Department of Applied Mathematics NTU “KhPI”

Proposal for Cooperation

Department of Applied Mathematics has almost 70 years of collective experience in scientific studies in the field of mathematics and mechanics.

We invite scientific and industrial organizations to carry out cooperation in the field of development and introduction of new numerical and analytical methods of investigation of regular and chaotic dynamics of non-linear systems, investigation of nonlinear effects in dynamics of thin-walled elements of modern constructions, using composite and functionally-graded materials.

Our scientific results are reflected in a large number of papers and monographs. Some of them are listed here:

- **Y.V. Mikhlin, K.V. Avramov.** Review of applications of nonlinear normal modes for vibrating mechanical systems. *Applied Mechanics Reviews* 65 (2), 2015, 020801.
- **K.Y. Plaksiy, Y.V. Mikhlin.** Resonance behavior of the limited power-supply system coupled with the nonlinear absorber. *Mathematics in Engineering, Science & Aerospace (MESA)* 6 (3), 2015.
- **K.Y. Plaksiy, Y.V. Mikhlin.** Dynamics of nonlinear dissipative systems in the vicinity of resonance. *Journal of Sound and Vibration* 334, 2015, 319-337.
- **NV Perepelkin, YV Mikhlin, C Pierre.** Non-linear normal forced vibration modes in systems with internal resonance. Int. Journal of Non-Linear Mechanics 57, 2013, 102-115.
- **YV Mikhlin, KV Avramov.** Nonlinear normal modes for vibrating mechanical systems. Review of theoretical developments. Applied Mechanics Reviews 63 (6), 2010, 060802.
- **J. Awrejcewicz, L.Kurpa, O. Mazur.** Dynamical instability of laminated plates with external cutout. *Int. Journal of Non-linear Mechanics* 81, 2016, 103-114.
- **J. Awrejcewicz, L. Kurpa, T. Shmatko.** Investigating geometrically nonlinear vibrations of laminated shallow shells with layers of variable thickness via the R-functions theory. *Composite Structures*, 125, 2015, 575–585.
- **J. Awrejcewicz, L. Kurpa, and A. Osetrov.** Investigation of the stress-strain state of the laminated shallow shells by R-functions method combined with spline-approximation. *ZAMM Z. Angew. Math. Mech*., 1 – 10, 2011. DOI 10.1002/zamm.201000164.
- **J.Awrejcewicz, L.Kurpa, O.Mazur.** On the parametric vibrations and meshless discretization of orthotropic plates with complex shape. *Int. J. of Nonlinear Science & Numerical Simulation* 11(5), 2010, 371–386

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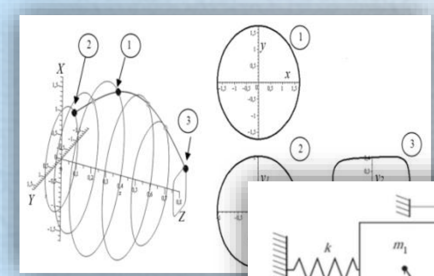
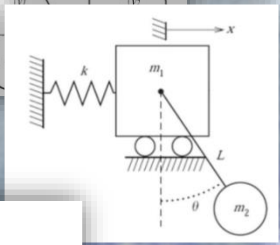
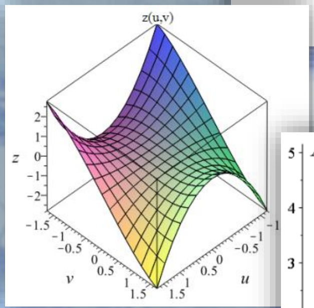
- **LV.Kurpa, TV. Shmatko, GN. Timchenko.** Free vibration analysis of laminated shallow shells with complex shape using the R-functions method // Composite Structures 93, 2010, 225-233.
- **LV. Kurpa, O.S. Mazur.** Method of R-functions for investigating parametric vibrations of orthotropic plates with complex shape. Journal of Mathematical Sciences, 171 (4), 2010, 1-14.
- **Burlayenko V.N., Sadowski T.** Simulations of post-impact skin/core debond growth in sandwich plates under impulsive loading. *Journal of Applied Nonlinear Dynamics* 3(4), 2014, 369–379.
- **Burlayenko V.N., Sadowski T.** Transient dynamic response of debonded sandwich plates predicted with finite element analysis. *Meccanica* 49 (11), 2014, 2617-2633.
- **Burlayenko V.N., Sadowski T.** Nonlinear dynamic analysis of harmonically excited debonded sandwich plates using finite element modelling. *Composite Structures* 108, 2014, 354–366.
- **Burlayenko V.N., Sadowski T.** Finite element nonlinear dynamic analysis of sandwich plates with partially detached facesheet and core. *Finite Elements in Analysis & Design* 62, 2012, 49-64.
- **Burlayenko V.N., Sadowski T.** A numerical study of the dynamic response of sandwich plates initially damaged by low velocity impact. *Computational Materials Science* 52(1), 2012, 212-216.
- **J. Awrejcewicz, L. Dzyubak.** Chaos caused by hysteresis and saturation phenomenon in 2-DOF vibrations of the rotor supported by the magneto-hydrodynamic bearing, *International Journal of Bifurcation and Chaos*, 21(10), 2011, 2801-2823.
- **J. Awrejcewicz and L.P. Dzyubak.** 2-dof nonlinear dynamics of a rotor suspended in the magneto-hydrodynamic field in the case of soft and rigid magnetic materials, *Int. J. of Non-Linear Mechanics* 45, 2010, 919–930.
- **J. Awrejcewicz, L. Dzyubak, C.-H. Lamarque.** Modelling of hysteresis using Masing–Bouc-Wen's framework and search of conditions for the chaotic responses, *Communications in Nonlinear Sciences and Numerical Simulation* 13, 2008, 939-958.

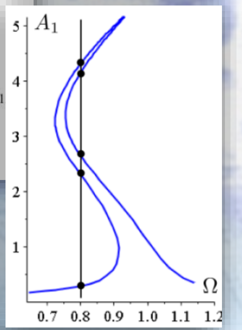
Proposal 1:

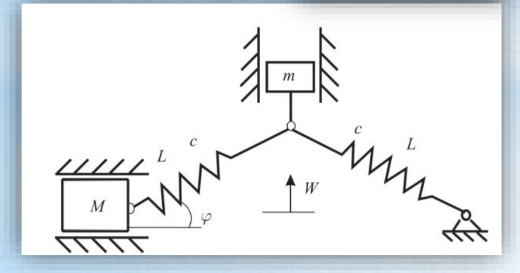
Studies in the field of regular and chaotic dynamics of non-linear systems. In particular, problems of vibration damping by means of nonlinear absorbers, problems of stability of motion, problems of vibro-impact oscillations, nonlinear dynamics of systems with limited power supply: analysis of resonance behavior etc.











Scientific advisor - *Professor Yu.Mikhlin* (muv@kpi.kharkov.ua)

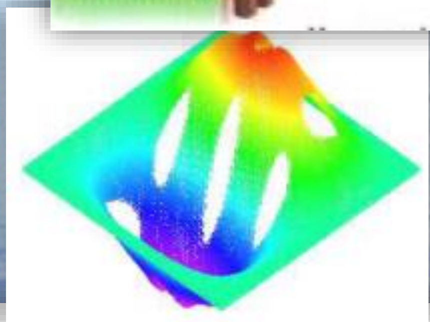
It is expected to describe interaction of vibration modes, the effect of localization of vibration energy, loss of vibration mode stability and appearance of new vibration regimes as a result of bifurcations etc.

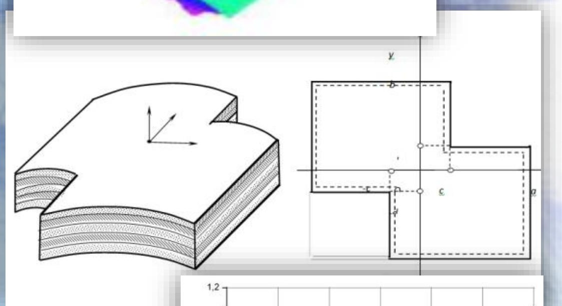
It is expected to determine the system's parameter regions where strong reduction of the vibration amplitudes can be obtained. Results of the investigation of resonance dynamics and vibration absorption during large amplitude resonance dynamics in such systems can be used in engineering practice.

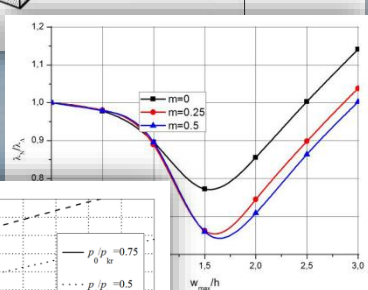
It is planed to investigate dynamics of the non-ideal systems (systems with limited power supply) containing some kinds of nonlinear absorbers, in particular, the pendulum absorber, the snap-through truss (Mises truss) etc. Both n-DOF and distributed non-ideal systems can be considered. In the latter case the Bubnov-Galerkin discretization procedure permits one to obtain the approximate finite-DOF model. Then the multiple scale method and the concept of nonlinear normal modes can be used in the investigation. Behavior of dissipative non-ideal systems with nonlinear absorber in vicinity of the resonance will be considered.

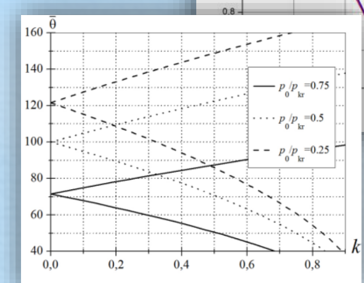
Proposal 2:

Investigation of geometrically nonlinear bending, free and parametric vibration of the laminated and functionally-graded shallow shells by meshless methods, based on R-functions theory









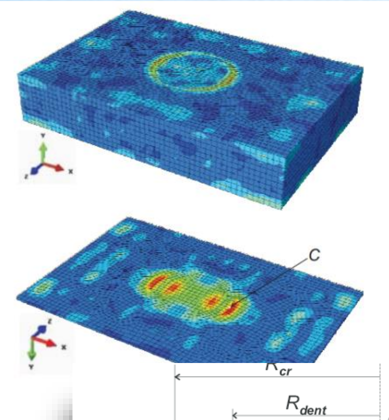
Scientific advisor - *Professor L.Kurpa* (kurpa@kpi.kharkov.ua)

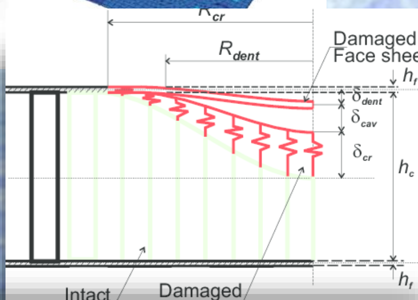
The goal of the project is creation of the universal numerically - analytical method for solving geometrically nonlinear static and dynamic problems of the laminated shallow shells theory with complex plan form and different types of the boundary conditions. The proposed method will be based on the application of the R-functions theory and variational methods, in particular methods by Ritz and Bubnov-Galerkin. This method will be the most competitive with FEM because allows to solve the whole classes of problems and to present unknown solution in analytical form.

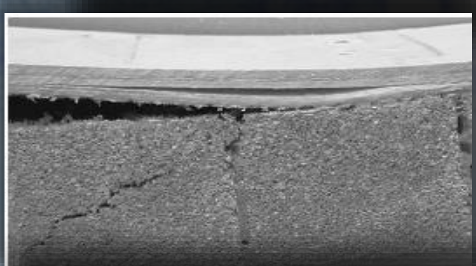
More specific tasks of this project are reduced to the following:

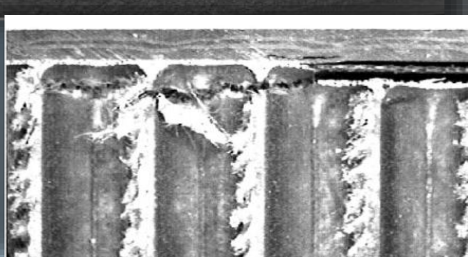
1. Within the framework of the classical and refined theories of the first order to develop algorithms in order to solve geometrically nonlinear bending problems, to find natural frequencies and forms of vibrations of multilayered and functionally-graded shallow shells of arbitrary form in plan.
2. To develop a method of research of geometrically nonlinear vibrations of laminated shallow shells with complex plan-form, using single and many modes approximation of unknown functions.
3. On the basis of the R-functions theory and variational methods to develop numerically - analytical method of research of parametrical vibration of laminated and functionally-graded plates with various kinds of boundary conditions and different geometric forms.

Proposal 3:









Investigation of reliability of material interfaces in laminated and sandwich composites under static and dynamic loads

Scientific advisor - *Assoc. Prof. V. Burlayenko* (burlayenko@kpi.kharkov.ua)

The goal of the proposed research activity is the development of efficient methods and techniques to predict and analyze accurately and realistically fracture of composite laminated and sandwich beams, plates and shells with damaged material interface under static and dynamic loads

Innovative aspects of the proposal

- a new mathematical background for modeling the crack growth phenomenon using adequate fracture criteria associated with mixed-mode fracturing in composite laminated and sandwich panels;
- innovative finite elements models of three-dimensional delaminated/debonded composite laminated and sandwich panels taking into account contact conditions, friction phenomenon and crack propagation;
- advanced finite element modeling techniques to simulate composite laminated and sandwich beams, plates and shells containing a damaged material interface using user-defined programming facilities of the ABAQUS code.

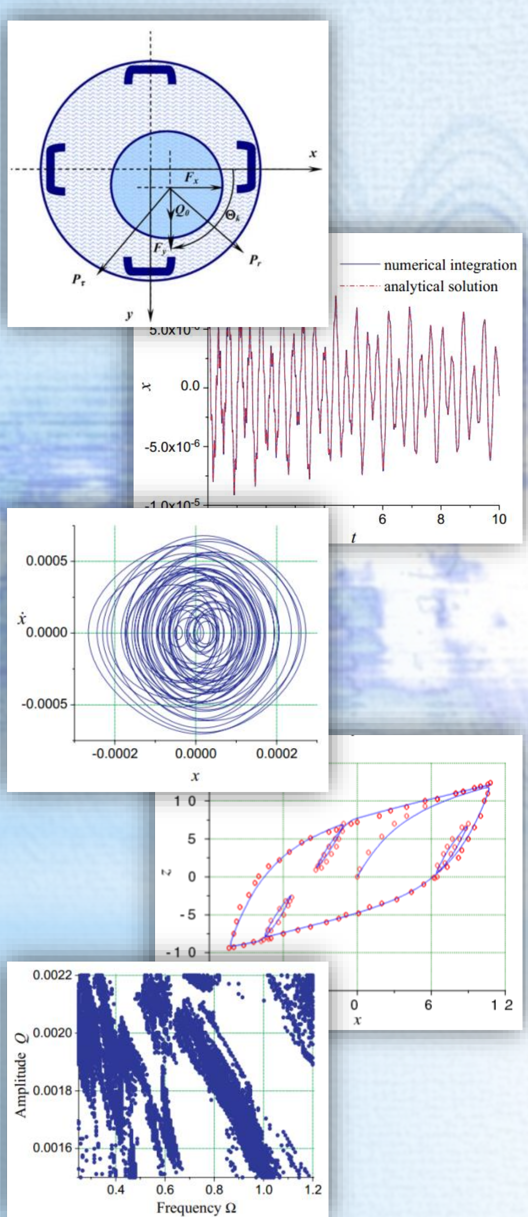
Possible implementation of proposal results

- new accurate and effective simulations will increase scientific knowledge in the field of reliable methods for strength and durability assessment of composite laminated and sandwich panels for real-life engineering applications, particularly, in aero-space, automotive and building manufacturers;
- advanced knowledge of the overall response of composite laminated and sandwich structures with partially damaged material interfaces has a potential to be implemented into innovative technologies for designing real-life composite panels;
- an advanced understanding of fracture modes acquired from the results of research can lead to improvements in design of experimental testing stands for composite materials.

Proposal 4:

Regular and chaotic dynamics of smooth/discontinuous nonlinear systems

Scientific advisor - *Assoc. Prof. L. Dzyubak* (ldzyubak@kpi.kharkov.ua)



In the framework of the proposed project we intend to study:

- **dynamics of impacting beams with clearance nonlinearity:** analytical solutions, describing the transient dynamics of impacting beams with tips separated by clearance, should be obtained. The systems of impacting beams reveal complex dynamics, including chaotic behaviour. It is expected to analyse transient dynamics surfaces, time histories of beams deflections, impacting forces and phase planes as well as conditions for chaotic behaviour depending on the parameters of the systems;
- **2-dof nonlinear dynamics of the rotor suspended in a magneto-hydrodynamic field in the case of soft and rigid magnetic materials:** in the case of soft magnetic materials the analytical solutions are obtained by means of the method of multiple scales. The non-resonant case, the cases of primary resonances with and without an internal resonance are investigated. Chaotic regions and the amplitude level contours of the rotor vibrations are obtained in various control parameter planes.
- **modeling of hysteresis by means of additional state variables:** the analytical models constructed for different types of hysteresis loops allow major and minor loops reproducing and provide a high degree of correspondence with experimental data. Substantial influence of a hysteretic dissipation value on the form and location of the chaotic regions, restraining and generating effects of the hysteretic dissipation on chaos occurrence are ascertained.
- **quantifying regular and chaotic dynamics:** numerous examples of search of conditions for chaotic responses are presented: chaos in the “smooth” test models – Duffing equation and Lorenz system, chaos in the three-well potential oscillator, chaos in the “non-smooth” systems – stick-slip chaotic oscillations in a quasi-autonomous mechanical system with Coulomb and viscous friction, chaos in hysteretic systems, evolution of chaotic regions of the coupled Masing hysteretic oscillators on the increase of the hysteretic dissipation, chaos in the coupled Bouc-Wen and hybrid hysteretic oscillators under sliding friction etc.

CONTACTS:

Postal address:
Department of Applied Mathematics
NTU "KhPI"
2 Kyrpychova (Frunze) str.
Kharkiv 61002
Ukraine

Phone:
Head of the department - (38057) 707 60 32

E-Mail:
kurpa@kpi.kharkov.ua