancement of sensitivity is restricted due to the state-of-the-art fabrication techniques. Here, we realized a new AFM system with high-sensitivity atomic force microscopy (AFM). This method is based on the eigenmode shift. As our previous research, to compensate for the effect of viscous damping, we produced self-excited oscillation by feedback control in the system. We experimentally confirmed the high sensitivity of the proposed method using prototype coupled macrocantilevers.

1) Yubo Lin, M.Sc.: Graduate School of Systems and Information Engineering, University of Tsukuba, Tsukuba Science City, 305-8573, Japan (JP), linyubo.mech@gmail.com.

2) Hiroshi Yabuno, Professor: Graduate School of Systems and Information Engineering, University of Tsukuba, Tsukuba Science City, 305-8573, Japan (JP), yabuno@esys.tsukuba.ac.jp.

3) Xuan Liu, M.Sc.: Graduate School of Systems and Information Engineering, University of Tsukuba, Tsukuba Science City, 305-8573, Japan (JP), lx19895156_0303@yahoo.ne.jp.

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Dynamical Systems — Theory and Applications

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paper id: EXP108

Switched Reluctance Motor dynamic eccentricity modelling

Jakub Lorencki

Abstract: SRM is a brushless electric motor built of iron. It is used in places where durability and efficiency are important. This is related to its increased resistance to damage than in other electric motors. Due to these applications, proper diagnostics of such a motor is a very important factor. Like any other electric motor it can be susceptible to various mechanical and electrical damages. One of the most common faults is dynamic eccentricity which occurs when the center of the rotor is not at the center of rotation and minimum air gap revolves with the rotor. This phenomenon will be simulated using the finite element method of the FEMM software. And then the data from this method is used in the Matlab program for dynamic simulations. Then it will be possible to see how this mechanical fault affects the motor's performance. This study can also compared with experimental research on a test stand that had been performed before.

[1)] Jakub Lorencki, M.Sc.: Warsaw University of Technology, 02-524 Warszawa, Poland (PL), jakub.lorencki@gmail.com .

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paper id: LIF319

Portable system for upper limb movement tracking

Michał Ludwicki, Kinga Ostrowska, Natalia Marcinowska, Mateusz Kaszowski

Abstract: This project deals with a development of motion capture system for upper limb movement tracking in 3D. It is based on a three inertial measurement unit (IMU) modules controlled by a microcontroller. The sensors are attached to arm, forearm and hand. Estimation of motion of each joint is processed on the basis of measured angular orientation, processed my Kalman filtering. This type of MoCap technique is used by commercial manufacturers. In this project, the emphasis was placed on the price vs accuracy of the obtained results. A comparative analysis was also carried out using a professional MoCap system, tracking retroreflective markers position in the IR spectrum. Acknowledgment The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700.

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1) Michał Ludwicki, Ph.D.: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Street, Poland (PL), michal.ludwicki@p.lodz.pl.

2) Kinga Ostrowska, B.A. (M.Sc. student): Faculty of Mechanical Engineering, Lodz University of Technology, Stefanowskiego 1/15 A22/K-16, Poland (PL), 208823@edu.p.lodz.pl.

3) Natalia Marcinowska, B.A. (M.Sc. student): Faculty of Mechanical Engineering, Lodz University of Technology, Stefanowskiego 1/15 A22/K-16, Poland (PL), 208819@edu.p.lodz.pl.

4) Mateusz Kaszowski, B.A. (M.Sc. student): Faculty of Mechanical Engineering, Lodz University of Technology, Stefanowskiego 1/15 A22/K-16, Poland (PL), 208804@edu.p.lodz.pl.

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paper id: CON278

Flexural waves propagation in piezoelectric metamaterial beam

Marcela Machado, Adriano Fabro, Braion Moura

Abstract: In this paper, we analysed a piezoelectric metamaterial to focus on flexural waves in beams modelled by using the spectral element method. The piezoelectric metamaterial is applied in cases of attenuation and control of waves, as well as, adopted in the designing process of the piezo-lens used to trace the waves trajectories in large frequency bands. The configuration considered of a periodic array of piezoelectric patches incorporated to a beam undergoing transverse motion. The periodic arrangement of shunted patches provides the beam with attenuation properties which depend on the resonant behaviour of the shunts. A numerical model predicts the flexural wave behaviour of the beam for different shunting configurations.

[1] Marcela Machado, Ph.D.: University of Brasilia, 70910-900, Brazil (BR), mromarcela@gmail.com.

[2] Adriano Fabro, Ph.D.: University of Brasilia, 70910-900, Brazil (BR), fabro@unb.br.

[3] Braion Moura, B.A. (M.Sc. student): University of Brasilia, 70910-900, Brazil (BR), braionmoura@hotmail.com.

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paper id: MAT247

Fractional dynamics and power law behaviour in soccer leagues

Jose Tenreiro Machado, Antonio Mendes Lopes

Abstract: This paper addresses the dynamical analysis of the performance of soccer teams during a given league. The modeling perspective adopts the concepts of fractional calculus and power law. The proposed modeling approach embeds implicitly details such as the behavior of players and coaches, strategical and tactical maneuvers during the matches, errors of referees and a multitude of other effects. The scale of observation focuses on the teams behavior in the perspective of their classification along the league. Data characterizing two European soccer leagues are processed and discussed. The computational and mathematical modeling leads to the emergence of patterns that are analyzed and interpreted in the light of complex systems.

[1] Jose Tenreiro Machado, Professor: Institute of Engineering of Polytechnic of Porto, Dept. of Electrical Engineering, Rua Dr. António Bernardino de Almeida, 431, 4249-015 Porto, Portugal (PT), jtm@isep.ipp.pt.

[2] Antonio Mendes Lopes, Ph.D.: Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal (PT), aml@fe.up.pt.

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paper id: BIF44

Traveling waves and spatio-temporal chaos in nonlinear dynamical systems

Nikolai Magnitskii

Abstract: The report will consider models of some physical, chemical and biological systems, described by nonlinear partial differential equations, such as the Ginzburg-Landau, Kuramoto-Sivashinsky, Schrödinger, FitzHugh-Nagumo equations, and having physical, chemical or biological turbulence regimes. It will be shown, that all such systems of partial differential equations can have an infinite number of different stable wave solutions, traveling along the space axis with arbitrary speeds, and also an infinite number of different states of spatio-temporal chaos (turbulence regimes). These chaotic (turbulent) solutions are generated by cascades of bifurcations of cycles or tori and singular attractors according to the universal bifurcation Feigenbaum-Sharkovsky-Magnitskii (FShM) theory in the three-dimensional or four-dimensional systems of ordinary differential equations, to which the systems of partial differential equations can be reduced by self-similar change of variables. 1. Magnitskii N.A. Universality of Transition to Chaos in All Kinds of Nonlinear Differential Equations, in “Nonlinearity, Bifurcation and Chaos - Theory and Appl.”, Chapter 6, edited by Jan Awrejcewicz, P. Hagedorn, Intech, Rijeka, 2012, p.133-174. 2. Magnitskii N.A. Bifurcation Theory of Dynamical Chaos, in “Chaos Theory”, Chapter 11, InTech, Rijeka, 2018, p.197-215.

[1] Nikolai Magnitskii, Professor: Russian academy of science, Moscow state university, Bd. 114, Apt. 37, Leninskii Prospect, Moscow, 119415, Russia, Russia (RU), nikmagn@gmail.com.

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Optimal control of constrained multi-rigid-body systems using recursive Hamiltonian formulation

Paweł Malczyk, Paweł Maciąg, Janusz Frączek

Abstract: The optimal control approach is exploited in many applications and, in general, aims at minimizing a certain performance index by satisfying one or several physical or artificial constraints imposed on the motion of a multibody system (MBS). The adjoint method is extensively used in this field in order to efficiently find the descent direction of the optimization procedure. On the other hand, there exists a large variety of recursive algorithms for efficient simulation of constrained multi-rigid-body dynamics. The purpose of this paper is twofold. In the first step, a recursive Hamiltonian based formulation for open-loop kinematic chains is demonstrated that generates the equations of motion in terms of joint coordinates and canonical momenta. In the second step, a novel recursive Hamiltonian-based algorithm for finding optimal control trajectories for holonomically constrained multi-rigid-body systems is proposed in the work. The differential-algebraic equations constituting equations of motion for MBS are solved numerically forward in time. The adjoint system of differential-algebraic equations is formulated in the same recursive manner. Systematic derivation of the adjoint equations is presented in the text and the recursive expressions are delivered. Explicit formulae for the calculation of a gradient of a performance measure are also included in the text. Sample planar test case is presented to demonstrate the validity of the proposed approach.
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[1] Paweł Malczyk, Ph.D.: Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, Nowowiejska 24, Poland (PL), pmalczyk@meil.pw.edu.pl.

[2] Paweł Maciąg, M.Sc. (Ph.D. student): Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, Nowowiejska 24, Poland (PL), pmaciag@meil.pw.edu.pl.

[3] Janusz Frączek, Professor: Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, Nowowiejska 24, Poland (PL), jfraczek@meil.pw.edu.pl.

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Thermoelastic large amplitude vibration of bi-material beams

Emil Manoach, Simona Doneva, Jerzy Warminski

Abstract: The main goal of this work is to develop an accurate numerical approach to study the geometrical nonlinear vibration of bi-material beams under the combined action of mechanical and thermal loads. Under considerations are beams subjected to dynamic mechanical loading and different thermal condition: elevated temperature, heat flux, convective heating/cooling. The governing equations of coupled vibration of the bi-material beam are deduced. The geometrically nonlinear version of the Timoshenko beam theory is used to describe the theoretical model of the problem. The equations of beam motion are transformed in coupled ordinary differential equations by using normal modes of the beam. The equation of the heat propagation is discretized by the finite difference method. The coupling terms of the mechanical and thermal equations are taken into account. The second approach used to study the problem is the creation of a 3D finite element model of the thermoelastic vibration of the beam. The finite element program ANSYS is used for the analytical model validation. The influence of the difference of the mechanical and thermal properties of the beams on the response of structure is studied in details. It is shown that the temperature condition can lead to buckling of the beam. The effects of the geometrical nonlinear terms and the heat condition on the buckling and post buckling vibration and on the frequency response functions are studied as well.

[1] Emil Manoach, Professor: Institute of Mechanics, Bulgarian Academy of Sciences, Acad. G. Bonchev streetm bl. 4, 1113 Sofia, Bulgaria (BG), e.manoach@imbm.bas.bg .

[2] Simona Doneva, M.Sc. (Ph.D. student): Institute of Mechanics, Bulgarian Academy of Sciences and Department of Applied Mechanics, Lublin University of Technology, Acad. G. Bonchev street bl. 4, 1113 Sofia, Bulgaria (BG), s.doneva@pollub.pl .

[3] Jerzy Warminski, Professor: Department of Applied Mechanics, Lublin University of Technology, Nadbystrzycka 36 , 20-618 Lublin, Poland (PL), j.warminski@pollub.pl .

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Dynamics assessment of mechanically induced solid phase transitions in shape memory alloys via nonlocal thermomechanical coupling

Adam Martowicz, Sławomir Kantor, Jan Pawlik, Jakub Bryła, Jakub Roemer

Abstract: The work deals with presentation of the properties and applications of the developed nonlocal model of shape memory alloys (SMA), which is dedicated for simulations of dynamic processes of mechanically induced solid phase transitions. To date, many various phenomenological, macroscopic, microscopic and the free energy based constitutive models have been proposed for SMA, however, none of them is able to reliable capture the complexity of SMA physical behavior in a comprehensive manner. The authors of the present work employ peridynamics to alternatively nonlocally formulate thermomechanical coupling in the modeled SMA, considering, therefore, its advantageous characteristics. Particularly, the phenomenon of superelasticity is investigated and the related phase transitions in SMA are studied. The elaborated peridynamic model of SMA is validated using the experimental data gathered with a fatigue testing machine and a high-speed infrared camera. With reference to the authors' recently published work, the newly proposed solution extends the functionalities of the former nonlocal SMA model, taking into account the influence of the temperature. As confirmed with the numerical results provided, the new capability allows for studying dynamic problems more conveniently, not being limited by the necessity of satisfying the condition of isothermal phase transition. This study was funded by National Science Center, Poland (Grant No. OPUS 2017/27/B/ST8/01822 Mechanisms of stability loss in high-speed foil bearings — modeling and experimental validation of thermomechanical couplings).

[1] Adam Martowicz, Ph.D.: AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), adam.martowicz@agh.edu.pl.

[2] Sławomir Kantor, M.Sc. (Ph.D. student): AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), slawomir.kantor@agh.edu.pl.

[3] Jan Pawlik, M.Sc. (Ph.D. student): AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), jan.pawlik@agh.edu.pl.

[4] Jakub Bryła, M.Sc. (Ph.D. student): AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), jakbryla@agh.edu.pl.

[5] Jakub Roemer, Ph.D.: AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), jroemer@agh.edu.pl.

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Improving capabilities of constitutive modeling of shape memory alloys for solving dynamic problems via application of neural networks

Adam Martowicz, Mikołaj Żabiński, Jakub Bryła, Jakub Roemer

Abstract: The paper addresses an issue of improving capabilities of the constitutive models elaborated for shape memory alloys (SMA) to solve dynamic problems. Artificial neural networks (ANN) are utilized to simulate the experimentally identified complex behavior of the mentioned type of smart materials. Although SMA are known and widely used in various engineering applications for many decades, both understanding and, therefore, modeling of their physical behavior suffer continuous limitations regarding accuracy and performance. The present work reports the results of the properties assessment carried out for the proposed ANN based constitutive model for SMA. As presented, the application of ANN allows to reliably model the hysteretic character of the stress-strain relationship observed by the authors for the experimentally tested SMA material — a wire made of Nitinol. The work is complemented with the results of a study on the influence of an ANN structure and training method on the quality of numerical results. The combined ANN-finite element method code is used to provide solutions for the given dynamic problems. Finally, improvement perspectives regarding SMA constitutive modeling are discussed making a reference to the identified capabilities of the ANN based material model. This study was funded by National Science Center, Poland (Grant No. OPUS 2017/27/B/ST8/01822 Mechanisms of stability loss in high-speed foil bearings — modeling and experimental validation of thermomechanical couplings).

[1] Adam Martowicz, Ph.D.: AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), adam.martowicz@agh.edu.pl.

[2] Mikołaj Żabiński, B.A. (M.Sc. student): AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), mzabinski@student.agh.edu.pl.

[3] Jakub Bryła, M.Sc. (Ph.D. student): AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), jakbryla@agh.edu.pl.

[4] Jakub Roemer, Ph.D.: AGH University of Science and Technology, Department of Robotics and Mechatronics, al. A. Mickiewicza 30, 30-059 Krakow, Poland (PL), jroemer@agh.edu.pl.

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Innovative application of quality methods to assess the homogeneity of the noise level distribution generated by F-16 multirole aircrafts

Agnieszka Misztal, Grzegorz M. Szymański, Wojciech Misztal

Abstract: The assessment of the nuisance of aviation noise in the environment surrounding the airport is usually based on measurements of the mean equivalent sound levels A. Due to the combustion engines with high power concentration used in military aviation, it is also reasonable to measure the instantaneous increases in the sound pressure level. Therefore, a research question was raised about differences in this level for various aircraft engines of the same type, i.e. F100-PW-229, to assess their size and statistical significance. The aim of the article is to discuss the attempt to check the significant difference between the parameters of the acoustic level generated by the F-16 multirole aircraft engines. Statistical methods dedicated to assessing production stability, ie. Shewhart card, were put to use. The essence of the card is the observation of the average value track. The components of the track are: the central line (it corresponds to the expected values of the statistical parameters) and the designated external control lines - upper and lower. They show the expected tolerance for the discrepancy of results considered stable. The measurements were carried out for 32 engines of the F-16 Block 52+ aircraft. The parameters of noise in the point system and in the octave distribution were subjected to analysis using the Shewhart card. The results of the analysis allowed to determine the size of the discrepancy and the level of compliance of analogous results. They can be an attitude to further research on the characteristics of this type of noise.

[1] Agnieszka Misztal, Associate Professor: Poznan University of Technology, 60-965 Poznań, M. Skłodowskiej - Curie 5, Poland (PL), agnieszka.misztal@put.poznan.pl.

[2] Grzegorz M. Szymański, Associate Professor: Poznan University of Technology, M. Skłodowskiej - Curie 5, 60-965 Poznań, Poland (PL), grzegorz.m.szymanski@put.poznan.pl.

[3] Wojciech Misztal, Ph.D.: 31. Tactical Air Base in Poznan-Krzesiny, Silniki 1, 61-325 Poznań, Poland (PL), wo.misztal@ron.mi.pl.

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Two sound sources in implanted middle ear – numerical analysis

Andrzej Mitura, Rafal Rusinek

Abstract: In this paper a lumped biomechanical model of the middle ear with an implant is presented. The model of healthy ear (without implant) is modified through a new element that represents an implant transducer. The transducer is a small electro-magnetic generator which stimulate the incus to improve hearing. However, sound approaching from surroundings to the tympanic membrane excites middle ear structure to motion, similarly like the transducer. An interaction between natural sound excitation and transducer stimuli can cause unexpected middle ear behaviour, That problem will be investigated in the paper. During numerical research different configurations of gains of both excitations will be tested. As a result, changes in implant settings can be modeled. Acknowledgements: The research was financed in the framework of the project: Nonlinear effects in middle ear with active implant, no.2018/29/B/ST 8/01293, funded by the National Science Centre, Poland.

[1] Andrzej Mitura, Ph.D.: Lublin University of Technology, Faculty of Mechanical Engineering, Nadbystrzycka 36, 20-618 Lublin, Poland (PL), a.mitura@pollub.pl.

[2] Rafal Rusinek, Associate Professor: Lublin University of Technology, Faculty of Mechanical Engineering, Nadbystrzycka 36, 20-618 Lublin, Poland (PL), r.rusinek@pollub.pl.

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Dynamical Systems — Theory and Applications

December 2-5, 2019. Lodz, POLAND.

paper id: ASY15

On the vibrational analysis for the motion of a rotating cylinder

Mohamed Mohamed, Mohamed Abohamer, Tarek Amer

Abstract: The main purpose of this work is to study the motion of 2-DOF of an auto-parametric dynamical system attached with a damped system. The governing equations of motion are gained utilizing Lagrange's equations in terms of the generalized coordinates. The method of multiple scales (MS) is used to obtain the solutions of the governing equations up to the third order of approximation. The primary external resonance simultaneously with the internal one are investigated to establish the solvability conditions and the modulation equations. The equilibrium points are obtained and represented graphically to obtain the possible steady state solutions near resonances in framework of the stability conditions of these solutions. The graphical representations of the time history together with the amplitude and phases of the dynamical system are represented in some plots to describe the motion of the system at any instance.

1) Mohamed Mohamed, Associate Professor: Tanta university, ELbahr Street, Egypt (EG), m.ali@f-eng.tanta.edu.eg.

2) Mohamed Abohamer, M.Sc.: Tanta university, Seperbay Campus, Egypt (EG), mbek@horus.edu.eg.

3) Tarek Amer, Professor: Tanta university, Mathematics Department, Faculty of Science, Tanta University, Tanta 31527, Egypt, Egypt (EG), tarek.saleh@science.tanta.edu.eg.

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On the spinning motion of a disc under the influence a gyrostatic moment

Mohamed Mohamed, Tarek Amer, Yasser Gamiel

Abstract: This work discusses the movement of a disc around one of its settled point different from its centre of mass in the presence of a constant gyrostatic moment about the principal axes of inertia. The governing system of motion comprises of six nonlinear differential equations and their first integrals are lessened to another quasilinear independent one of 2DOF besides one first integral. At first, it is conjectured that the body is quickly spun around one of its principal axes. The technique of small parameter of Poincaré is utilized to accomplish the desired approximate arrangements of the conditions of movement. Euler's angles are utilized to translate the movement of the body at any flicker. The numerical arrangements of self-governing framework are explored utilizing the fourth order Runge-Kutta algorithms(RKA). The examination of both two solutions uncovers that the numerical solutions are in good agreement with the approximate ones and the deviation between them is very small. The significance of this work is centered around its extraordinary applications in numerous fields, for example, in designing, material science and modern applications for ships stabilizers, racing cars, pointing devices for computer, satellites and like.

[1] Mohamed Mohamed, Associate Professor: Tanta university, ELbahr Street, Egypt (EG), m.ali@f-eng.tanta.edu.eg.

[2] Tarek Amer, Professor: Tanta university, Mathematics Department, Faculty of Science, Tanta University, Tanta 31527, Egypt, Egypt (EG), tarek,saleh@science.tanta.edu.eg.

[3] Yasser Gamiel, Ph.D.: Tanta university, Sperpay campos, Egypt (EG), y_egcglass@hotmail.com.

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Modeling of electro-hydraulic servo-drive for advanced control system design

Jakub Mozaryn, Damian Suski, Arkadiusz Winnicki

Abstract: The paper describes the synthesis of a mathematical model of the electro-hydraulic servo-drive. Due to the complexity of the electro-hydraulic servo-drive system and the difficulty in determining all system's coefficients, the simplification of the mathematical model is proposed. The model includes different nonlinearities such as the friction or the pressure-dependent oil bulk module. The simulation results are presented, and the comparison with the data collected from the real servo drive is discussed. With the proposed methodology it was possible to choose the values of physical parameters such that the real electro-hydraulic servo-drive is modeled with the accuracy suitable for the fast prototyping and design of the advanced control system.

[1)] Jakub Mozaryn, Ph.D.: Institute of Automatic Control and Robotics, Warsaw University of Technology, ul. Sw A. Boboli 8, 02-525, Warsaw, Poland (PL), jakub.mozaryn@pw.edu.pl.

[2)] Damian Suski, M.Sc.: Institute of Automatic Control and Robotics, Warsaw University of Technology, ul. Sw A. Boboli 8, 02-525, Warsaw, Poland (PL), damian.suski@pw.edu.pl.

[3)] Arkadiusz Winnicki, Ph.D.: Institute of Automatic Control and Robotics, Warsaw University of Technology, ul. Sw A. Boboli 8, 02-525, Warsaw, Poland (PL), arkadiusz.winnicki@pw.edu.pl.

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Electrostatically actuated initially curved micro beams: analytical and finite element modelling

Nadezhda Mozhgova, Alexey Lukin, Ivan Popov

Abstract: Nowadays, industrial production microelectromechanical systems (MEMS) is developing rapidly, so they are widely used in various spheres of human activity: medicine, energy, various systems navigation in the automotive and petroleum industries, etc. Regardless of the purpose of the MEMS, sensitive elements commonly undergo an initial curvature imperfection, due to the microfabrication process. Initial curvature imperfection significantly affects the mechanical behavior of microplates, beams, etc. For example, initially curved microbeams loaded by concentrated forces may exhibit bistability (the existence of two different stable equilibria under the same loading). The transition between two stable states in these structures is commonly referred to as a snap-through buckling. The basic sensitive elements were chosen for the analysis: a nonlinearly elastic string in a geometrically exact framework, initially curved beam. Equilibria forms branching for various configurations of electric field and initial curvature was investigated utilizing model order reduction technique (MOR) and numerical continuation methods. In addition to the bifurcation diagrams, natural frequencies of the above mentioned structures were also considered, and their dependency on the magnitude of the electric field and the other parameters of the system was analyzed. Finite element modeling of the above mentioned problems of electroelasticity was carried out in the ANSYS software system and conclusions were drawn on the degree of applicability of FEM and ROM-FEM methods under various conditions.

[1] Nadezhda Mozhgova, B.A.: Saint-Petersburg Polytechnic University, Russia, St.Petersburg, Budapeshtskaya st., 71, Russia (RU), nmojgova@yandex.ru.

[2] Alexey Lukin, B.A. (M.Sc. student): Saint-Petersburg Polytechnic University, -, Russia (RU), lukinalexei@yandex.ru.

[3] Ivan Popov, B.A.: Saint-Petersburg Polytechnic University, -, Russia (RU), mnadenka77@gmail.com.

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System size resonance in a 1-D array of noisy bistable piezoelectric harvesters

Aravindan Muralidharan, Shaikh Faruque Ali

Abstract: Research studies in the past have shown from time to time that bistable harvesters offer a lucrative solution for harnessing substantial magnitude of power across frequency broadband. This exciting potential of bistable harvesters has bred interest towards investigating the possibility of enhancement in power by coupling multiple of them. In this regard, the present work analyzes the behavior of a finite 1-D array of bistable piezoelectric harvesters mechanically coupled in the nearest-neighbor configuration under a noise perturbed periodic base excitation. A reduced order model has been developed for the same and preliminary investigations have been carried out to characterize the energy harvesting capabilities of the system under study. The dynamics of the system is studied mainly focusing on the total power harvested by the system. The numerical study reports a resonant-like behavior in the system size where the total power exhibits a non-monotonic dependence on the number of harvesters for certain noise levels of excitation. The parametric regimes to which the system size resonance effect is confined have been identified. The feasibility of exploiting the intricate bifurcation structures found in these regimes for significant wideband power generation has also been probed. The present study attempts to provide an intuitive understanding into the role of system size on the total harvested power under a noisy environment. Hence, the outcomes of this analysis shall aid in the proposition of efficient system design for broadband energy harvesting.

[1] Aravindan Muralidharan, M.Sc. (Ph.D. student): Indian Institute of Technology Madras, IIT P.O., Chennai 600 036 INDIA, India (IN), aravindanm24@gmail.com .

[2] Shaikh Faruque Ali, Associate Professor: Indian Institute of Technology Madras, IIT P.O., Chennai 600 036 INDIA, India (IN), sfali@iitm.ac.in .

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paper id: VIB172

Investigation of coupled piezoelectric and multiple electromagnetic hybrid vibration energy harvester

Rajarathinam Murugesan, Aravindan Muralidharan, Shaikh Faruque Ali

Abstract: Vibrational energy harvesting used for powering small electronic components has received more attention in the recent years for various applications. A lot of early research on vibrational energy harvesting was on linear, single frequency based resonance harvesting devices. These harvesters give maximum power only at the resonance and the efficiency drops drastically as the excitation frequency moves away from resonance. In reality, the ambient vibration sources are random in nature. Hence, considering realistic application, narrowband linear systems are inefficient. To overcome this drawback, the present work proposes a hybrid transduction based vibration energy harvester for achieving sufficient power across wide band of frequencies. In the present work, a cantilever beam with an unimorphed macro fibre composite patch is used to harvest piezoelectric energy and a spring-magnet mass system moving within a solenoid hung in different places of the cantilever is used to harvest electromagnetic energy out of motion in a magnetic field. The present study analyzes the implications of the number of electromagnetic units on the total harvested power of the hybrid system and the saturation trends for various energy levels have been reported. Comparison studies have also been made to show the increase in the order of power bandwidth obtained in a hybrid system with reference to its standalone counterparts.

[1] Rajarathinam Murugesan, Ph.D.: Indian Institute of Technology Madras, IIT P.O., Chennai 600 036 INDIA, India (IN), rajmiitm@gmail.com .

[2] Aravindan Muralidharan, M.Sc. (Ph.D. student): Indian Institute of Technology Madras, IIT P.O., Chennai 600 036 INDIA, India (IN), aravindanm24@gmail.com .

[3] Shaikh Faruque Ali, Associate Professor: Indian Institute of Technology Madras, IIT P.O., Chennai 600 036 INDIA, India (IN), sfali@iitm.ac.in .

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paper id: BIF5

Nonlinear dynamics of the hierarchic system of oscillators

Sergiy Mykulyak, Sergii Skurativskyi

Abstract: Significant part of materials under appropriate conditions manifests their internal structure. In particular, this concerns the geomedia which are endowed with discrete and hierarchic structure. To examine the dynamics of such systems, we develop the mathematical model [1-3] on the basis of Hamiltonian formalism. This model describes the motion of the hierarchically connected oscillators interacting with each other via the power law. For certain simplifying constrains, we reduce the model to the three level strongly nonlinear system of ODE. The problem considered is the analysis of the system dynamics, when the friction is incorporated and the harmonic force is applied to the most upper level of the system. Using the numerical and qualitative analysis methods, the existence of periodic, quasiperiodic and chaotic attractors are revealed. The bifurcations of these regimes with respect to the structural parameter are studied in more detail. The statistical properties of chaotic attractors are considered as well. [1] Mykulyak S.V., Skurativska I.A., Skurativskyi S.I. Forced nonlinear vibrations in hierarchically constructed media, Int. J. of Non-Linear Mech. 98 (2018) 51–57. [2] Mykulyak S., Skurativskyi S. Nonlinear dynamics of the system of hierarchically coupled oscillators with power law interactions. Int. Conf. on Diff. Eq., Math. Phys. and App. (DEMPhA-2017, Cherkasy, Ukraine), p.42-43. [3] Danylenko V.A., Mykulyak S.V., Skurativskyi S.I. Energy redistribution in hierarchical systems of oscillators. Euro. Phys. J. B. 2015. 88. P.143(8).

1) Sergiy Mykulyak, Ph.D.: Subbotin Institute of Geophysics NAS of Ukraine, Bohdan Khmelnytsky str. 63 G, Kyiv-54, 01054, Ukraine (UA), mykulyak@ukr.net.

2) Sergii Skurativskyi, Associate Professor: Subbotin Institute of Geophysics NAS of Ukraine, Bohdan Khmelnytsky str. 63 G, Kyiv-54, 01054, Ukraine (UA), skurserg@gmail.com.

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paper id: BIF210

On qualitative analysis of lattice dynamical system of two- and three-dimensional biopixels array: bifurcations and transition to chaos

Oleksandr Nakonechnyi, Vasyl Martsenyuk, Aleksandra Kłos-Witkowska

Abstract: We consider the model of two- or three-dimensional biopixels array, which can be used for design of biosensors. The model is based on the system of lattice differential equations with time delay, describing interactions of biological species of neighbouring pixels. The qualitative analysis includes permanence and extinctions of solutions, stability investigation, bifurcations and transition to chaos. The stability conditions are obtained with help of the method of Lyapunov functionals. They are formulated in terms of the value of time necessary for immune response. Numerical research are presented with help of phase portraits, square and hexagonal lattice plots and bifurcation diagrams.

1) Oleksandr Nakonechnyi, Professor: Taras Shevchenko National University of Kyiv, Glushkova Av.4 Build.6, Kyiv, Ukraine (UA), a.nakonechniy@gmail.com.

2) Vasyl Martsenyuk, Professor: University of Bielsko-Biala, 2 Willowa St, 43-300 Bielsko-Biała, Poland (PL), vmartsenyuk@ath.bielsko.pl.

3) Aleksandra Kłos-Witkowska, Ph.D.: University of Bielsko-Biala, Willowa Str 2, Poland (PL), awitkowska@ath.bielsko.pl.

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paper id: OPT281

Optimization of the actuator/sensor placement for active vibration control of a funnel shaped piezoelectric structure

Tamara Nestorović, Kevin Hassw, Atta Oveisi

Abstract: Placement of piezoelectric actuators and sensors implemented in the form of thin piezoelectric films plays an important role in active vibration control of structures, since after applying they remain permanently integrated with a structure. In this work we analyze a funnel shaped structure – inlet of the magnetic resonance imaging (MRI) tomopraph and perform a balanced optimization of the actuator/sensor placement based on H2 and Hinf norms. The applied procedure is a global one, seeking for optima across the entire domain of the structure. A thorough study of the mesh refinement influence with respect to the eigenfrequency analysis was performed in order to obtain a reliable numeric finite element (FE) model for the optimization purposes. The material parameter optimization was performed as well. Based on placement indices optimal placement study was performed under consideration of several eigenmodes of interest. The optimization was performed for individual modes as well as for simultaneous consideration of multiple modes. A software in the loop approach with recurrent communication in each iteration of the optimization between the numerical simulation FE software and optimization tool designed in Python was implemented through out evaluation of the placement indices for candidate locations over the entire curved surface of the structure. Depending on support conditions the optimal locations of piezoelectric are proposed.

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[1] Tamara Nestorović, Professor: Ruhr-Universität Bochum, Universitätsstr. 150, 44803 Bochum, Germany (DE), tamara.nestorovic@rub.de.

[2] Kevin Hassw, M.Sc.: Ruhr-Universität Bochum, Universitätsstr. 150, 44803 Bochum, Germany (DE), Kevin.Hassw@rub.de.

[3] Atta Oveisi, M.Sc.: Ruhr-Universität Bochum, Universitätsstr. 150, 44803 Bochum, Germany (DE), atta.oveisi@rub.de.

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paper id: NUM335

On the use of transmissibility to estimate vibro-acoustic responses in operational conditions

Miguel Neves, Hugo Policarpo, Nuno Maia, Dmitri Tcherniak

Abstract: This work briefly reviews the concepts of displacement transmissibility, acoustic transmissibility as well as vibro-acoustic transmissibility used to relate excitations from some parts with their counterpart. One application where the concept appears naturally is the operational transfer path analysis (OTPA). It is based solely on operational measurements (conducted when the machine is in operation), not requiring any FRFs, thus significantly reducing the complexity of the measurement campaign and reducing the measurement time. The OTPA method has advantages depending on the conditions of the problem. Here, the authors are concerned with the influence of the stiffness values of the vibration source (excitation) mounts on the response inside the structurally connected acoustic cavity. In this article, the authors conclude that if the stiffness of the mounts approaches zero, the OTPA contributions coincide with the baseline ones independently of having cross talk or not. If the mount stiffness approaches infinity, the contributions coincide with the OTPA contributions obtained when the indicator signals are measured on the passive side of the mount. Therefore, placing the indicator accelerometers on the active side of the mounts are advantageous as this will produce a lesser error than when they are placed on the passive side of the mounts. Placing the indicator accelerometers on the both sides of the mount produces no cross-talk error. These results illustrate in which conditions the contributions from classical TPA and OTPA compare.

[1] Miguel Neves, Ph.D.: Instituto Superior Técnico, Av. Rovisco Pais 1049-001, Lisbon, Portugal (PT), miguel.matos.neves@tecnico.ulisboa.pt.

[2] Hugo Policarpo, Ph.D.: Universidade Nova de Lisboa, Caparica 2829-516, Portugal (PT), hugo.policarpo@tecnico.ulisboa.pt.

[3] Nuno Maia, Associate Professor: Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisbon, Portugal (PT), nuno.manuel.maia@tecnico.ulisboa.pt.

[4] Dmitri Tcherniak, Ph.D.: Brüel & Kjaer Sound and Vibration Measurement A/S, Skodsborgvej 307, DK 2850 Naerum, Denmark (DK), dmitri.tcherniak@bksv.com.

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paper id: BIF91

Suppression of impact oscillations in a railway current collection system with an additional oscillatory system

Naoto Nishiyama, Kiyotaka Yamashita

Abstract: A railway current collection system consists of a wire and a pantograph. The wave-like wear on the surface of an overhead rigid conductor line can cause contact loss between the conductor line and the pantograph. To explain the dynamical features of this problem, the essential model of the impact oscillations between the pantograph and the rigid conductor line has been previously proposed based on the results of experiments on an actual pantograph system. This model consists of a single-degree-of-freedom system and an external excitation source that pushes against the system. In the present study, we add an oscillatory system is coupled to this model. We investigate the effects of the added system on the impact ocsillations between the main mass and the excitation source. When the excitation frequency is near the second mode natural frequency, the impact oscillations between the main mass and the external excitation source are suppressed. In particular, a series of experiments are conducted with slowly increasing the excitation frequency to verify this theoretical result. The experimental results confirm the suppression of the impact oscillations.

[1] Naoto Nishiyama, M.Sc. (Ph.D. student): Fukui University of Technology, 3-6-1 gakuen fukui-shi fukui, Japan (JP), nishiyama@fukui-ut.ac.jp.

[2] Kiyotaka Yamashita, Professor: Fukui University of Technology, 3-6-1 Gakuen Fukui-shi Fukui, Japan (JP), yamashita@fukui-ut.ac.jp.

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paper id: CON38

Lyapunov function-based control of a DC/DC buck converter using Hybrid Systems formalism

Luz Adriana Ocampo, Fabiola Angulo, David Angulo-Garcia

Abstract: In this paper we propose a switched control strategy for the buck converter based on Lyapunov functions and the hybrid systems framework. First, we in- troduce the differential inclusion describing the dynamics of the buck converter in the hybrid systems formalism using the Krasovskii regularization. Then, a Lyapunov function is derived for the hybrid system, which naturally defines switching control surfaces that guarantee global stability of the system. With the aim of extending the degree of tuning of the Lyapunov-based switched control, we include a nonlinear term to the functions describing the switch- ing manifolds, which preserves the stability features of the system allowing to further control transient behavior of the system. Finally, we show by means of numerical simulations that the proposed controller is robust to the switch position and can flexibly adjust the transient dynamics via a suitable selection of gains in the added nonlinear terms.

[1)] Luz Adriana Ocampo, M.Sc. (Ph.D. student): Universidad Nacional de Colombia, Sede Manizales, Campus La Nubia, Manizales, Colombia (CO), laocampona@unal.edu.co.

[2)] Fabiola Angulo, Professor: Universidad Nacional de Colombia - Sede Manizales, Facultad de Ingeniería y Arquitectura, Departamento de Ingeniería Eléctrica, Electrónica y Computación, Percepción y Control Inteligente, Bloque Q, Campus La Nubia, Manizales, 170003, Colombia (CO), fangulog@unal.edu.co.

[3)] David Angulo-Garcia, Associate Professor: Instituto de Matemáticas Aplicadas, Grupo de Modelado Computacional, Dinámica y Complejidad de Sistemas, Universidad de Cartagena, Carrera 6 No. 36 - 100. Cartagena, Colombia (CO), dangulog@unicartagena.edu.co.

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Numerical and experimental investigations of dynamics of magnetic pendulum with an aerostatic bearing

Ewelina Ogińska, Krystian Polczyński, Dariusz Grzelczyk, Jan Awrejcewicz

Abstract: In this paper, both numerical and experimental results of the dynamics of a magnetic pendulum with an aerostatic bearing are presented. The experimental stand consists of the pendulum and a neodymium magnet at its end, whereas two electric coils are placed underneath. The pivot of the pendulum is supported on aerostatic bearing therefore, the resistance of the motion is negligible and it is of a viscous character. The electric current flows through the coils is of a square waveform with a given frequency and duty cycle. Mathematical and physical models with experimentally confirmed system parameters are derived. The magnetic interaction is presented as a moment of force in the function of the electric current and position of the pendulum. The results of the simulation and experiment showed the rich dynamics of the system, including various types of regular motion (multi-periodicity) and chaos. Acknowledgment: The work has been supported by the National Science Centre of Poland under the grant OPUS 14 no. 2017/27/B/ST8/01330.

[1] Ewelina Ogińska, B.A. (M.Sc. student): Technical University of Lodz, Stefanowskiego 1/15, Poland (PL), 190440@edu.p.lodz.pl.

[2] Krystian Polczyński, M.Sc. (Ph.D. student): Technical University of Lodz, Stefanowskiego 1/15, Poland (PL), krystian.polczynski@edu.p.lodz.pl.

[3] Dariusz Grzelczyk, Ph.D.: Technical University of Lodz, Stefanowskiego 1/15, Poland (PL), dariusz.grzelczyk@p.lodz.pl.

[4] Jan Awrejcewicz, Professor: Technical University of Lodz, Stefanowskiego 1/15, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: MTR1

Analysis of dynamical response of a Stewart platform operating in six degrees of freedom

Paweł Olejnik, Jan Awrejcewicz

Abstract: Stewart platforms belong to a wide range of forcing devices and form the basis for positions testing properties and dynamic responses of various objects (e.g., vehicles, machine parts, combat machines, moving components of production lines and others). Mechanical enforcement in the form of various functions of position, velocity or acceleration must be precise, because it serves as a reference point (dynamic reference) in the assessment of the response of objects placed on the platform table and subjected to excitation. This work describes several performance tests of the tested platform, as well as the reaction rate for selected forms of excitation is recorded. In LabVIEW environment, on the basis of the readings from the motion sensors, the time delays of the open control system were determined, the system was qualitatively evaluated and the time response characteristics of the dynamic response were presented.

[1)] Paweł Olejnik, Associate Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowski Street, 90-924 Lodz, Poland (PL), pawel.olejnik@p.lodz.pl.

[2)] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowski Street, 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: EXP277

Verification of various leak detection algorithms based on flow dynamics model using liquid transmission pipeline prototype

Paweł Ostapkowicz

Abstract: Liquid transmission pipelines are equipped with leak detection systems (LDS) which in most cases are developed with the use of so-called internal methods. The most advanced internal methods are considered the ones that are based on the use of process dynamics models. Such internal methods are especially useful in reference to complex flow conditions. In order to improve efficiency, such advanced internal methods implemented on real pipelines should be tuned and tested with the wide range of operational conditions and various leakages characteristics. In many cases the testing of elaborated procedures on real pipelines is not possible and dangerous. On the other hand, the tests consisting in the use of data acquired from pipeline simulators are not good solution because the problems concerning fully and explicit mapping of flow phenomena. This paper focuses on experimental verification, commonly used as well as modified by author leak detection algorithms which are based on the use of process dynamics models. The experiments carried out on a laboratory water pipeline. The pipeline is 380 meters long and is made of polyethylene (PEHD) pipes. The tests were conducted including typical operational conditions of the pipeline with the wide range of their change as well as various leakages characteristics. Many aspects related to the use of process dynamics models are considered, i.e. different structure and model description, estimation of unavailable (not acquired from the measurement) state variables and friction coefficient, as well as adaptive alarm threshold selection.

[1)] Paweł Ostapkowicz, Ph.D.: Bialystok University of Technology, Politechnika Białostocka, 15-351 Białystok, Wiejska 45C, Poland (PL), p.ostapkowicz@pb.edu.pl.

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paper id: CON60

A comparative survey of software computational tools in the field of optimal control

Stepan Ozana, Tomas Docekal, Filip Krupa, Jakub Nemcik, Jakub Mozaryn

Abstract: Optimal control (OC) is the process of determining control and state trajectories for a dynamic system in order to achieve a given performance index. Most real-world optimal control problems (OCP) are too large and complex to be solved analytically as typically the dynamics is nonlinear and there are predefined constraints governing the allowed behavior of the system. The motivation of this paper is to give a brief overview of some ready-to-use numerical software tools available on the market and capable of solving optimal control problems. It summarizes their basic properties such as licensing policy and approach, and also the general formulation of OCP common for the described tools. As the optimal control uses an extensive theory with many approaches and methods for software implementation, the interest is reduced and focused on finding a feed-forward control signal as a solution of a deterministic continuous-time OCP over a fixed time interval, using Matlab-based third party toolboxes. The paper presents a particular case study which compares chosen numerical software tools in terms of achieved results and computational performance. This is done for a mathematical model of a single pendulum on the cart which represents a highly complex and nonlinear system that is suitable to be used as a benchmark.

1) Stepan Ozana, Associate Professor: Faculty of Electrical Engineering and Computer Science, Department of Cybernetics and Biomedical Engineering, VSB-Technical University of Ostrava, 17. listopadu 2172/15, 708 00 Ostrava, Czech Republic (CZ), stepan.ozana@vsb.cz.

2) Tomas Docekal, M.Sc. (Ph.D. student): Faculty of Electrical Engineering and Computer Science, Department of Cybernetics and Biomedical Engineering, VSB-Technical University of Ostrava, 17. listopadu 2172/15, 708 00 Ostrava, Czech Republic, Czech Republic (CZ), tomas.docekal@vsb.cz.

3) Filip Krupa, M.Sc. (Ph.D. student): Faculty of Electrical Engineering and Computer Science, Department of Cybernetics and Biomedical Engineering, VSB-Technical University of Ostrava, 17. listopadu 2172/15, 708 00 Ostrava, Czech Republic (CZ), filip.krupa@vsb.cz.

4) Jakub Nemcik, M.Sc. (Ph.D. student): Faculty of Electrical Engineering and Computer Science, Department of Cybernetics and Biomedical Engineering, VSB-Technical University of Ostrava, 17. listopadu 2172/15, 708 00 Ostrava, Czech Republic (CZ), jakub.nemcik@vsb.cz.

5) Jakub Mozaryn, Ph.D.: Warsaw University of Technology, Faculty of Mechatronics, Insitute of Automatic Control and Robotics, Pl. Politechniki 1 00-661 Warsaw, Poland (PL), jakub.mozaryn@pw.edu.pl.

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paper id: MAT183

Analytical and numerical modelling of surface acoustic waves in rotating piezoelastic media

Alexei Papirovskiy, Alexei Lukin, Ivan Popov

Abstract: This paper presents results of analytical and numerical research of surface acoustic waves propagation process in rotating piezoelastic media, taking into account the coupling of physical fields. Various wave parameters such as frequency, phase velocity, wave mode are analyzed and their dependencies on angular velocity is investigated. The results obtained can be used to develop microelectromechanical devices in the field of navigation and signal processing.The relationship between phase velocity and rotation was determined without simplifying assumptions and was compared with previously obtained results from the literature. Dependencies were found for materials of ST-quartz and Lithium niobate (LiNbO_3). Based on the obtained analytical solutions, the numerical solution in COMSOL was verified. There is a great difficulty in solving such problems with rotating media by the finite element method, due to required numerical precision and necessity to solve eigenvalue boundary problem for non-self-adjoint linear operator. Equation-based COMSOL solver was used as a numerical method for such problems. The solution of the initial equations by the method of finite differences was also obtained.

[1] Alexei Papirovskiy, M.Sc. (Ph.D. student): Peter the Great St. Petersburg Polytechnic University, 195267, Russia (RU), apapirovskiy@gmail.com.

[2] Alexei Lukin, Ph.D.: Peter the Great St. Petersburg Polytechnic University, 195251, Russia (RU), lukin_av@spbstu.ru.

[3] Ivan Popov, Ph.D.: Peter the Great St. Petersburg Polytechnic University, 195251, Russia (RU), popov_ia@spbstu.ru.

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Vibrations of flexible beam NEMS elements in a temperature field taking into account Coulomb forces

Irina V. Papkova, Vadim A. Krysko, Jan Awrejcewicz, Alena A. Zakharova, Anton V. Krysko

Abstract: A mathematical model of nonlinear vibrations of flexible beam NEMS elements located in a stationary temperature field and under the action of electrostatic forces (Coulomb force) was constructed. Nanobeams are considered as a Cosserat continuum with constrained particle rotation (pseudo-continuum). The governing PDEs of the beam element, the boundary and initial conditions are obtained based on the Hamilton's principle, and the Euler-Bernoulli hypotheses and geometric nonlinearity by the T. von Karman model are taken into account. The system of nonlinear partial differential equations (PDEs) is reduced to the Cauchy problem by the second-order finite difference method. The Cauchy problem is also solved by the fourth-order Runge-Kutta method. The effect of the Coulomb force on the nonlinear dynamics of the structural members of the NEMS in the form of beams located in the temperature field is illustrated and discussed.

[1] Irina V. Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), ikravzova@mail.ru.

[2] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

[3] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[4] Alena A. Zakharova, Professor: Department of Informatics and Software Engineering, Bryansk State Technical University, Boulevard 50 years of October 7, 241035 Bryansk, Russia (RU), zaa@tu-bryansk.ru.

[5] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

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Alternative inverse kinematic calculation methods in velocity and acceleration level

Dóra Patkó, Ambrus Zelei

Abstract: Inverse kinematics calculation of manipulators is a common building block in most of the robotic control processes. However, the numerical implementation of the inverse kinematics calculation has several alternatives yielding certain advantages and disadvantages. This paper compares two approaches. In the classical one, the joint position increment is stepwise calculated based on the local velocity vector of the desired trajectory. In contrast, the joint position increment is obtained from the error between the desired and the realized trajectory in some alternative methods. The two approaches are also distinguished on the acceleration level. Our analytical and numerical studies show the benefits and drawbacks of these inverse kinematics methods.

[1] Dóra Patkó, M.Sc.: Budapest University of Technology and Economics, Muegyetem rkp. 3-5. Budapest, 1111, Hungary (HU), dora.patko94@gmail.com.

[2] Ambrus Zelei, Ph.D.: MTA BME Research Group on Dynamics of Machines and Vehicles, Muegyetem rkp. 3-5. Budapest, 1111, Hungary (HU), zelei.ambrus@gmail.com.

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Experimental evaluation of PLC based fractional order PI^lambdaD^mu temperature control in pipeline

Jakub Petryszyn, Jakub Mozaryn, Stepan Ozana

Abstract: The following paper presents the experimental evaluation of the fractional order PI$^\lambda$D$^\mu$ temperature control in the pipeline, using standard PLC Siemens S7-1200 controller. Controller is based on the implementation of the Gr\"unwald-Letnikov differintegral Continuous Fraction Expansion approximation and tuned using Interior-Point optimization method with Integral Time Squared Error (ITSE) criterion. The PI$^\lambda$D$^\mu$ temperature control system was evaluated using simulations, and experiments on the laboratory stand. There is given the discussion of results obtained during the simulation, HIL and experimntal research, and further developements considering the accuracy and robustness of PLC based fractional order PI$^\lambda$D$^\mu$ control system.

[1] Jakub Petryszyn, B.A. (M.Sc. student): Institute of Automatic Control and Robotics, Warsaw University of Technology, ul. Sw A. Boboli 8, 02-525, Warsaw, Poland (PL), jakub.petryszyn.stud@pw.edu.pl.

[2] Jakub Mozaryn, Ph.D.: Institute of Automatic Control and Robotics, Warsaw University of Technology, ul. Sw A. Boboli 8, 02-525, Warsaw, Poland (PL), jakub.mozaryn@pw.edu.pl.

[3] Stepan Ozana, Associate Professor: Faculty of Electrical Engineering and Computer Science, Department of Cybernetics and Biomedical Engineering, VSB-Technical University of Ostrava, 17. listopadu 2172/15, 708 00 Ostrava, Czech Republic (CZ), stepan.ozana@vsb.cz.

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Theoretical and numerical analysis of different modes in a system of a "kicked" magnetic pendulum

Krystian Polczyński, Adam Wijata, Jan Awrejcewicz

Abstract: A non-linear magnetic pendulum system has been studied theoretically and numerically. The main component of the system is a pendulum equipped with a neodymium magnet, which is "kicked" by alternating magnetic field form an electrical coil underneath. The current signal which flows through the coil is repeatedly switched on and off with a given frequency and duty cycle. Switched on magnetic field introduces a two-well potential instead of a single-well gravitational potential, what results in two stable fixed points and one saddle from a dynamical point of view. Describing the system with a discrete two-state equation, different modes of regular motion have been analyzed. Existence of different solutions has been examined in terms of switching signal parameters, that is a frequency and a duty cycle. Obtained numerical results from discrete as well as continuous simulative models have been justified against experimental data from a specially constructed laboratory stand.

[1] Krystian Polczyński, M.Sc. (Ph.D. student): Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Łódź, Poland (PL), krystian.polczynski@edu.p.lodz.pl.

[2] Adam Wijata, M.Sc. (Ph.D. student): Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Łódź, Poland (PL), adam.wijata@edu.p.lodz.pl.

[3] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Łódź, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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Stability and vibration of a two-member cantilever column with an integrated PZT rod

Jacek Przybylski, Krzysztof Kuliński

Abstract: This paper concerns the problem of transversal vibration a geometrically non-linear two-member column with a piezoceramic rod being a component of the structure. In the considered system, the external load applied to the column with an unintentional eccentricity and the internal piezo force are distributed among both members. The piezo rod is mounted discretely with an offset distance in regard to the host column what makes that the piezoelectric actuation may be effective in suppressing of prebuckling deflection in the whole range of the external load. Although the main role of the piezoelectric force generated by the actuator is the control of the column shape, it affects also the natural vibration frequency of the system. To analyze the problem a non-linear analytical model of the structure is developed on the basis of Hamilton's principle and solved with use of the perturbation method. Performing adequate computations, the static deflection and internal axial force distribution modified by the electric field application are determined by changing column properties such as the offset distance and the eccentricity of the external load. In the dynamic analysis, the fundamental vibration frequency of the deflected column and the adequate modes are studied in relation to both the external load and the piezoelectric force. It has been proved that the natural vibration frequency, affected by the piezoelectric force, also depends on the matched column and rod materials, the ratio of the cross section of the rod to the host column and the direction of the electric field.

[1] Jacek Przybylski, Professor: Częstochowa University of Technology, Dąbrowskiego 69, 42 201 Częstochowa, Poland (PL), jacek.pr@imipkm.pcz.pl .

[2] Krzysztof Kuliński, M.Sc.: Częstochowa University of Technology, Dąbrowskiego 69, 42 201 Częstochowa, Poland (PL), krzysztku@gmail.com .

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Numerical procedure for sensitivity analysis of hybrid systems

Radosław Pytlak, Damian Suski, Tomasz Tarnawski

Abstract: The paper presents the numerical procedure for the evaluation of adjoint equations for hybrid systems i.e. the systems with mixed discrete-continuous dynamics. With the help of adjoint equations the gradients of state functionals with respect to controls are calculated efficiently. Our procedure can be used in optimization procedures for solving optimal control problems with hybrid systems. The procedure is based on the implementation of a Runge-Kutta method which is advocated as the most suitable numerical procedure for integration of differential equations with controls represented by piecewise constant controls ([Pytlak, Numerical Methods for Optimal Control Problem With State Constraints, Lecture Notes in Mathematics, Springer--Verlag, 1999], [Hager, Runge--Kutta methods in optimal control and the transfmored adjoint equations, Numer. Math.. 2000]). Since we are dealing with hybrid systems our numerical procedure is equipped with the procedure for locating switching points which determine the change of a discrete state of the hybrid system. The evaluation of adjoint equations is consistent with the system equation discretization. We show that discrete time adjoint equations for the discretized system equations resulting from applying Radau IIa integration scheme are in fact Radau Ia integration scheme applied to the continuous time adjoint equations. We show the effectiveness of our procedure on several examples such as the Coulomb-Striebck friction model and the model of a racing car motion with drift.

[1] Radosław Pytlak, Professor: Warsaw University of Technology, Faculty of Mathematics and Information Science, 00-662 Warsaw, ul. Koszykowa 75, Poland (PL), r.pytlak@mini.pw.edu.pl .

[2] Damian Suski, M.Sc. (Ph.D. student): Warsaw University of Technology, Faculty of Mechatronics, 02-525 Warsaw, ul. Sw. Andrzeja Boboli, Poland (PL), d.suski@mchtr.pw.edu.pl .

[3] Tomasz Tarnawski, Ph.D.: Warsaw University of Technology, Faculty of Mathematics and Information Science, 00-662 Warsaw, ul. Koszykowa 75, Poland (PL), t.tarnawski@mini.pw.edu.pl .

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paper id: NUM259

Identification of nonlinear joint interface parameters using instantaneous power flow balance approach

Anish Rajan, Shankar Krishnapillai

Abstract: Joints in assembled structures can affect the dynamic behaviour of mechanical structures under dynamic loading conditions. Mathematical modelling of such structures, one need to consider the joint interface effects accurately. In this paper a bolted lap joint is modelled with a nonlinear spring and a damper to simulate the nonlinear effects like softening phenomena due to slip, associated with the joint structures. The known parametric model of the assembled beam structure with joint interface non-linearity was simulated ‘experimentally’ under a harmonic external excitation to find the responses. The parameter identification was formulated as an inverse problem using Particle Swarm Optimization algorithm. The error between experimentally measured and numerically predicted response matching and a novel Instantaneous Power Flow Balance criteria based objective functions are used for the identification of nonlinear parameters. The analysis was carried out on noise polluted response data to examine the performance of the proposed method under noisy conditions. The identified nonlinear parameters show the accuracy of the current method over other time domain methods.

[1] Anish Rajan, M.Sc. (Ph.D. student): Research Scholar, Optimization Lab, Machine Design Section, IIT Madras, India (IN), mail2anishrajan@gmail.com.

[2] Shankar Krishnapillai, Professor: Department of Mechanical Engineering, Indian Institute of Technology Madras, Machine Design Section, Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai, India (IN), skris@iitm.ac.in.

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paper id: NUM173

Parametric identification of non linear structures using Particle Swarm Optimization based on power flow balance criteria

Anish Rajan, Shankar Krishnapillai

Abstract: This paper discusses a novel approach for nonlinear parameter identification of structures. An optimization problem was formulated as an inverse problem, using two objective functions in time domain. The first objective function is formulated as an error between measured acceleration and predicted acceleration of the model. While the second objective function minimizes the substructure Instantaneous Power Flow Balance, which is the sum of input power, dissipated power, transmitted power and time rate of kinetic and strain energy to zero. Here a cubic nonlinearity in spring (Duffing equation) and a quadratic nonlinearity in damper are used to model the nonlinear system. Numerical simulations were performed on a 10-DOF nonlinear system under harmonic excitation using Particle Swarm Optimization tool under noise-free and 5% noisy cases. Identified results are compared in terms of mean absolute percentage error, with other methods in nonlinear parameter identification available in literatures. Simulation results show the accuracy of proposed method in nonlinear parameter identification even at high noise contamination cases.

[1] Anish Rajan, M.Sc. (Ph.D. student): Research Scholar, Machine Design Section, Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai, India (IN), mail2anishrajan@gmail.com.

[2] Shankar Krishnapillai, Professor: Department of Mechanical Engineering, Indian Institute of Technology Madras, Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai, India (IN), skris@iitm.ac.in.

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paper id: MAT282

Detection of chaotic behavior of the dynamical system using methods of deformable active contours

Constantin Ruchkin

Abstract: In this paper we consider the problem of detection chaotic behavior of the dynamical system with a special Hamiltonian structure. The numerical investigation of the phase space presented on the Poincaré sections of this system show of the cloud of points in the chaotic cases. To set the chaotic behavior of the system can be in the event of a phase portrait of a dynamical system consist closed areas of two type: circles or algebraic curve. To solve problem of detection this areas we use methods of deformable parametric models. Conformity assessment deformable parametric model shown in the image data is also produced by the energy of the model. The energy model that depends on the material parameters, the sum of the internal energy, which expresses the value of the configuration of the model limits set by the developer, and the external energy, which measures the goodness of fit model and the data in the image. The adaptation process is similar to the image pattern from the case and is to search parameter vector reaching global maximum energy model. The form of the models used for the allocation of chaotic regions, defined by a set of algebraic curves of the second, third or higher order with certain restrictions imposed on their possible configurations. In this work we developed of the model and algorithm for selection chaotic regions as algebraic curve, using the method modificated deformable active contours, and calculated scale of chaos these regions.

[1)] Constantin Ruchkin, Associate Professor: DonNTU, Bakhmut, Gorbatova 79/45, Ukraine (UA), construchk@gmail.com.

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paper id: CON7

The algorithm solution of the problem of optimal control in a dynamic one-sector economic model with a discrete time based on dynamic programming method

Anna Rudak

Abstract: In this paper we study a new formulation of the optimal control problem in a dynamic single-sector economic model with discrete time. In the task, the states are the values of the specific capital, that is, the total amount of capital related to the unit of labor resources. The role of management is played by a parameter rep-resenting the proportion of the specific product produced that is directed to investment. The target functionality is the sum of two components. The first one expresses the specific consumption accumulated during the evolution of the system. The second is expressed as a given function of the value of the specific capital at the final point in time and describes the level of technological development in the system formed at that moment. The main limitation is the dynamic ratio for the specific capital, describing its change under the influence of management. The initial state in the system is assumed to be fixed. The study is based on the dynamic programming method. The Bellman equations for the problem are obtained. Based on the well-known theoretical assertions, it is established that the sequence of controls satisfying the Bellman equations is optimal. An algorithm has been created and described in detail that allows one to solve the Bellman functional equations numerically and find a sequence of optimal controls for the problem posed.

[1] Anna Rudak, B.A. (M.Sc. student): National Research University Higher School of Economics, 121609, Moscow, Russia (RU), aorudak@edu.hse.ru.

paper id: LIF41

Effect of electromechanical coupling in the middle ear with implantable hearing device

Rafal Rusinek, Krzysztof Kecik, Andrzej Mitura

Abstract: The middle ear is the smallest biomechanical system of human being which sometimes has to be modified to improve hearing process. An implantable middle ear hearing device (implant) is one of the most innovative method of hearing loss treatment. Therefore, an explanation of the active implant role in the middle ear structure and its influence on the human ear dynamics is the main aim of the paper. The multi degrees of freedom nonlinear biomechanical model of the middle ear should generate interesting nonlinear phenomena especially when the system is coupled to an electrical system of the implant. An interaction between the mechanical and electrical system will be source of additional phenomena that have not been investigated in the literature before. The coupling coefficient, defined as a constant or nonlinear relation has the main role in system dynamics. That problem will be investigated in the paper. Acknowledgements: The research was financed in the framework of the project: Nonlinear effects in middle ear with active implant, no.2018/29/B/ST 8/01293, funded by the National Science Centre, Poland.

[1] Rafal Rusinek, Associate Professor: Lublin University of Technology, Nadbystrzycka 38D, 20-618 Lublin, Poland (PL), r.rusinek@pollub.pl.

[2] Krzysztof Kecik, Associate Professor: Lublin University of Technology, Nadbystrzycka 38D, 20-618 Lublin, Poland (PL), k.kecik@pollub.pl.

[3] Andrzej Mitura, Ph.D.: Lublin University of Technology, Nadbystrzycka 38D, 20-618 Lublin, Poland (PL), a.mitura@pollub.pl.

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Study of the Duffing van der Pol system dynamics using RQA measures

Andrzej Rysak, Magdalena Gregorczyk

Abstract: The work presents a detailed study of the Duffing van der Pol system dynamics in different ranges of the driving force amplitude and linear damping parameter. Bifurcation diagrams reveal evolution of the system dynamics between periodic, quasi-periodic and chaotic regimes. These specific dynamical states of the system are distinguished by the Lyapunov exponents, phase diagrams and Fourier spectra. Applying the recurrence analysis provides new variables confirming changes observed in the system dynamics. In addition, the recurrence measures show some changes that are not detected by other well-establish methods.

[1] Andrzej Rysak, Associate Professor: Lublin University of Technology, Faculty of Mechanical Engineering, Nadbystrzycka 36, 20-618 Lublin, Poland (PL), a.rysak@pollub.pl .

[2] Magdalena Gregorczyk, M.Sc.: Lublin University of Technology, Faculty of Mechanical Engineering, Nadbystrzycka 36, 20-618 Lublin, Poland (PL), a.rysak@pollub.pl .

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A comparison of the common types of nonlinear energy sinks

Adnan S. Saeed, Mohammad AL-Shudeifat

Abstract: Real life dynamical structures are subjected to different sources of excitations such as earthquakes, blasts, collisions, fluid-structure interaction, impacts, etc. that may induce high vibration levels and increase the risk of system failure. Hence, linear vibrations absorbers have been employed to protect such dynamical structures from collapse. However, these are only effective at a specified primary structure natural frequencies and their performance significantly deteriorates as the frequency changes. The newly proposed vibration absorbers, usually referred to as Nonlinear Energy Sinks (NESs) incorporate the essential nonlinear property that enables efficient and rapid vibration mitigation for wide frequency-energy domain. Consequently, many types of NESs have been proposed in literature and those are classified by the method of nonlinearly attaching the NES to the associated floor of the primary structure into stiffness-based, rotary-based and impact-based NESs. This paper presents a numerical investigation in which the most common NES types: cubic-stiffness NES, rotary NES, double-sided and single-sided vibro-impact (SSVI) NESs, are optimized, discussed and compared for energy transfer and dissipation for an impulsive excitation into a large-scale nine-story dynamical structure. The system description and governing equations of each coupled system are given first followed by a numerical optimization to maximize energy transfer and dissipation. It is found that an optimized SSVI NES gives the best performance to achieve highly efficient targeted energy transfer (TET).

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[1] Adnan S. Saeed, M.Sc. (Ph.D. student): Aerospace Engineering, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, United Arab Emirates (AE), adnansalem991@gmail.com.

[2] Mohammad AL-Shudeifat, Associate Professor: Aerospace Engineering, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, United Arab Emirates (AE), mohd.shudeifat@ku.ac.ae.

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A study on the coefficient of restitution effect on single-sided vibro-impact nonlinear energy sink

Adnan S. Saeed, Mohammad AL-Shudeifat

Abstract: Vibration mitigation is an essential factor in many engineering applications given the high risk of failure due to the frequent occurrence of earthquakes, blasts, collisions and fluid-structure interaction. Linear and nonlinear vibration absorbers have been continuously studied to be employed in such structures to decrease the vibration levels and therefore protect them from destruction. Up to date, the most effective and efficient passive vibration absorber is the single-sided vibro-impact (SSVI) nonlinear energy sink (NES) which consists of a small mass attached to the primary structure via linear stiffness and linear damping coupling elements in addition to a rigid barrier that enables it to engage in non-smooth inelastic impacts. It has been shown in the literature that an accurately optimized SSVI NES is capable of transferring and dissipating high percentages of the initial input energy into the primary structure. However, most of the investigations in the literature implement a coefficient of restitution of 0.7 corresponding to steel-to-steel impacts. Consequently, this paper investigates further improvements to the SSVI NES by studying the effect of changing the coefficient of restitution to increase the efficiency of targeted energy transfer (TET). It is found that lowering the coefficient of restitution increases the efficiency of the SSVI NES to transfer and dissipate energy from a large-scale nine-story structure.

[1] Adnan S. Saeed, M.Sc. (Ph.D. student): Aerospace Engineering, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, United Arab Emirates (AE), adnansalem991@gmail.com.

[2] Mohammad AL-Shudeifat, Associate Professor: Aerospace Engineering, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, Khalifa University of Science and Technology, Abu Dhabi, 127788, UAE, United Arab Emirates (AE), mohd.shudeifat@ku.ac.ae.

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Ggeometry optimization of aeroelastic energy harvester

Filip Sarbinowski, Roman Starosta

Abstract: Geometry optimization was performed using a genetic algorithm (GA) that processes data from CFD calculations. This algorithm generated a random population of twenty to-arm geometrical figures. Each geometry was subjected to a numerical experiment during which its movement in a fluid-filled channel was simulated and resultant force acting on body was calculated. The calculations were repeated for angular orientation of the object varying from 0 to 180˚, every 2˚, in order to obtain a complete characteristic describing aerodynamical forces acting on body related to its angular orientation. For each of the obtained functions, satisfaction of Dan Hertog's criterion is examined, which is the basis for geometry evaluation. In order to accelerate the calculations, classical GA has been modified by completely eliminating the random factors in favor of operations determined through chaotic processes - in this case, a logistic map. The numerical calculations was carried by Method of Fundamental Solutions.

1) Filip Sarbinowski, M.Sc. (Ph.D. student): Poznan University of Technology, Institute of Applied Mechanics, Jana Pawła II 24, 60-965 Poznań, POLAND, Poland (PL), filip.j.sarbinowski@doctorate.put.poznan.pl.

2) Roman Starosta, Associate Professor: Poznan University of Technology, Institute of Applied Mechanics, Jana Pawła II 24, 60-965 Poznań, POLAND, Poland (PL), roman.starosta@put.poznan.pl.

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Control of tremors of human's arm by a passive nonlinear absorber

Alireza Ture Savadkoohi, Claude Henri Lamarque, Celien Goosaert

Abstract: The aim of the this work is to develop a mechanical nonlinear absorber for cancelation of tremors of human's arm due some disease such as Parkinson. Governing equations of the upper limb representing by a two-degrees-of-freedom pendulum are coupled to the equation of the nonlinear absorber. A time multiple scale method is exploited for detecting the responses of the system at different time scales, i.e. fast and slow scales. After revealing fast dynamics of the system, the characteristic points of the system are tracked. These points should correspond to comfortable amplitude variations of the arm. Analysis of the dynamics of the system provides tools for tuning parameters of the absorber.

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[1] Alireza Ture Savadkoohi, Professor: ENTPE/LTDS UMR 5513 CNRS, rue Maurice Audin 69518 Vaulx-en-Velin Cedex, France (FR), alireza.turesavadkoohi@entpe.fr.

[2] Claude Henri Lamarque, Professor: ENTPE/LTDS UMR 5513 CNRS, rue Maurice Audin 69518 Vaulx-en-Velin Cedex, France (FR), lamarque@entpe.fr.

[3] Celien Goosaert, B.A. (M.Sc. student): ENTPE/LTDS UMR 5513 CNRS, rue Maurice Audin 69518 Vaulx-en-Velin Cedex, France (FR), Celien.Goosaert@entpe.fr.

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Investigation of a tensegrity structure with multiple equilibrium configurations as jumping motion system

Philipp Schorr, Valter Böhm, Lena Zentner, Klaus Zimmermann

Abstract: Often, the operating range of mobile robots is limited by environmental circumstances like obstacles or gaps. Therefore, an adaptation of the motion principle is required to enable such robots to continue to operate. A jumping motion is a promising approach. This motion type allows to cross gaps or to overcome obstacles where common motion principles which bases on wheels or legs fail. However, especially during landing large forces occur as a consequence of the impact with the ground. This issue encourages the use of compliant tensegrity structures which feature a great shock resistance. In this paper a tensegrity structure with multiple equilibrium configurations is considered. The two-dimensional structure is equipped with two actuators to vary the prestress of the system. The tensegrity structure is in contact to a horizontal plane due to gravity. Two actuation strategies are derived. Beside varying the prestress state of the structure, a jump can be realized by changing the equilibrium configuration. Both actuation strategies and the corresponding motion characteristics are evaluated by numeric simulations. The results emphasize the advantageous properties of tensegrity structures for a jumping motion system. In particular, the multistabilty of the structure allows a simple actuation strategy for a reliable jumping motion.

[1] Philipp Schorr, M.Sc. (Ph.D. student): Technical University of Ilmenau, Max-Planck Ring 12, 98693 Ilmenau, Germany (DE), philipp.schorr@tu-ilmenau.de .

[2] Valter Böhm, Professor: Ostbayerische Technische Hochschule Regensburg, Galgenbergstrasse 30, 93053 Regensburg, Germany (DE), valter.boehm@oth-regensburg.de .

[3] Lena Zentner, Professor: Technical University of Ilmenau, Max-Planck Ring 12, 98693 Ilmenau, Germany (DE), lena.zentner@tu-ilmenau.de .

[4] Klaus Zimmermann, Professor: Technical University of Ilmenau, Max-Planck Ring 12, 98693 Ilmenau, Germany (DE), klaus.zimmermann@tu-ilmenau.de .

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Alternation of stability character in systems with positional non-conservative forces

Yury Selyutskiy

Abstract: The influence of non-conservative forces (both positional and velocity-dependent) upon stability of equilibrium positions of mechanical systems is discussed in many papers. In particular, it is well known that small dissipative forces can lead to instability. In the present work, the evolution of stability character of equilibrium is studied for the case when potential force corresponding to one generalized coordinate changes in presence of positional non-conservative forces. It is shown that, if parameters of the system satisfy certain conditions then the alternation of the stability character is observed (stability-instability-stability), as the stiffness in one of generalized coordinates increases. This effect is illustrated by the example of an aeroelastic system with two degrees of freedom.

[1)] Yury Selyutskiy, Professor: Lomonosov Moscow State University, 119192, Michurinsky prosp. 1, Moscow, Russia (RU), seliutski@imec.msu.ru .

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Integrable dissipative dynamical systems: backgrounds, methods, and applications

Maxim V. Shamolin

Abstract: We establish the integrability of some homogeneous (with respect to a part of variables) dynamical systems of odd (third and fifth) order. In the class of such systems, we extract a system on the tangent bundle of smooth manifolds. The force field is separated into the internal (conservative) force field and the external force field with alternating dissipation. The external force field is introduced by using a certain unimodular transformation and generalizes the cases studied by the author earlier. It is rather difficult to give a general definition of a dynamical system, but it can be done in some particular cases: certain coefficients in the system characterize the energy scattering in some domains and the energy pumping in other domains of the phase space. The latter leads to the loss of known first integrals (the laws of conservation) expressed in terms of smooth functions. However, as soon as attracting or repelling limit sets appear in the system, one have to forget about a complete list of even continuous first integrals in the whole phase space.

[1)] Maxim V. Shamolin, Professor: Institute of Mechanics, Lomonosov Moscow State University, 1 Michurinskii Ave., 119899, Moscow, Russia (RU), shamolin@rambler.ru.

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A delta-robot-based test bench for validation of smart products

Renan Siqueira, Osman Altun, Paul Gembarski, Roland Lachmayer

Abstract: With the development of new technologies, such as smart components, additive manufacturing or multi-materials, product performance tests play a decisive role in supporting effective design and product reliability. However, test machines are mostly designed to attend norms and perform standard tests, which requires a need for the development of new machines when dealing with new cutting-edge technologies or reliability of a specific product. Therefore, these test benches must be designed to be flexible and robust, in order to attend the highest number of possibilities for a certain kind of test and a range of different components. With this intent, an innovative test bench for high loads was here designed and constructed based on a delta-robot configuration. This configuration, which is commonly applied for high-speed kinematic systems, was adapted to apply high transverse loads in three axes while keeping a considerably large range of movement. Thereunto, dynamic simulations were conducted considering a hydraulic actuation and the robust control approach of Sliding Mode Control (SMC), which delivered satisfactory results. Finally, after mechanical design, construction and calibration, first tests were performed for a self-sensing suspension arm, where the load prediction ability of the component was analyzed and the ability of the developed system to test complicated components under multi-axial load was evaluated.

[1] Renan Siqueira, M.Sc. (Ph.D. student): Leibniz University Hannover, Welfengarten 1A, 30167 Hannover, Germany (DE), siqueira@ipeg.uni-hannover.de.

[2] Osman Altun, M.Sc.: Leibniz University Hannover, Welfengarten 1A, 30167 Hannover, Germany (DE), altun@ipeg.uni-hannover.de.

[3] Paul Gembarski, Ph.D.: Leibniz University Hannover, Welfengarten 1A, 30167 Hannover, Germany (DE), gembarski@ipeg.uni-hannover.de.

[4] Roland Lachmayer, Professor: Leibniz University Hannover, Welfengarten 1A, 30167 Hannover, Germany (DE), lachmayer@ipeg.uni-hannover.de.

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Digital prototype of test station for gears and belts dynamic analysis

Anna Šmeringaiová, Zuzana Murčinková

Abstract: For the areas of technical mechanics and design, computer simulations are the first stage where information on the behavior of mechanical systems can be obtained. The paper presents a digital prototype of a test station designed for experimental dynamic tests of various types of gears. The test station is designed with a possibility to simulate different operating conditions and simultaneously test transmissions with different structural modifications under the same operating conditions. The digital prototype is a copy of a real test station that allows predicting the behavior of mechanical systems. Using the functional simulation of the dynamic test conditions in a virtual environment, it is possible to pre-verify, respectively to confirm and then optimize the course and results of experimental tests of gearing and belt transmissions performed at the real test station.

[1] Anna Šmeringaiová, Ph.D.: Faculty of Manufacturing Technologies of the Technical University of Košice with the seat in Prešov, Bayerova 1, 080 01 Prešov, Slovakia (SK), anna.smeringaiova@tuke.sk.

[2] Zuzana Murčinková, Associate Professor: Faculty of Manufacturing Technologies of the Technical University of Košice with the seat in Prešov, Bayerova 1, 080 01 Prešov, Slovakia (SK), zuzana.murcinkova@tuke.sk.

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Experimental assessment of the test station support structure rigidity by the vibration diagnostics method

Anna Šmeringaiová, Imrich Vojtko

Abstract: The paper presents the results of the impact test. The test has been done to assess the rigidity of the test station support frame. Test station was designed and constructed to test different types of gearing and belt transmissions. The test station allows to simulate different operating conditions. The procedure of the tests can be both short-term and long-term with different load levels. The basic support frame structure of the test station was evaluated as unsufficient based on the results of measurement and processing of the measured low and high frequency vibration values in the verification series of experimental tests. The basic failure of the original design were the significant resonance actions that were the results of the dominant sources of vibration being near the natural frequencies of the vertical and horizontal beams of the test station base. A structural design of the test station supporting frame was designed and implemented. The impact tests were used to determine the values of the natural frequencies of the most stressed parts of the supporting structure - vertical and horizontal beams, before and after implementation of structural modifications. The comparability of the impact test results was determined by adherence to identical measurement conditions.

[1] Anna Šmeringaiová, Ph.D.: Faculty of Manufacturing Technologies of the Technical University of Košice with the seat in Prešov, Bayerova 1, 080 01 Prešov, Slovakia (SK), anna.smeringaiova@tuke.sk.

[2] Imrich Vojtko, Associate Professor: Faculty of Manufacturing Technologies of the Technical University of Košice with the seat in Prešov, Bayerova 1, 080 01 Prešov, Slovakia (SK), imrich.vojtko@tuke.sk.

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Dynamics of a turbocharger rotor supported on floating ring journal bearings with shallow axial grooves of uncertain dimensions

Luboš Smolík, Pavel Polach, Michal Hajžman

Abstract: Rotors of turbochargers are supported in floating ring journal bearings (FRJB) in most applications because these bearings are cheap and are not prone to the fatigue damage unlike rolling element bearings. However, due to their design with two oil films, FRJBs cause non-linear vibrations and instability of the turbocharger rotors, and also high power losses. Both dynamic and tribological properties of the bearing can be improved if several shallow axial grooves are machined in the inner surface of the floating ring. The grooves are usually not manufactured precisely in order to keep the cost of production as low as possible. Engineering tolerances may even be of the same order as the bearing clearance. This work deals with an analysis of dynamics of the turbocharger rotor supported on FRJBs with shallow axial grooves of uncertain dimensions. More specifically, the effects of the precise grooves on dynamics of the system are explained and then the influence of the uncertainties on both vibrations and hydrodynamic power losses in the bearings is investigated. In order to do so, a robust numerical approach is used: motions of rotating bodies are described employing a multi-body system formalism and forces acting in the bearings are calculated with a finite-element model which considers some thermal effects.

[1)] Luboš Smolík, Ph.D.: University of West Bohemia, Univerzitní 2732/8, 301 00 Plzeň, Czech Republic (CZ), carlist@ntis.zcu.cz .

[2)] Pavel Polach, Ph.D.: Research and Testing Institute Plzeň, Tylova 1581/46, 301 00 Plzeň, Czech Republic (CZ), polach@vzuplzen.cz .

[3)] Michal Hajžman, Ph.D.: University of West Bohemia, Univerzitní 2732/8, 301 00 Plzeň, Czech Republic (CZ), mhajzman@ntis.zcu.cz .

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Instability and vibration control by means of piezoceramic element

Krzysztof Sokół

Abstract: The control of vibration frequency and stability of slender systems is a very important issue in engineering. The control phenomenon can be realized with the use of different methods, while prestressing is one of them. In this paper, the studies on an influence of the prestressing caused by a force generated by a piezoceramic element on stability and vibrations of a multi-member column subjected to the specific load are presented. At this load one can find divergence and divergence-pseudoflutter shapes of the characteristic curves. The boundary problem is formulated by use of Hamilton's principle on the basis of which the differential equations of motion as well as natural boundary conditions are obtained. The main goal of this study is to find such a magnitude of the presressing force at which the control of vibration frequency can be done as well as the change of instability regions at different parameters of the loading unit.

[1)] Krzysztof Sokół, Ph.D.: Politechnika Częstochowska, ul. J.H. Dąbrowskiego 69 42-201 Częstochowa, Poland (PL), sokol@imipkm.pcz.pl.

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Dynamic analysis and damage of composite layered plates reinforced by unidirectional fibers subjected low velocity impact

Josef Soukup, MIlan Žmindák, Pavol Novák, František Klimenda, Michal Kaco, Lenka Rychlikova

Abstract: In the recent years a big focus is subjected to the response of structures subjected to out-of-plane loading such as blasts, impact, etc. Currently, for wave propagation modeling in composite structures at low and high speeds are used mainly Finite Element Method (FEM), BEM, Fast Multipole BEM, respectively, Finite Volume Method (FVM), meshless formulations and recently connection of FEM and element free based formulations. For the analysis of dynamical problems commercial program systems LS-DYNA, AUTODYN and PAM CRASH etc. are used in practice. In the present study, low-velocity impact response of composite laminates was studied using ABAQUS/Explicit and ANSYS APDL finite element code (FEM) to investigate damage by employing various damage criteria. The basic material properties in and transverse to the fiber directions, such as the elastic moduli, strains at failure, and plastic moduli among others are determined by simple tests in tension, compression, and shear. The material properties AS4/PEEK was used in numerical simulations and have been taken from the literature. Plate consists of layers which are reinforced with unidirectional fibers in hexagonal and square array. Layer is considered as homogeneous transversely isotropic and layer stacking sequence is symmetrical or unsymmetrical. In the plates examined, von Mises's stress and damage caused shear stress in the matrix and fiber were evaluated. From the results obtained, it was found that the von Mises stress was approximately the same for all types layer stacking sequence.

[1] Josef Soukup, Associate Professor: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), josef.soukup@ujep.cz.

[2] MIlan Žmindák, Professor: University of Žilina, , Faculty of Mechanical Engineering, Univerzitná 1, 010 26 Žilina, Slovakia (SK), milan.zmindak@fstroj.uniza.sk.

[3] Pavol Novák, Ph.D.: University of Žilina, , Faculty of Mechanical Engineering, Univerzitná 1, 010 26 Žilina, Slovakia (SK), pavol.novak@fstroj.uniza.sk.

[4] František Klimenda, Ph.D.: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), frantisek.klimenda@ujep.cz.

[5] Michal Kaco, M.Sc. (Ph.D. student): Faculty of Mechanical Engineering, Department of Applied Mechanics, University of Žilina, Univerzitna 1, 010 26, Zilina, Slovakia (SK), michal.kaco@fstroj.uniza.sk.

[6] Lenka Rychlikova, M.Sc. (Ph.D. student): FME UJEP in Usti nad Labem, Pasteurova 1, 400 96, Usti nad Labem, Czech Republic (CZ), lenka.rychlikova@ujep.cz.

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Experimental determination of natural frequencies and response stiffness elastically supported body

Josef Soukup, František Klimenda, Blanka Skočilasová, Lenka Rychlíková, Jan Skočilas

Abstract: prerequisite for dynamic analysis and evaluation of rolling stock is experimental determination. Verification of basic suspension characteristics. A method was developed and used to determine these characteristics for two-axle vehicles. This method requires knowledge of the center of gravity and the major mean moments of inertia. When examining these characteristics, it is assumed that the vehicle body, chassis frames and wheelsets are rigid units. The spring characteristics are linear or can be linearized. The vehicle housing generally performs a spatial motion. A method for obtaining search characteristics required for dynamic vehicle analysis is proposed.

[1)] Josef Soukup, Associate Professor: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), josef.soukup@ujep.cz.

[2)] František Klimenda, Ph.D.: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), frantisek.klimenda@ujep.cz.

[3)] Blanka Skočilasová, Ph.D.: University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), blanka.skocilasova@ujep.cz.

[4)] Lenka Rychlíková, M.Sc. (Ph.D. student): University of J. E. Purkyne in Usti nad Labem, Faculty of Mechanical Engineering, Na Okraji 1001, 400 01, Czech Republic (CZ), lenka.rychlikova@ujep.cz.

[5)] Jan Skočilas, Ph.D.: CTU in Prague, Faculty of Mechanical Engineering, Technicka 4, 166 07, Prague 6, Czech Republic (CZ), jan.skocilas@fs.cvut.cz.

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paper id: MTR310

Mechanical design of an exoskeleton for rehabilitation of lower limbs

Bartosz Stańczyk, Dariusz Grzelczyk, Olga Jarzyna, Jan Awrejcewicz

Abstract: Impairment of the locomotion system is a serious medical and social problem. Its prevalence is constantly growing and traditional forms of rehabilitation often lead to occupational health problems of physiotherapists. Therefore, it is important to design medical devices aimed at replacing the laborious work of therapists and helping the patients restore their mobility. This paper presents mechanical design of a prototype of a 10-DoF exoskeleton for rehabilitation of lower limbs and gait. Aside from motions in the hip, knee and ankle joints, additional movements of the upper body and toes are also facilitated. The length of particular elements of the device can be adjusted to a patient.

1) Bartosz Stańczyk, Ph.D.: Politechnika Łódzka K16, Pawlikowice, Poland (PL), Bartchez@gmail.com.

2) Dariusz Grzelczyk, Ph.D.: Politechnika Łódzka K16, Stefanowskiego 1/15, Poland (PL), Dariusz.grzelczyk@p.lodz.pl.

3) Olga Jarzyna, M.Sc. (Ph.D. student): Politechnika Łódzka K16, Stefanowskiego 1/15, Poland (PL), Olga.jarzyna@dokt.p.lodz.pl.

4) Jan Awrejcewicz, Professor: Politechnika Łódzka K16, Stefanowskiego 1/15, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: STA12

Rolling heavy ball over the surface with arbitrary shape in real Rn3 spave

Katic R. (Stevanovic) Hedrih

Abstract: The research results of the rolling, without sliping, of a homogeneous heavy ball over the surface with arbitrary shape, in the real Rn 3 space, are presented. The system is holonomic stationary, since the ball is subjected to geometric constraints, and has three degrees of freedom of movement. Two orthogonal unit vectors in the tangent plane to the surface of ball and surface along which ball rolls, are determined. The unit vector of the normal to the surface of the ball and the surface along which ball rolls without slipping, through the current contact point of ball and surface, and passes through the center of the ball. At each moment, fot the current position of the point of the contact between the ball and the surface, the position vector of the center of the ball is determined. Also, the corresponding vector of velocity of the center of the ball is determined. Using the velocity vector of the center of the ball, the current angular velocity of rolling the ball over the surface in the function of generalized coordinates is determined, as well as their direction. The direction of the elementary arch of the curvilinear trace through current contact point, of rolling the ball over the surface, as well as the direction of the momentary axis around which the ball is rolling without slipping, are determined. Kativa (Stevanovic) Hedrih , (2019),"Rolling heavy ball over the sphere in real Rn3 space", Nonlinear Dynamics, Springer . in press, DOI: 10.1007/s11071-019-04947-1.

[1)] Katic R. (Stevanovic) Hedrih, Professor: Mathematical Institute of Serbian Academy of Science and Arts, 11000, Serbia (RS), katicah@mi.sanu.ac.rs.

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Complex patterned precipitation dynamics in toroidal reactors with two diffusion sources

Rabih Sultan, Huria Ibrahim, Dalia Ezzeddine

Abstract: A toroidal reactor of 1.00 cm cross-sectional diameter, 6.50 cm inner diameter and 8.5 cm outer diameter is filled with CoCl2·6H2O (0.10-0.20 M) and 1% agar gel solution. Two outer electrolytes, of suitably chosen concentrations, are employed to diffuse into the gelled solution: from one end NH4OH to precipitate Co(OH)2, and from the other end Na3PO4 to precipitate Co3(PO4)2. The resulting diffusion-precipitation (Liesegang) pattern exhibits unusual trends wherein abnormal gaps, front wave stopping and formation of cobalt phosphate polymorphs are observed. The self-organized structure reveals a complex underlying dynamical scenario. Using the well-known generic empirical laws, we attempt the computation of the band locations and represent them graphically within the torus.

[1] Rabih Sultan, Professor: American University of Beirut (AUB), American University of Beirut, Lebanon (LB), rsultan@aub.edu.lb.

[2] Huria Ibrahim, B.A.: American University of Beirut (AUB), American University of Beirut, Lebanon (LB), hsi01@mail.aub.edu.

[3] Dalia Ezzeddine, B.A. (M.Sc. student): American University of Beirut (AUB), Department of Chemistry - AUB, Lebanon (LB), dme34@mail.aub.edu.

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Resonance study of spring pendulum based on MSM solutions with polynomial approximation

Grażyna Sypniewska-Kamińska, Jan Awrejcewicz, Henryk Kamiński, Robert Salamon

Abstract: The nonlinearities of geometric nature that is characteristic for pendulum-type systems are expressed by the trigonometric functions. In order to apply the method of multiple scales (MSM) in time domain to solve problems concerning such systems, the trigonometric functions of the generalised coordinates are usually approximated by a few terms of their Taylor series. In the paper we apply the polynomial approximation with orthogonal and non-orthogonal bases. In contrast to the Taylor series, the proposed manner approximates the functions not around a given point but in the given interval. Quality and accuracy of the solutions obtained using the multiple scales method based on such approach have been tested. The steady state responses in the main resonance have been also examined and compared with their counterparts obtained using the MSM based on the Taylor series.

[1] Grażyna Sypniewska-Kamińska, Associate Professor: Poznan University of Technology, ul. Jana Pawła II 24, 60-965 Poznań, Poland (PL), grazyna.sypniewska-kaminska@put.poznan.pl.

[2] Jan Awrejcewicz, Professor: Łódź University of Technology, 90-924 Łódź, ul. Stefanowskiego 1/15, Poland (PL), awrejcew@p.lodz.pl.

[3] Henryk Kamiński, Associate Professor: Poznan University of Technology, ul. Jana Pawła II 24, 60-965 Poznań, Poland (PL), henryk.kaminski@put.poznan.pl.

[4] Robert Salamon, M.Sc.: Poznan University of Technology, ul. Jana Pawła II 24, 60-965 Poznań, Poland (PL), robert.salamon@put.poznan.pl.

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Free vibration frequencies of simply supported bars with variable cross section

Olga Szlachetka, Jacek Jaworski, Marek Chalecki

Abstract: Using the Rayleigh method, the authors developed a procedure for determination of higher natural frequencies and derived formulas for frequencies of first three modes of free (transverse) vibrations of simply supported bars having the shape of truncated cone and truncated wedge. The bars are made of a homogeneous and elastic material and are considered as Bernoulli-Euler beams. It was assumed that the shape of the bar axis deflected during vibration corresponds to a deflection line resulting from action of a specific continuous static load. Dimensionless frequency parameters for bars with various truncation factors, obtained as a result, were compared to those known form literature and to results of application of FEM. High concordance of results was found for the first natural frequency. For the second and third frequencies, however, the results acceptable from engineer's point of view (i.e. burdened with an error lower than 6%) were obtained only for bars with the truncation factor not lower than 0.6 (for the truncated cone) and 0.4 (for the truncated wedge). It means that the hypothesis assumed in the study for the shape of a beam axis deflection line during vibrations, enabling determination of higher frequencies of free vibrations and being proper for bars having shapes close to a solid cylinder or cuboid, loses its appropriateness for bars approaching the shape of cone or wedge.

[1)] Olga Szlachetka, Ph.D.: Warsaw University of Life Sciences, Faculty of Civil and Environmental Engineering, Department of Civil Engineering, 166 Nowoursynowska Street , 02-787 Warsaw, Poland (PL), olga_szlachetka@sggw.pl.

[2)] Jacek Jaworski, Ph.D.: Retired researcher, Warsaw, Poland (PL), jacek_jaworski@sggw.pl.

[3)] Marek Chalecki, Ph.D.: Warsaw University of Life Sciences, Faculty of Civil and Environmental Engineering, Department of Civil Engineering, 166 Nowoursynowska Street, 02-787 Warsaw, Poland (PL), marek_chalecki@sggw.pl.

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Robust design of inhibitory neuronal networks displaying rhythmic activity

Joseph D. Taylor, Kamal Abu-Hassan, Joanne van Bavel, Marc Vos, Alain Nogaret

Abstract: Central pattern generators (CPGs) are neuronal circuits which autonomously produce patterns of phase-locked activity. The need for bioelectronic implants that adapt to physiological feedback calls for novel methods for designing synthetic CPGs that respond identically to their biological counterparts. Nonlinearity within such networks make both the prediction of network behaviour and, inversely, the design of networks with desired behaviour non-trivial. Here, we demonstrate the utility of optimization-based parameter estimation for identifying sets of synaptic parameters which give rise to network activity with specific temporal properties. We reduce the dimension of the problem by visualizing the network dynamics in a coordinate system composed of the relative phases of the oscillators, and we reduce each oscillator to its phase response curve (PRC). While recent work has employed parameter estimation to optimize single neuron models, reducing the component oscillators to their PRCs allows us to estimate parameters of networks of arbitrarily complex neuron models without incurring prohibitive computational costs. We highlight a possible application of our approach by estimating parameters of a CPG emulating the phase-locked activity associated with ECG data. This work paves the way for the design of synthetic networks which may be interfaced with nervous systems.

[1] Joseph D. Taylor, M.Sc. (Ph.D. student): University of Bath, Department of Physics, University of Bath, Bath BA2 7AY, United Kingdom, England (GB), j.taylor@bath.ac.uk.

[2] Kamal Abu-Hassan, Ph.D.: Department of Physics, University of Bath, Claverton Down, Bath, BA2 7AY, United Kingdom, England (GB), kjaahh20@bath.ac.uk.

[3] Joanne van Bavel, M.Sc. (Ph.D. student): Department of Medical Physiology, Division of Heart & Lungs, University Medical Center Utrecht, UMC Utrecht, Heidelberglaan 100, 3584 CX Utrecht, Netherlands (NL), j.j.a.vanbavelh@umcutrecht.nl.

[4] Marc Vos, Professor: Department of Medical Physiology, Division of Heart & Lungs, University Medical Center Utrecht, UMC Utrecht, Heidelberglaan 100, 3584 CX Utrecht, Netherlands (NL), m.a.vosh@umcutrecht.nl.

[5] Alain Nogaret, Professor: University of Bath, Department of Physics, University of Bath, Bath BA2 7AY, United Kingdom, England (GB), a.r.nogareth@bath.ac.uk.

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Chaos, bifurcations and strange attractors in environmental radioactivity dynamics of some geosystems

Eugeny Ternovsky, Alexander V. Glushkov, Olga Khetselius, Alexander Belodonov

Abstract: We develop the theoretical foundations of new universal complex chaos-dynamical approach to description of the deterministic chaos, bifurcations and strange attractors in dynamics of the environmental radioactivity systems. In particular, the atmospheric radon 222Rn concentration temporal dynamics is studied and computed. The nonlinear analysis methods include advanced versions of the correlation integral and multifractal analysis, algorithms of average mutual information, false nearest neighbors, surrogate data, Lyapunov's exponents and Kolmogorov's energy analysis, non-linear prediction schemes, predicted trajectories algorithms, spectral methods etc (in versions [1,2]). The chaos-dynamical approach is applied to quantitative analysis, modeling and forecasting temporal and spatial evolution of the atmospheric radon 222Rn concentration. The detailed data of measurements of the radon concentrations at Environmental Measurements Laboratory (US Department of Energy, and Goddard Institute of Space Studies Chester, New Jersey, USA (1978-2001; c.g.[3]) are used. The perspectives of computing chaos, bifurcations and strange attractors characteristics in other geo- and bio-systems are analyzed. References: [1] Glushkov A.V.: Methods of a Chaos Theory. Odessa: Astroprint, 2012. [2] Glushkov A.V., Khetselius O.Yu., Svinarenko A.A., Buyadzhi V.V.: Methods of computational mathematics and mathematical physics, P.1. Odessa: TEC, 2015. [3] Jacob D., Prather M.: Tellus. 42b, 118 (1990).

[1] Eugeny Ternovsky, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), ternovskyev@gmail.com.

[2] Alexander V. Glushkov, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), glushkovav@gmail.com.

[3] Olga Khetselius, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), okhetsel@gmail.com.

[4] Alexander Belodonov, B.A. (M.Sc. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), belodonovas17@gmail.com.

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Dynamics of non-linear processes in backward-wave tubes chain: chaos and strange attractors

Valentin Ternovsky, Alexander V. Glushkov, Eugeny Ternovsky, Andrey Tsudik

Abstract: We present the results of the computational analysis, modeling and forecasting the temporal dynamics for the chain of backward-wave tubes with study of a chaos elements, bifurcations and strange attractors. The nonlinear dynamics of the system is described by means of the nonstationary nonlinear theory differential equations for the evolution of the amplitude of the electromagnetic field in time and space and the motion of the beam. The nonlinear analysis methods include advanced versions of the correlation integral and multifractal analysis, algorithms of average mutual information, false nearest neighbors, surrogate data, Lyapunov's exponents and Kolmogorov's energy analysis, non-linear prediction schemes, predicted trajectories algorithms, spectral methods etc (in [1,2]). Using universal chaos-geometric and multisystem approach it is studied chaotic dynamics of the nonlinear processes in the chain of backward-wave tubes. There are theoretically studied scenarios of generating chaos, obtained complete quantitative data on the dynamical and topological parameters of dynamics as in the chaos regime as the hyperchaos regime and for the different modes of operation. References: [1] Glushkov A.V., Methods of a Chaos Theory. Odessa: Astroprint, 2012. [2] Glushkov A.V., Khetselius O.Yu., Svinarenko A.A., Buyadzhi V.V., Methods of computational mathematics and mathematical physics, P.1. Odessa: TEC, 2015.

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1) Valentin Ternovsky, Associate Professor: Odessa National Maritime Academy, Didrikhsona str., 4, Odessa, 65000, Ukraine (UA), ternovskyvb@gmail.com.

2) Alexander V. Glushkov, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), glushkovav@gmail.com.

3) Eugeny Ternovsky, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), ternovskyev@gmail.com.

4) Andrey Tsudik, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), tsudik14@gmail.com.

paper id: MAT273

Deterministic chaos, bifurcations and strange attractors in nonlinear dynamics of relativistic backward-wave tube

Valentin Ternovsky, Alexander V. Glushkov, Andrey Tsudik, Oleksii Mykhailov

Abstract: We present the results of analysis, modeling and forecasting a chaos elements, bifurcations and strange attractors characteristics in a temporal dynamics for relativistic backward-wave tube (RBWT) with accounting relativistic effects (g=1.5-6), dissipation (factor D), space charge effect etc. The advanced dynamical model is presented and the temporal dependencies of the normalized field amplitudes (power) are calculated in a wide range of variation of the controlling parameters, which are characteristic for distributed relativistic electron-waved self-vibrational systems: electric length of an interaction space N, bifurcation parameter proportional to (current I) Pirse one J and relativistic factor g. The nonlinear analysis methods include advanced versions of the correlation integral and multifractal analysis, algorithms of average mutual information, false nearest neighbors, Lyapunov's exponents and Kolmogorov's energy analysis, non-linear prediction schemes, spectral methods etc (in [1-3]). The dynamical and topological invariants of the RBWT dynamics in auto-modulation(AUM)/chaotic regimes are computed. There are constructed the bifurcation diagrams with definition of the dynamics self-modulation/chaotic areas in planes, namely, "J-g", "D-J". References: [1] Glushkov A.V., Methods of a Chaos Theory. Odessa: Astroprint, 2012. [2] Glushkov A.V., Khetselius O.Yu., Svinarenko A.A., Buyadzhi V.V., Methods of computational mathematics and mathematical physics, P.1. Odessa: TEC, 2015. [3] Prepelitsa G., Buyadzhi V., Ternovsky V., Photoelectronics. 22, 103-107 (2013).

[1] Valentin Ternovsky, Associate Professor: Odessa National Maritime Academy, Didrikhsona str., 4, Odessa, 65000, Ukraine (UA), ternovskyvb@gmail.com.

[2] Alexander V. Glushkov, Professor: Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), glushkovav@gmail.com.

[3] Andrey Tsudik, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), tsudik14@gmail.com.

[4] Oleksii Mykhailov, M.Sc. (Ph.D. student): Department of Applied Mathematics, Odessa State Environmental University, L'vovskaya str., 15, of. 408, Odessa, 65016, Ukraine (UA), veronevonor@gmail.com.

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paper id: STA141

General decay stability analysis of coupled systems of stochastic neural networks

Biljana Tojtovska

Abstract: In this paper we consider a model of coupled systems of stochastic neural networks, represented by stochastic differential equations. The model generalizes many models in the literature and to the best of our knowledge, there are no results on stability analysis of such a model. Coupled networks consist of parts with individual dynamics which mutually interact based on some coupling structure. The structure can be modeled by a graph, where each node represents a system with nonlinear or stochastic dynamics. However, it is known that dynamical systems may lose the stability property after coupling. There are examples which show that even if all the individual systems are stable, the coupled dynamical system may not be stable. Existence of an equilibrium state for a neural network is important for the process of learning, pattern formation and characterization of different statistical properties of the network. Hence, it is important to give conditions on the network which will imply stability of the coupled system. The goal of our research is to give sufficient conditions on pth moment general decay stability of the equilibrium point of this model. This includes as a special case the exponential, polynomial and logarithmic stability and the methods allow us to discuss the pth moment stability even when results for exponential stability cannot be applied. The discussion in our paper is based on M-matrix theory, on the Lyapunov method and we use known inequality techniques. The results are original and have not been published yet.

[1] Biljana Tojtovska, Ph.D.: Faculty of Computer Science and Engineering, Rudger Boshkovich 16, 1000 Skopje, Macedonia (MK), btojtovska@gmail.com .

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paper id: BIF223

Railway vehicle dynamics, bifurcations and transitions

Hans True

Abstract: The Railway Vehicle Dynamical problems are multibody problems with from 7 to 80+ degrees of freedom. The mathematical models are nonlinear and non-smooth with tabulated constraints. Only autonomous problems are considered. The dynamics depend on the speed V as a control parameter and the vehicles can run steady, oscillate symmetric or asymmetric periodically, multi periodically, quasiperiodically or chaotic, possibly with multiple attractors. Several kinds of bifucations exist. The theoretical dynamical models are investigated numerically and problems connected herewith will be briefly presented. Some interesting modes and bifurcations will be shown.

1) Hans True, Professor: DTU Compute, Richard Petersens Plads 324, DK-2800 Kgs. Lyngby, Denmark (DK), htru@dtu.dk.

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On the influence of external stochastic excitation on linear oscillators with subcritical self-excitation applied to brake squeal

Nguyễn Thái Minh Tuấn, Paul Wulff, Nils Gräbner, Utz Von Wagner

Abstract: A characteristic of linear systems with self-excitation is the occurrence of non-normal modes. Because of this non-normality, there may be a significant growth in the vibration amplitude at the beginning of the transient process even in the case of solely negative real parts of the eigenvalues, i.e. subcritical self-excitation and asymptotic stability of the trivial solution. If such a system is excited additionally with white noise with small intensity, this process is continually restarted and a stationary vibration with a dominating single frequency and comparably large amplitudes can be observed. Similar observations can be made during brake squeal, a high-frequency noise resulting from self-excitation due to the frictional disk-pad contact. Although commonly brake squeal is considered as a stable limit cycle with the necessity of corresponding nonlinearities, comparable noise phenomena can in the described model even observed in a pure linear case when the trivial solution is asymptotically stable.

[1] Nguyễn Thái Minh Tuấn, Ph.D.: Department of Applied Mechanics - Hanoi University of Science and Technology, Bộ môn Cơ học ứng dụng - Đại học Bách khoa Hà Nội, Vietnam (VN), nguyenthaiminhtuan@gmail.com.

[2] Paul Wulff, M.Sc.: Department of Applied Mechanics, TU Berlin, Einsteinufer 5, 10587 Berlin, Germany (DE), paul.wulff@tu-berlin.de.

[3] Nils Gräbner, Ph.D.: Department of Applied Mechanics, TU Berlin, Eintseinufer 5, 10587 Berlin, Germany (DE), nils.graebner@tu-berlin.de.

[4] Utz Von Wagner, Professor: Department of Applied Mechanics, TU Berlin, Einsteinufer 5, 10587 Berlin, Germany (DE), utz.vonwagner@tu-berlin.de.

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paper id: ASY139

Nonlinear dynamics of the sensory element of the atomic force microcopy

Pavel Udalov, Ivan Popov, Alexey Lukin

Abstract: In this paper, a microscope with a sensitive element in the form of a cantilever beam operating in the frequency contact mode. The problem of obtaining approximate analytical expressions describing the dynamics of the sensitive element in the case of forced oscillations, taking into account the pre-stressed state caused by static deformation and non-linear force of interaction with the sample. Asymptotic and variational methods of mathematical physics, a model is constructed and estimates are obtained, the result is compared with a numerical solution by the finite element method. The key focus in this work is the analysis of the nonlinear dynamics of the sensitive element of an atomic force microscope and the selection of the information signal from the nonlinear effects associated with the interaction of the indenter and the sample. It is interesting and practically important to conduct a qualitative analysis of the dynamics of a sensitive element using asymptotic methods of the nonlinear theory of oscillations, and to obtain final analytical expressions and curves that could serve as a basis for highlighting useful signal. Due to the generality of the method, the range of applicability of these results would not be limited to an atomic force microscope, and they would also prove useful in designing gyroscopic instruments.

[1] Pavel Udalov, B.A.: Peter the Great St.Petersburg Polytechnic University, Russia, 195251, St.Petersburg, Polytechnicheskaya, 29, Russia (RU), forsteam1231@mail.ru.

[2] Ivan Popov, M.Sc. (Ph.D. student): Peter the Great St.Petersburg Polytechnic University, Russia, 195251, St.Petersburg, Polytechnicheskaya, 29, Russia (RU), popov_ia@spbstu.ru.

[3] Alexey Lukin, M.Sc. (Ph.D. student): Peter the Great St.Petersburg Polytechnic University, Russia, 195251, St.Petersburg, Polytechnicheskaya, 29, Russia (RU), lukin_av@spbstu.ru.

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Nonlinear vibrations of simply supported column loaded by the mass element

Sebastian Uzny, Łukasz Kutrowski, Michał Osadnik

Abstract: The stability and free vibrations of slender support systems were the subject of many scientific and research works. This paper presents the boundary problem of column vibrations in which the longitudinal inertia of the mass element, which loads the slender system, is taken into account. The column was analysed as a simply supported structure. The formulation of boundary problem was carried out by using kinetic criterion of stability. The consideration of the load from longitudinal inertia of mass element in the mathematical model means that considered system is nonlinear. The non-linear components occurred in mathematical equations have been developed into a power series of a small parameter. Numerical calculations were carried out, on the basis of which the influence of the amplitude of the column oscillations on the non-linear component of the natural frequency of the system was determined. It has been shown that in the case of supporting systems loaded by mass element, the influence of the vibrations amplitude on natural frequency at appropriately selected parameters of the system is significant.

[1)] Sebastian Uzny, Associate Professor: Częstochowa University of Technology, Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), uzny@imipkm.pcz.pl.

[2)] Łukasz Kutrowski, M.Sc. (Ph.D. student): Częstochowa University of Technology, Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), kutrowski@imipkm.pcz.pl.

[3)] Michał Osadnik, M.Sc. (Ph.D. student): Częstochowa University of Technology, Dąbrowskiego 69, 42-201 Częstochowa, Poland (PL), mosadnik@imipkm.pcz.pl.

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paper id: OPT8

On the solution of the optimal control problem of inventory of a discrete product in stochastic model of regeneration

Nikita Vakhtanov, Petr Shnurkov

Abstract: On the Solution of the Optimal Control Problem of Inventory of a Discrete Product in Stochastic Model of Regeneration The work considers a new model of discrete product inventory control in regeneration scheme with a Poisson flow of customer requirements, random delivery delay and deferred demand. The control parameter r is the level of the stock, at which achievement it is necessary to make an order for replenishment, and this parameter is determined in accordance with a discrete probability distribution, which plays the role of a control strategy. As an indicator of control efficiency, we consider the average specific profit obtained during the re-generation period. In order to obtain an explicit representation for this indicator, a special version of the classical ergodic theorem was proved for the additive cost functional. The optimal control problem is solved on the basis of the statement about the extremum of a fractional-linear integral functional on the set of discrete probability distributions. Explicit representations are derived for the mathematical expectations of the increments of the profit functional on the regeneration period under all possible conditions on the control parameter. These analytical representations enable us to explicitly obtain the stationary cost indicator of control efficiency as a function of the control parameter and, for given model characteristics, numerically determine the optimal value of the control, which contributes to solving one of the important applied problems of the modern economy.

[1] Nikita Vakhtanov, B.A. (M.Sc. student): National Research University Higher School of Economics, 1 Komsomolskaya Ulitsa, Odintsovo, Odintsovsky District, Moscow Region, 143006, Russia (RU), navakhtanov@edu.hse.ru.

[2] Petr Shnurkov, Ph.D.: National Research University Higher School of Economics, 20 Myasnitskaya Ulitsa, Moscow, 101000, Russia (RU), pshnurkov@hse.ru.

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paper id: ENG321

Vibration Busters – an interdyscyplinary approach to education of dynamical systems

Ryszard Walentyński, Damian Słota, Marcin Szczygieł

Abstract: There is an implementation project "Silesian University of Technology as a Center for Modern Education based on research and innovation" (POWR.03.05.00-IP.08-00-PZ1/17), financed by the European Funds of the Operational Program Knowledge Education Development. Within other activities there is a project called "Individual Study Programs implemented in the form of Project Based Learning". A group of 6 pre-graduated students of Civil Engineering, Mathematics and Mechatronics studied problems dynamics of structures within a sub-project called Vibrations Busters. They worked under supervision of professors from among mentioned departments. Students, according to their competencies, implemented a procedure of numerical analysis of the problem within Mathematica system, built a physical model of a frame and loaded it with vibrating electrical engines and measured behavior of the structure. The aim of the project was to develop methods of passive and active controlling of vibrations of building structures. To built a structure a technology of 3D printing was implemented. Thanks to the project students of different depatments had an opportunity to share their skills and knowledge and receive several new hard and soft competencies. This was also a unique experience for supervisors and great opportunity to extend fields of interdisciplinary cooperation. The aim of the presentation is to share results of this extraordinary and successful educational project with other scientists.

[1] Ryszard Walentyński, Associate Professor: Silesian University of Technology, Akademicka 5, Poland (PL), ryszard.walentynski@polsl.pl.

[2] Damian Słota, Associate Professor: Silesian University of Technology, Akademicka 2A, 44-100 Gliwice, Poland (PL), damian.slota@polsl.pl.

[3] Marcin Szczygieł, Ph.D.: Silesian University of Technology, Akademicka 2A, 44-100 Gliwice, Poland (PL), marcin.szczygiel@polsl.pl.

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Optimisation of energy absorbers in driver's cab Impuls I rail vehicle

Paweł Wątroba, Mariusz Pawlak, Damian Gąsiorek

Abstract: During numerical modelling of the impact test of electric multiple units (EMU) driver's cab Impuls I rail vehicle from Newag S.A. was noticed the need to investigate the methodology of design of energy absorbers, because properly designed crush zones provide a controlled collision process for specific conditions. The most popular method in the design of energy absorbers is to estimate square cross-section tube thickness and the tube width from the equation of dynamic axial crushing force. When the shape of axially loaded tubes is circular, or honeycomb than modelling with Finite Element Method is necessary, and crashworthiness criteria are introduced in the process of design. Compared to the current state of the art, the novel approach is trying to take into consideration all shapes of cross-sections: rectangles, circles, honeycomb, etc. The finite element method is combined with rigid body dynamics and friction model. The developed method allows to apply optimisation process of energy absorbers used in Impuls I rail vehicle crash tests. Design criteria for crashworthiness and energy presented in this article are absorption energy-based metrics with energy absorption EA, specific energy absorption SEA and crash load efficiency. The paper presents current results of numerical calculation that are intended to complement the test results and develop modified energy absorbers models.

[1] Paweł Wątroba, M.Sc. (Ph.D. student): Research and Development Department in NEWAG IP Management, ul. Klimeckiego 24, 30-705 Cracow, Poland (PL), pawel.watroba@newag.pl .

[2] Mariusz Pawlak, Ph.D.: Silesian University of Technology, ul. Akademicka 2A, 44-100 GLIWICE, Poland (PL), mariusz.pawlak@polsl.pl .

[3] Damian Gąsiorek, Professor: Silesian University of Technology, ul. Akademicka 2A, 44-100 GLIWICE, Poland (PL), damian.gasiorek@polsl.pl .

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paper id: LIF332

Dynamics of chains as a tool to study thermomechanical properties of proteins

Piotr Weber

Abstract: Polymer dynamics can be formulated on different levels of detail. One approach eliminates microscopic degrees of freedom and a polymer molecule is represented by a simplified structure - a chain. Dynamics of chain is due to thermal energy, which is a reason a transitions between polymer's states. In the simplest case a chain is an ideal chain. Monomers of ideal chain have fixed length, and their orientation is independent of the orientations and positions of neighbouring monomers. This is reason that two monomers can co-exist at the same place, so ideal chain model doesn't describe correctly the local structure of polymer, but correctly describe the property on large-scale. In reality, however monomers in a chain interact each other in space. One of such interaction is a steric effects, since monomer has a volume. Additionally there exists also electrical interactions between parts of polymer. Environment is another factor, which influence on polymer and can be source of thermodynamic forces. Polymers often operate under such non-equilibrium conditions, therefore dynamics of polymers has to fulfil laws of nonequilibrium thermodynamics. In a living systems there are a special polymers-proteins, that can operate under non-equilibrium conditions. During biochemical processes, they changes its states. I my work I will analyse influence, above mentioned, internal and external factors, which influence on proteins during changes of its states. In this context I will also present a certain formalism of non-equilibrium thermodynamic when non-Markovian processes appear.

[1)] Piotr Weber, Ph.D.: Department of Atomic, Molecular and Optical Physics, Faculty of Applied Physics and Mathematics, Gdańsk University of Technology., ul. Gabriela Narutowicza 11/12 80-233 Gdańsk, Poland (PL), piotr.weber@pg.edu.pl.

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Nonlinear forced oscillations of the coupled masses between repelling magnets

Krzysztof Witkowski, Grzegorz Kudra, Sergii Skurativskyi, Grzegorz Wasilewski, Jan Awrejcewicz

Abstract: In these studies we consider oscillations in the physical model consisting of two carts mounted on a guide. The movement of these carts is restricted by the repelling magnets. The interaction between carts is provided by spring or impact element. The harmonic external loading is applied to one of the carts. To describe this system, the nonlinear mathematical model is developed. The results of model parameter identification are presented. Moreover, the procedure of model validation on the bases of experimental and numerical analysis of system dynamics is discussed as well.

[1)] Krzysztof Witkowski, M.Sc. (Ph.D. student): Lodz University of Technology, Stefanowskiego 1/15, 90-924, Lodz, Poland (PL), krzys_wit@wp.pl.

[2)] Grzegorz Kudra, Associate Professor: Lodz University of Technology, Stefanowskiego 1/15, 90-924, Lodz, Poland (PL), grzegorz.kudra@p.lodz.pl.

[3)] Sergii Skurativskyi, Associate Professor: Subbotin Institute of Geophysics, Palladin av. 32, Kyiv, Ukraine (UA), skurserg@gmail.com.

[4)] Grzegorz Wasilewski, Ph.D.: Lodz University of Technology, Stefanowskiego 1/15, 90-924, Lodz, Poland (PL), grzegorz.wasilewski@p.lodz.pl.

[5)] Jan Awrejcewicz, Professor: Lodz University of Technology, Stefanowskiego 1/15, 90-924, Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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The pair of oscillators coupled by the electromagnetic field

Mateusz Wojna, Grzegorz Wasilewski, Jan Awrejcewicz

Abstract: The paper concerns numerical and experimental study of a system consisting of two identical oscillators coupled by the electromagnetic field. A system contains two permanent neodymium magnets hung up on the two vertical springs and vibrating in the hollows of two coils. The system with both, linear and non-linear springs has been considered and studied. The coils are connected in series, what makes the oscillators coupled. The coupling is determined by the currents which are induced by moving magnets in the nearby of coils. Based on the Faraday's law, the coupling variables are velocities of the magnets. Such a system can be easily applicable. One of the potential use in the field of energy harvesting is scavenging the energy from ocean waves. The work consists of modelling, numerical simulation and experimental study of the earlier introduced mathematical model. The results of numerical simulations are confronted with experimental data and taken under discussion.

[1)] Mateusz Wojna, M.Sc. (Ph.D. student): Lodz University of Technology, Faculty of Mechanical Engineering, Department of Automation, Biomechanics and Mechatronics, Stefanowskiego 1/15, 90-924, Lodz, Poland (PL), mateusz.wojna@edu.p.lodz.pl.

[2)] Grzegorz Wasilewski, Ph.D.: Lodz University of Technology, Faculty of Mechanical Engineering, Department of Automation, Biomechanics and Mechatronics, Stefanowskiego 1/15, 90-924, Lodz, Poland (PL), grzegorz.wasilewski@p.lodz.pl.

[3)] Jan Awrejcewicz, Professor: Lodz University of Technology, Faculty of Mechanical Engineering, Department of Automation, Biomechanics and Mechatronics, Stefanowskiego 1/15, 90-924, Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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Gravity waves in channels with corrugated bottom: an asymptotic approach

Ryszard Wojnar, Włodzimierz Bielski

Abstract: We consider a propagation of long one-dimensional gravity waves of a homogeneous incompressible fluid in a channel with corrugated bottom (micro-periodic corrugation). If foreseeable wave disturbance is long, and if take it for a length unit, then we have the inequalities l << h << 1, where l denotes the period of the bottom corrugation, and h - the depth of channel liquid in equilibrium. The value of the bottom corrugation vertical amplitude a and the wave amplitude on the surface of the fluid, it is its vertical disturbance \eta, both are of the order of l. In an introductory discussion of the gravity waves problem we are dealing with two tasks: the linear approximation, which permits describe the phenomenon by the common wave equation with the velocity \sqrt{g h^{eff}} and the higher, non-linear approximation, which leads to Korteweg – de Vries equation. After writing appropriate gravity wave equations for the channel with periodic micro-corrugated bottom, we perform asymptotic homogenisation of the problems and obtain homogenised equations of long gravity waves in both cases. References: 1) Korteweg, D. J.; de Vries, G., On the change of form of long waves advancing in a rectangular canal, and on a new type of long stationary waves, Philosophical Magazine 39 (240) 422-443, 1895. 2) Lamb G. L., Jr., Elements of soliton theory , John Wiley & Sons, New York - Chichester - Brisbane - Toronto, 1980.

[1] Ryszard Wojnar, Ph.D.: Institute of Fundamental Technological Research PAS, Pawińskiego 5B, 02-106 Warszawa, Poland (PL), rwojnar@ippt.pan.pl.

[2] Włodzimierz Bielski, Associate Professor: Institute of Geophysics Polish Academy of Sciences, ul. Księcia Janusza 64, 01-452 Warsaw, Poland (PL), wbielski@igf.edu.pl.

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Parameter identification of the Hamiltonian dynamic model of a robot

Łukasz Woliński, Paweł Malczyk, Marek Wojtyra

Abstract: Recent studies suggest that the use of the Hamiltonian formalism for the description of multibody system behavior may significantly increase the efficiency of modelling and simulation. Parametric identification is of crucial importance when high-fidelity models are required. In this work, the methods of identification, applicable to the Hamiltonian models, are developed. Standard identification methods used in robotics consist of a few steps. First, the dynamic model is written in form of a regressor matrix (dependent on the joint positions, velocities and accelerations) multiplied by the vector of inertial parameters. Second, a sufficiently exciting trajectory is derived. Third, the joint torques and positions are measured while the robot is tracking the trajectory. Fourth, the dynamic parameters are estimated using the least-squares method. The fifth step consists of validation of the model. An application of the standard method to the Hamiltonian framework requires some extensions due to the fact that momenta measurements are not directly available. In this work we present a preliminary investigation on parameter identification procedure. A mathematical model of a system expressed in terms of positions and conjugate momenta is used to formulate the key relations between identified parameters and output measurements. The feasibility study is demonstrated in the work. A general problem of parameter identification is brought to the analysis of a sample test case. Acknowledgements. This work has been supported by the National Science Centre grant 2018/29/B/ST8/00374.

[1)] Łukasz Woliński, M.Sc. (Ph.D. student): Warsaw University of Technology; Faculty of Power and Aeronautical Engineering, Nowowiejska 24, 00-665 Warsaw, Poland (PL), lwolinski@meil.pw.edu.pl.

[2)] Paweł Malczyk, Ph.D.: Warsaw University of Technology; Faculty of Power and Aeronautical Engineering, Nowowiejska 24, 00-665 Warsaw, Poland (PL), pmalczyk@meil.pw.edu.pl.

[3)] Marek Wojtyra, Associate Professor: Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, Nowowiejska 24; 00-665 Warsaw, Poland (PL), mwojtyra@meil.pw.edu.pl.

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paper id: VIB304

Contact interaction of NEMS elements composed of a plate/beam, taking into account the Casimir and Van der Waals forces and under additive white noise

Tatyana V. Yakovleva, Jan Awrejcewicz, Svetlana A. Mitskevich, Irina V. Papkova, Vadim A. Krysko

Abstract: A mathematical model of the contact interaction of a nanostructure, which is a nanoplate, supported by a nanobeam in its center, is constructed. There is a small clearance between the nanoplate and the nanobeam. An external alternating transverse distributed load and an external field of additive white noise act on the nanoplate. The noise component depends on the spatial variable of the mechanical nanostructure. Additive noise is added to the system of equations in the form of a random term with constant intensity. An electric field acts on the nanobeam (Casimir and Van der Waals forces). The nanoplate is described by the Kirchhoff kinematic model, and the Euler-Bernoulli nanobeam. To take into account nanoscale parameters, a modified moment elasticity theory proposed by Young is applied. The contact interaction between the elements of the plate-beam nanostructure is taken into account according to the Winkler model based on the Cantor's theory. Contact interaction leads to occurrence of a design nonlinearity of the nanostructure. The mathematical model of the nanostructure is developed taking into account the geometric nonlinearity according to the theory of von Karman. The system of equations is derived from the Hamilton's principle. The studies performed make it possible to consider problems as systems with an almost infinite number of degrees of freedom. The methods of the qualitative theory of differential equations are used to analyze the influence of the noise and electric fields on the contact interaction of a nanoplate and a nanobeam.

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1) Tatyana V. Yakovleva, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), yan-tan1987@mail.ru.

2) Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

3) Svetlana A. Mitskevich, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), svetlana.mitskevich@gmail.com.

4) Irina V. Papkova, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), ikravzova@mail.ru.

5) Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Nonlinear stability of a spring-supported pipe conveying fluid

Kiyotaka Yamashita, Naoto Nishiyama, Kohsuke Katsura, Hiroshi Yabuno

Abstract: Instabilities of pipes conveying fluid have been investigated for a long time. The dynamics of the lateral displacement in pipe system is described by non-self-adjoint partial differential governing equation and the eigen-functions in this problem do not belong to the system of orthogonal functions. In addition to that, it has been well known that the system shows many complex nonlinear motions. Therefore, nonlinear dynamics of pipes conveying fluid has been regarded as an essential model of the self-excited vibration in the continuous system from the view points of the non-conservative elastic problems and the flow-induced vibrations. In this study, a spring-supported pipe conveying fluid is considered. We take up the problem of double degeneracy point associated with a pitchfork and a Hopf bifurcation. In the theoretical analysis, we use the adjoint eigen-functions to project system nonlinearity to the unstable eigen-spaces. In particular, the experiments are conducted with the silicon rubber pipe and the lateral displacements of the pipe are measured by the image processing system. In a certain range of the flow velocity, we confirm that there are three steady-state solutions (1) two stable buckled states (2) a self-excited vibration around the straight position of the pipe.

[1] Kiyotaka Yamashita, Professor: Fukui university of technology, 3-6-1 gakuen fukui-shi fukui, Japan (JP), yamashita@fukui-ut.ac.jp.

[2] Naoto Nishiyama, M.Sc. (Ph.D. student): Fukui university of technology, 3-6-1 gakuen fukui-shi fukui, Japan (JP), nishiyama@fukui-ut.ac.jp.

[3] Kohsuke Katsura, B.A. (M.Sc. student): Fukui university of technology, 3-6-1 gakuen fukui-shi fukui, Japan (JP), kosuke.katsura@gmail.com.

[4] Hiroshi Yabuno, Professor: University of Tsukuba, 1-1-1, Ten-no-dai, Tsukuba Science, Ibaraki, Japan (JP), yabuno@esys.tsukuba.ac.jp.

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Dynamics of vibrating machines with inertia excitation considering drive elasticity

Nikolai Yaroshevich, Olha Yaroshevych, Mykola Yevsiuk

Abstract: The results of the study of the dynamics of vibration machines with unbalance drive taking into account the elasticity of links are given. An expression describing the torsional vibrations of the drive near the stationary modes of rotation of the vibration exciter and the formula of vibration moment that allows estimating the dynamic load of the engine is obtained. The dependences take into account the case of the "sticking" of the angular velocity of the motor in the zone of the natural frequencies of the vibrator. It is shown that when starting the machines in the case of the Sommerfeld effect, resonant oscillations of the elastic-damping elements are excited, which connect the rotors of the engine and the vibroexciter. It is established that in the presence of an elastic element in the drive, the frequencies of the vibratory machine's natural oscillations are added to its critical frequencies.

[1] Nikolai Yaroshevich, Professor: Lutsk National Technical University, Volyn Region, Lutsk, Lvivska 75, 43018, Ukraine (UA), yaroshevichmp@gmail.com.

[2] Olha Yaroshevych, M.Sc. (Ph.D. student): Lutsk National Technical University, Volyn Region, Lutsk, Lvivska 75, 43018, Ukraine (UA), jaroshewytsch.olia@gmail.com.

[3] Mykola Yevsiuk, Ph.D.: Lutsk National Technical University, Volyn Region, Lutsk, Lvivska 75, 43018, Ukraine (UA), mykola.hunter@gmail.com.

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On the dynamics of blood through the circular tube along with magnetic properties

Azhar Ali Zafar, Jan Awrejcewicz

Abstract: In this talk, we will investigates a blood flow model with suspended magnetic particles. The fluid is influenced by an external magnetic field and an oscillating pressure gradient. Exact solutions for the velocity of fluid and velocity of magnetic particles will be obtained by means of integral transforms. Obtained results will be expressed in terms of post transient and transient parts. Moreover, to study the influence of the material parameters, numerical simulations and graphical illustrations will be used and useful consequences will be summarized.

[1] Azhar Ali Zafar, Ph.D.: Department of Automation, Biomechanics and Mechatronics, Lodz University of Technology, 1/15 Stefanowski Str., building A22, 90-924 Lodz, Poland (PL), azharalizafar@gmail.com.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowski Street, 90-924 Łódź, Poland (PL), jan.awrejcewicz@p.lodz.pl.

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paper id: EXP89

Towards online transient simulation of a real heat pump

Mariusz Zamojski, Paul Sumerauer, Christoph Bacher, Fadi Dohnal

Abstract: Efficiency and flexibility are key aspects of modern heat pumps for the household. A nonlinear model of the refrigeration cycle is developed in the framework of Matlab/Simulink that will allow for simulation and control design of multiphase fluid dynamics of an existing heat pump. The complexity of the model is balanced against the calculation speed since the ultimate aim is to embed the model-predictive capability in existing products. A finite volume model of the evaporator and the condenser is tuned and benchmarked against real measurements at stationary operation. This capability is the basis for transient startup and shutdown dynamics which enables robust model-predictive control design.

1) Mariusz Zamojski, M.Sc. (Ph.D. student): UMIT GmbH, Linker Iselweg 21, A-9900 Lienz, Austria (AT), mariusz.zamojski@umit.at.

2) Paul Sumerauer, M.Sc.: IDM Energiesysteme GmbH, Seblas 16 - 18, 9971 Matrei in Osttirol, Austria (AT), paul.sumerauer@idm-energie.at.

3) Christoph Bacher, M.Sc.: IDM Energiesysteme GmbH, Seblas 16 - 18, 9971 Matrei in Osttirol, Austria (AT), christoph.bacher@idm-energie.at.

4) Fadi Dohnal, Professor: UMIT GmbH, Linker Iselweg 21, 9900 Lienz, Austria (AT), fadi.dohnal@umit.at.

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A dynamic finite element analysis of metatarsal stress during forefoot and rearfoot strike

Yan Zhang, Jan Awrejcewicz

Abstract: Finite element (FE) method enables the prediction of internal stress distribution of the foot due to its ability to model irregular geometries and complex material properties of different tissues with assigning specific boundary and loading conditions. The purpose of this study is to investigate the bony stresses in metatarsals during forefoot and rearfoot strike. A detailed subject specific FE foot model is developed and validated. A hexahedral dominated meshing scheme was applied to the components of bones and the encapsulated soft tissue. An explicit solver (Abaqus/Explicit) was used to stimulate the transient processes of foot strikes. All materials except for the encapsulated soft tissue considered as hyperelastic property were considered isotropic and linearly elastic. The main bony geometries were embedded in the encapsulated soft tissue volume. The displacement-time data from kinematical experiments was applied on the cross sections of tibia and fibula. The time period of landing phase took 0.1s from initial to full contact. It showed an overall higher average stress level in the metatarsals during the entire landing phase of forefoot strike. The increase rate of the metatarsal stress from initial contact to full contact is 30.76% and 21.39% for forefoot and rearfoot strike respectively. The maximum rate of stress increase among the five metatarsals is observed on the 1st metatarsal in both landing modes. The results indicate that relatively higher stress level during forefoot landing may increase potential of metatarsal injuries such as bony fracture.

[1] Yan Zhang, M.Sc. (Ph.D. student): Department of Automation, Biomechanics and Mechatronics, Piotrkowska 277A, Poland (PL), zhangyannbu@gmail.com.

[2] Jan Awrejcewicz, Professor: Department of Automation, Biomechanics and Mechatronics, Zeromskiego 116, Poland (PL), awrejcew@p.lodz.pl.

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Investigation of influence of various parameters on nonlinear dynamics of contact interaction of Bernoulli-Euler nanobeams

Maxim V. Zhigalov, Jan Awrejcewicz, Sergey P. Pavlov, Vadim A. Krysko

Abstract: Micro-and nanoscale beams in contact with each other are widely used in various micro-and nano-electromechanical systems (vibration sensors, micro-drives, micro-switches). At the same time, as a rule, they work in a wide range of dynamic loads. In this paper, the mathematical model of contact interaction of Bernoulli-Euler beams on the basis of gradient deformation theory is constructed. With the help of Hamilton's variational principle the resolving system of differential equations and the corresponding boundary conditions are obtained. The resulting system of nonlinear partial differential equations is reduced to a system of ordinary differential equations by the method of finite differences of the second order. The Cauchy problem is solved by the fourth order Runge-Kutta method. Fourier and wavelet analysis, phase portraits, Poincaré maps and dynamic analysis of the largest Lyapunov exponents are used to analyze the nonlinear dynamics of the contact interaction. Phase chaotic synchronization is also investigated. With the help of the developed algorithms and programs, the influence of three scale parameters of the length of the material on the deflection of the beam, the natural frequency and oscillation modes of the beam are studied. The problems with different values of clearances between beams and different dissipation factors are considered. Studies have shown a significant effect of the scale parameters of the length of the material, the clearance and the dissipation factor on the dynamic modes of contact interaction of nanobeams.

[1] Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[2] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), jan.awrejcewicz@p.lodz.pl.

[3] Sergey P. Pavlov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), pspsar@yandex.ru.

[4] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Study of EEG signals in a wide range of frequencies in schizophrenia

Maxim V. Zhigalov, Sergey P. Pavlov, Anton V. Krysko, Olga A. Saltykova, Irina V. Papkova, Tatyana Y. Yaroshenko, E.Yu. Krylova, Ilya E. Kutepov, Nikolai P. Erofeev, Jan Awrejcewicz, Vadim A. Krysko

Abstract: The appearance of oscillations in all frequency bands is associated with networks of brake interneurons. Coordinated modulation of membrane potentials of pyramidal cell networks allows groups of neurons to work synchronously in the form of vibrational electrical activities. Numerous publications on the study of EEG in schizophrenia have shown that considering only alpha, beta, gamma, delta and theta ranges separately can lead confusions. For example, a decrease in the power and synchronization of the gamma range is recorded in schizophrenia in a stationary state, sensory gating, arithmetic task, speech, the situation of a random event (oddball), etc. However, there are opposite conclusions. Namely, increase of brain activity in the gamma range has been described in other works for somatosensory stimulation, visual recognition tasks and non-drug treatment in schizophrenia. Recent studies using higher sampling rates (2000 Hz and higher) have shown that high-frequency EEG oscillations can have physiological and pathological significance for humans. A comparative analysis of the results of healthy people and symptoms of schizophrenia for a certain age group is carried out. We have employed Fourier and wavelet analyses, autocorrelation function, Lyapunov exponents analysis, etc. It is shown that high-frequency oscillations (up to 5000 Hz) can serve as a new biomarker for determining schizophrenia.

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[1] Maxim V. Zhigalov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), zhigalovm@ya.ru.

[2] Sergey P. Pavlov, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), pspsar@yandex.ru.

[3] Anton V. Krysko, Professor: Department of Applied Mathematics and Systems Analysis, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), anton.krysko@gmail.com.

[4] Olga A. Saltykova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), olga_a_saltykova@mail.ru.

[5] Irina V. Papkova, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), ikravzova@mail.ru.

[6] Tatyana Y. Yaroshenko, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tyyaroshenko@gmail.com.

[7] E.Yu. Krylova, Associate Professor: Department of Mathematical and Computer Modeling, Saratov State University, 410054 Saratov, Russia (RU), Kat.Krylova@bk.ru.

[8] Ilya E. Kutepov, Associate Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), iekutepov@gmail.com.

[9] Nikolai P. Erofeev, M.Sc. (Ph.D. student): Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), erofeevnp@mail.ru.

[10] Jan Awrejcewicz, Professor: Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland (PL), awrejcew@p.lodz.pl.

[11] Vadim A. Krysko, Professor: Department of Mathematics and Modeling, Saratov State Technical University, Politehnicheskaya 77, 410054 Saratov, Russia (RU), tak@san.ru.

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Energy pumping into mechanistic chain oscillator model

Ádám János Zsiros, János Lelkes, Tamás Kalmár-Nagy, Bendegúz Dezső Bak

Abstract: In this work, we search for an analogy between the energy distribution of a continuous longitudinal vibration of an inhomogeneous rod model and the Kolmogorov spectrum of turbulent flow. This rod model is a continuous limit of a chain oscillator with a spring and a damper between a fixed wall and one end of the chain oscillator. The model describing the system is a wave equation with viscous and elastic boundary conditions. In order to determine the eigenvalues, mode shapes of the rod, separation of variables (space and time) was applied. This method results in a Sturm-Liouville problem for the spatial part. Using series solution for this independent variable, the distributions of the kinetic and the potential energy are calculated. The energy spectrum of the rod is determined for exponentially varying stiffness inhomogeneity.

[1] Ádám János Zsiros, B.A. (M.Sc. student): Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Fluid Mechanics, 1111 Budapest, Műegyetem rakpart 3., Hungary (HU), adam.zsiros@live.com.

[2] János Lelkes, M.Sc. (Ph.D. student): Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Fluid Mechanics, 1111 Budapest, Műegyetem rakpart 3., Hungary (HU), lelkes@ara.bme.hu.

[3] Tamás Kalmár-Nagy, Associate Professor: Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Fluid Mechanics, 1111 Budapest, Műegyetem rakpart 3., Hungary (HU), dsta2019@kalmarnagy.com.

[4] Bendegúz Dezső Bak, M.Sc. (Ph.D. student): Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Fluid Mechanics, 1111 Budapest, Műegyetem rakpart 3., Hungary (HU), bak@ara.bme.hu.

INDEX OF AUTHORS

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