ORGANIZATIONAL DETAILS

All the details concerning participation in the work of the conference and other organizational details you can find at our website

www.apm-conf.spb.ru

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RUSSIAN ACADEMY OF SCIENCES

Institute for **P**roblems in **M**echanical **E**ngineering

POLYTECH
Peter the Great
St.Petersburg Polytechnic
University

APM
Advanced Problems in Mechanics

XLIV International Summer School - Conference

BOOK OF ABSTRACTS

Dedicated to the 30th anniversary of IPME RAS

St.Petersburg, Russia, 2016

XLIV International Conference
“Advanced Problems in Mechanics”

June 27 – July 02, 2016,
St. Petersburg, Russia

APM 2016
BOOK OF ABSTRACTS

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General Information

The International Conference "Advanced Problems in Mechanics – 2016" is the forty fourth in a series of annual summer schools held by Russian Academy of Sciences. The Conference is organized in commemoration of its founder, Ya.G. Panovko by the Institute for Problems in Mechanical Engineering of the Russian Academy of Sciences (IPME RAS), Peter the Great St.Petersburg Polytechnic University (Institute of Applied Mathematics and Mechanics), Scientific Council on Solid Mechanics (RAS) (chairman N.F. Morozov), Russian National Committee on Theoretical and Applied Mechanics (chairman I.G. Goryacheva) under the patronage of the Russian Academy of Sciences (RAS). The main purpose of the meeting is to gather specialists from different branches of mechanics to provide a platform for crossfertilisation of ideas.

The list of problems under investigation is not limited to questions of mechanical engineering, but includes practically all advanced problems in mechanics, which is reflected in the name of the conference. The main attention is given to problems on the boundary between mechanics and other research areas, which stimulates the investigation in such domains as micro- and nanomechanics, material science, physics of solid states, molecular physics, astrophysics and many others. The conference "Advanced Problems in Mechanics" helps us to maintain the existing contacts and to establish new ones between foreign and Russian scientists.

Young scientists' school-conference "Modern Ways in Mechanics" (MWM), which is held within the annual international conference "Advanced Problems in Mechanics" (APM), is meant for broadening scientific outlook of young researchers in the field of mechanics and also for organizing their scientific dialogue. It is supposed that students, Ph. D. students and young Ph. D.'s under 30 (date of birth is later than 12/31/1985) from different all over the world, specializing in the sphere of theoretical and applied mechanics become the main participants of the conference. In order to attract the largest possible number of various scientific areas and schools, organizing committee suggests a partial compensation for the costs connected with participation in conference, as well as extensive cultural program. One of the major purposes of conference is transfer of scientific experience from well-known scientists to their young colleagues.

History of the School

The first Summer School was organized by Ya.G. Panovko and his colleagues in 1971. In the early years the main focus of the School was on nonlinear oscillations of mechanical systems with a finite number of degrees of freedom. The School specialized in this way because at that time in Russia (USSR) there were held regular National Meetings on Theoretical and Applied Mechanics, and also there were many conferences on mechanics with a more particular specialization. After 1985 many conferences and schools on mechanics in Russia were terminated due to financial problems. In 1994 the Institute for Problems in Mechanical Engineering of the Russian Academy of Sciences restarted the Summer School. The traditional name of "Summer School" has been kept, but the topics covered by the School have been much widened, and the School has been transformed into an international conference. The topics of the conference cover now all fields of mechanics and associated into interdisciplinary problems.

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The conference is organized with help of our service agency “Monomax PCO”: www.monomax.ru

Scientific Program

Presentations devoted to fundamental aspects of mechanics, or spreading the field of applications of mechanics, are invited. We are particularly keen to receive contributions that show new effects and phenomena or develop new mathematical models. The topics of the conference cover all fields of mechanics, including, but not restricted, to

- mechanics of media with microstructure, phase and chemical transformations
- nano- and micromechanics
- computational mechanics
- wave motion
- nonlinear dynamics, chaos and vibration
- solids and structures
- fluid and gas
- mechanical and civil engineering applications
- molecular and particle dynamics
- biomechanics and mechanobiology
- phase transitions
- dynamics of rigid bodies and multibody dynamics
- aerospace mechanics

Accompanying Events

[MS1] Minisymposium " Stochastic Finite Element Techniques for Non-Linear Solids and Structures" (Chair: Prof. U. Nackenhorst)

[MS2] Minisymposium " Mathematical and numerical modelling on Hydraulic Fracture" (Co-chairs: Profs. A. Krivtsov, A. Linkov, G. Mishuris)

[MS3] Minisymposium "Generalized Continuum Theories" (Co-chairs: Profs. W.H. Müller, F. dell'Isola)

Four different forms of presentations are offered, namely, plenary lectures (35 minutes), presentations at minisymposia and short communications (20 minutes), and posters.

The working language for oral presentations is English. Regrettably we can not provide simultaneous translation, and due to the international nature of the conference all the oral presentations must be in English. The working languages for poster sessions are English and Russian.

Attention: each participant may only give one oral presentation. The number of posters for each participant is not limited.

The Summer School – Conference has two main purposes: to gather specialists from different branches of mechanics to provide a platform for cross-fertilization of ideas, and to give the young scientists a possibility to learn from their colleagues and to present their work. Thus the Scientific Committee encouraged the participation of young researchers, and did its best to gather at the conference leading scientists belonging to various scientific schools of the world.

We believe that the significance of Mechanics as of fundamental and applied science should much increase in the eyes of the world scientific community, and we hope that APM conference makes its contribution into this process.

We are happy to express our sincere gratitude for the help in organization to Russian Foundation for Basic Research, Russian Academy of Sciences (RAS), the Ministry of education and science of the Russian Federation. This support has helped substantially to organize the conference and to increase the participation of young researchers.

Russian Academy of Sciences

РФФИ

Day 1 – Monday

ROOM I

08.45–09.30	REGISTRATION
09.30–09.45	OPENING CEREMONY
09.45–11.30	PLENARY LECTURES – I
	COFFEE BREAK
11.50–13.35	PLENARY LECTURES – II
	LUNCH BREAK
14.40–15.15	MWM OPENING
15.15–16.30	MWM PRESENTATIONS
	COFFEE BREAK
16.50–18.20	MWM POSTERS, POSTER SESSION
18.20–19.20	**ENGINEERING COMPETITIONS**
19.30	**WELCOME PARTY**

Day 2 – Tuesday

ROOM I

08.45–10.30	PLENARY LECTURES – III
	COFFEE BREAK
10.50–13.10	PLENARY LECTURES – IV
	LUNCH BREAK
14.20–16.30	MINISYMPOSIUM "MATHEMATICAL AND NUMERICAL MODELLING ON HYDRAULIC FRACTURE"
	COFFEE BREAK
16.50–18.50	COMPUTATIONAL MECHANICS

ROOM II

14.50–15.30	FLUID AND GAS
	BREAK
15.50–16.30	PHASE TRANSITIONS
	COFFEE BREAK
16.50–18.10	BIOMECHANICS AND MECHANOBIOLOGY
19.00–20.00	**INFORMAL CONVERSATION WITH TOP SCIENTISTS**

20.15 CITY TOUR

Day 3 – Wednesday

ROOM I		ROOM II	
09.00–10.45	PLENARY LECTURES – V		
	COFFEE BREAK		
11.05–12.50	PLENARY LECTURES – VI		
	LUNCH BREAK		
14.30–16.20	MECHANICS OF MEDIA WITH MICROSTRUCTURE – I	14.20–16.20	WAVE MOTION
			COFFEE BREAK
	COFFEE BREAK	16.40–19.00	NONLINEAR DYNAMICS, CHAOS AND VIBRATION
16.40–18.20	MECHANICS OF MEDIA WITH MICROSTRUCTURE - II		

19.00–20.30 SCIENTIFIC QUEST

22.00 NIGHT EXCURSION

Day 4 – Thursday

ROOM I		ROOM II	
09.00–10.55	PLENARY LECTURES – VII		
	COFFEE BREAK		
11.15–13.00	PLENARY LECTURES – VIII		
	LUNCH BREAK		
14.00–16.00	MECHANICAL AND CIVIL ENGINEERING APPLICATIONS	14.20–16.00	MINISYMPOSIUM "STOCHASTIC FINITE ELEMENT TECHNIQUES FOR NON-LINEAR SOLIDS AND STRUCTURES"
	COFFEE BREAK		COFFEE BREAK
16.20–18.50	MOLECULAR AND PARTICLE DYNAMICS	16.20–18.20	SOLIDS AND STRUCTURES

20.00 BANQUET

Day 5 – Friday

ROOM I		ROOM II	
09.30–11.50	PLENARY LECTURES – IX		
	COFFEE BREAK		
12.10–13.55	PLENARY LECTURES – X		
	LUNCH BREAK		
15.00–16.40	NANO-AND MICROMECHANICS	15.40–16.40	MINISYMPOSIUM "GENERALIZED CONTINUUM THEORIES"
16.40–17.00	**CLOSING CEREMONY**		

SURPRISE FROM THE ORGANIZERS
17.30 PICNIC

Day 6 – Saturday

10.00 EXCURSION TO PETERHOF

Day 1 ‐ Monday

ROOM I

08.45–09.30 **REGISTRATION**
09.30–09.45 **OPENING CEREMONY**
09.45–11.30 **PLENARY LECTURES – I** *(Chair: D.A. Indeitsev)*
09.45–10.20 ***A.M. Krivtsov***. Unsteady thermal processes in harmonic crystals.
10.20–10.55 ***W.A. Curtin***. The multiscale challenge in modeling fracture of metals.
10.55–11.30 ***M. Kachanov***, *I. Sevostianov*. Microstructures of «irregular» geometry and their quantitative modeling: Towards linking mechanics and materials science.
11.30–11.50 **COFFEE BREAK**
11.50–13.35 **PLENARY LECTURES – II** *(Chair: A.M. Krivtsov)*
11.50–12.25 ***M. Wiercigroch***. Unveiling Complexities of Drill-String and BHA Dynamics.
12.25–13.00 ***G. Mishuris***. Slepyan's method for solving wave and fracture propagation problems in lattice structures: Advantages and limitations.
13.00–13.35 ***L. Banks-Sills***. Statistical Analysis of Interface Fracture and Delamination Failure of Composites.

LUNCH BREAK

14.40–15.15 **MWM OPENING** *(Chair: P.A. Dyatlova)*
L. Beex, E. Schenone, J.S. Hale. POD-based Reduction Methods, the Quasicontinuum Method and their Resemblance.
15.15–16.30 **MWM PRESENTATIONS**
16.30–16.50 **COFFEE BREAK**
16.50–18.20 **MWM POSTERS, POSTER SESSION**
18.20–19.20 **ENGINEERING COMPETITIONS**

19.30 WELCOME PARTY

Day 2 – Tuesday

ROOM I

08.45–10.30 **PLENARY LECTURES – III** *(Chair: E. Grekova)*

08.45–09.20 ***A.B. Freidin,*** *W.H. Müller, S.E. Petrenko, L.L. Sharipova, E.N. Vilchevskaya.* Chemical affinity tensor and kinetics of stress-assisted chemical reaction fronts in solids.

09.20–09.55 ***J. Qu.*** Electro-Chemo-Mechanics of Solids and Its Applications in Fuel Cells and Batteries.

09.55–10.30 ***V.A. Levin,*** *T.A. Zhuravskaya.* Detonation combustion in a supersonic gas flow in a plane channel.

10.30–10.50 **COFFEE BREAK**

10.50–13.10 **PLENARY LECTURES – IV** *(Chair: G. Mishuris)*

10.50–11.25 ***T. Michelitsch,*** *B. Collet, A. Riascos, A. Nowakowski, F. Nicolleau.* Fractional Lattice Dynamics: Nonlocal constitutive behavior generated by power law matrix functions and their fractional continuum limit kernels.

11.25–12.00 ***S. Rudykh.*** Mechanics of Soft Microstructured Materials.

12.00–12.35 ***T.S. Burczynski,*** *A. Mrozek, W. Kus.* Grahpene-like carbon lattices – optimal searching for new stable nanostructures.

12.35–13.10 ***A.M. Linkov.*** The Modified Theory of Hydraulic Fracturing and Its Applications.

LUNCH BREAK

14.20–16.30 **MINISYMPOSIUM "MATHEMATICAL AND NUMERICAL MODELLING ON HYDRAULIC FRACTURE"** *(Chairs: A.M. Linkov, G. Mishuris)*

14.20–14.50 Key-note lecture. ***G. Mishuris,*** *M. Wrobel.* Numerical modelling of Hydraulic Fractures - essentials of accurate and stable computations.

14.50–15.10 ***D. Peck,*** *M. Wrobel, G. Mishuris.* Radial model of hydraulic fracture: benchmark solutions and particle velocity based simulation.

15.10–15.30 ***A.N. Baykin,*** *S.V. Golovin.* Hydraulic fracture propagation in inhomogeneous poroelastic medium.

15.30–15.50 ***A.D. Stepanov,*** *A.M. Linkov.* On increasing efficiency of hydraulic fracture simulation by using dynamic approach of modified theory.

15.50–16.10 ***E. Rejwer,*** *L. Rybarska-Rusinek, D. Jaworski, A.M. Linkov.* Universal computational module accounting for strong field concentration with application to hydraulic fractures.

16.10–16.30 ***I.O. Gladkov.*** Efficient simulation of hydraulic fractures by solving dynamic problem for P3D model.

16.30–16.50 **COFFEE BREAK**

16.50–18.50 **COMPUTATIONAL MECHANICS** *(Chair: V.A. Kuzkin)*

16.50–17.10 ***J. Niiranen,*** *J. Kiendl, A.H. Niemi, V. Balobanov, S. Khakalo, A. Reali, S. Hosseini.* Variational formulations and isogeometric analysis of gradient-elastic thin-walled structures.

17.10–17.30 ***S.N. Shubin,*** *A.B. Freidin.* Nonlinear behavior of rubber-based composites closely filled with ellipsoidal particles.

17.30–17.50 ***E.Yu. Vitokhin.*** Comparison explicit and implicit scheme in case of the hyperbolic heat conduction.

17.50–18.10 ***V.D. Sulimov,*** *P.M. Shkapov.* Application of hybrid algorithms to inverse eigenvalue problems for hydromechanical systems.

18.10–18.30 ***D.A. Potianikhin.*** Numerical simulation of interaction between longitudinal shock wave and the interface of two elastic bodies.

18.30–18.50 ***M.V. Polonik.*** About reducing the residual stresses in metals at temperatures that do not lead to plastic flow.

20.15 CITY TOUR

Day 2 – Tuesday

ROOM II

14.50–15.30 **FLUID AND GAS** *(Chair: O.S. Loboda)*
14.50–15.10 ***I.Yu. Krutova,*** *S.P. Bautin, A.G. Obukhov*. Mathematical and Experimental Simulation of the Ascending Twisting Flows.
15.10–15.30 ***S.A. Chivilikhin.*** Dynamics of high-viscosity fluid droplet on a solid surface.
15.30–15.50 **BREAK**
15.50–16.30 **PHASE TRANSITIONS** *(Chair: E.N. Vilchevskaya)*
15.50–16.10 ***A. Knyazeva.*** Modeling of high temperature synthesis of three layer ceramic composite under loading.
16.10–16.30 ***M.A. Skotnikova,*** *N.A. Krylov*. Phase transitions in titanium alloys at high-speed mechanical effect.
16.30–16.50 **COFFEE BREAK**
16.50–18.10 **BIOMECHANICS AND MECHANOBIOLOGY** (*Chair: O.S. Loboda)*
16.50–17.10 ***K.P. Frolova,*** *E.N. Vilchevskaya, S.M. Bauer*. Determination of the shear viscosity of sclera.
17.10–17.30 ***O.V. Brazgina,*** *E.A. Ivanova, E.N. Vilchevskaya*. Mechanical model of the lung tissue considered as a saturated porous medium.
17.30–17.50 ***G. Vitucci,*** *G.A. Mishuris*. TITH model for cartilage and the related 3D contact problem towards explanation of in-vivo experiments.
17.50–18.10 ***L.B. Maslov.*** Finite-element simulation of fracture healing of a human tibia using mechano-regulation algorithm.

19.00–20.00 INFORMAL CONVERSATION WITH TOP SCIENTISTS

20.15 CITY TOUR

Day 3 – Wednesday

ROOM I

09.00–10.45 **PLENARY LECTURES – V** *(Chair: Chair: A.Metrikine)*
09.00–09.35 ***I. Goryacheva,*** *Y. Makhovskaya.* Modeling of self-lubrication effect in friction interaction of multicomponent alloys.
09.35–10.10 ***L.J. Wang,*** *J.F. Xu, J.X. Wang.* Peridynamic Green's Functions for Elastic and Diffusive Problems.
10.10–10.45 ***S.A. Lurie,*** *V.V. Vasiliev, N.P. Tuchkova.* Nonlocal differential calculus, Helmholtz type theory of elasticity and their applications to singular problems in mechanics of solids.
10.45–11.05 **COFFEE BREAK**
11.05–12.50 **PLENARY LECTURES – VI** *(Chair: S.A. Lurie)*
11.05–11.40 ***B. Markert,*** *S. Patil, Y. Heider.* Linking molecular and continuum mechanics with application to biomimetic nanomaterials and brittle fracture.
11.40–12.15 ***A.V. Metrikine.*** Dynamics of offshore structures in ice.
12.15–12.50 ***A.V. Porubov.*** Control of nonlinear waves in mechanical systems.

LUNCH BREAK

14.30–16.20 **MECHANICS OF MEDIA WITH MICROSTRUCTURE – I** *(Chair: V. Slesarenko)*
14.30–15.00 Key-note lecture. ***E. Charkaluk,*** *P. Baudoin, D. Magisano, A. Constantinescu.* Shakedown state in polycrystals: a direct numerical assessment.
15.00–15.20 ***B. Collet,*** *T. Michelitsch.* Nonlocal approach for simple modes of vibration in cubic crystal nanoplates.
15.20–15.40 ***A.L. Korzhenevskii.*** Metamorphose of near crack tip stress distribution in elastic medium with microstructure.
15.40–16.00 ***I.E. Berinskii.*** Elastic networks model to predict effective auxetic properties of cellular materials.
16.00–16.20 ***A.V. Goshkoderia,*** *S. Rudykh.* Numerical analyses of macroscopic instabilities in soft dielectric elastomers.
16.20–16.40 **COFFEE BREAK**
16.40–18.20 **MECHANICS OF MEDIA WITH MICROSTRUCTURE – II** *(Chair: I.E. Berinskii)*
16.40–17.00 ***V. Slesarenko,*** *S. Rudykh.* Tunable interfaces in soft visco-hyperelastic composites.
17.00–17.20 ***Y.O. Solyaev,*** *A.V. Volkov, S.A. Lurie.* Numerical simulation of the four-point and three-point bending tests in the theory of elastic materials with voids.
17.20–17.40 ***E.E. Batukhtina,*** *V.A. Romanova, R.R. Balokhonov.* Numerical simulation for the deformation behavior of aluminum polycrystals in terms of crystal plasticity.
17.40–18.00 ***Ah. Hakem,*** *Am. Hakem, Y. Bouafia.* Influence of the treatments on the behavior and the damage in tensile and with the shock of the recovery alloy AlSi12: application to the recycling of waste.
18.00–18.20 ***S.H. Sargsyan,*** *M.V. Khachatryan.* Mathematical model of static deformation of micropolar elastic circular thin bar.

19.00–20.30 SCIENTIFIC QUEST

22.00 NIGHT EXCURSION

Day 3 – Wednesday

ROOM II

14.20–16.20 **WAVE MOTION** (*Chair: A.V. Porubov*)

14.20–14.40 *E.L. Aero,* ***A.N. Bulygin,*** *Yu.V. Pavlov.* Functionally invariant solutions of the nonlinear nonautonomous Klein-Fock-Gordon equation.

14.40–15.00 ***M.G. Zhuchkova.*** Scattering of flexural-gravitational waves by a periodic array of obstacles in an elastic plate floating on a thin fluid layer.

15.00–15.20 ***G.V. Filippenko.*** The analysis of energy flux in the infinite cylindrical shell filled with acoustical fluid.

15.20–15.40 ***P.I. Galich,*** *S. Rudykh.* Elastic wave propagation in highly deformable composite materials.

15.40–16.00 ***N. Gorbushin,*** *G. Mishuris.* The prediction of regimes of stable steady-state crack propagation in brittle solids based on discrete model.

16.00–16.20 ***O.V. Dudko.*** Shock wave as a result of increasing nonstationary compression at the boundary of a perfectly elastic porous half-space.

16.20–16.40 **COFFEE BREAK**

16.40–19.00 **NONLINEAR DYNAMICS, CHAOS AND VIBRATION** (*Chair: A.D. Sergeyev*)

16.40–17.00 ***J.F.R. Archilla,*** *Y.O. Zolotaryuk, Yu.A. Kosevich, V.J. Sánchez-Morcillo.* Bound kink states in a model for a cation layer.

17.00–17.20 ***A.V. Ivanov.*** On homoclinics and heteroclinics of Lagrangian systems in a non-stationary force field.

17.20–17.40 ***Y. Vetyukov.*** Modeling nonlinear dynamics of axially moving strings in Eulerian and Lagrangian descriptions.

17.40–18.00 ***I. Golovin,*** *S. Palis, A. Timoschenko, V. Klepikov.* Damping of friction-induced self-excited vibrations applying parallel compensator.

18.00–18.20 ***M. Roohnia,*** *R. Asgari.* Evaluation of sound velocity and dynamic modulus of elasticity in plywood panal by longitudinal vibration test.

18.20–18.40 ***E.B. Azarov,*** *S.A. Rumyantsev.* Self-synchronisation stability of laboratory bench vibrational existers during workload modelling.

18.40–19.00 ***A.A. Mantcybora,*** *M.V. Polonik.* Dynamic problem of longitudinal spherical shock wave in elastic-plastic medium with self-similar restrictions.

19.00–20.30 SCIENTIFIC QUEST

22.00 NIGHT EXCURSION

Day 4 – Thursday

ROOM I

09.00–10.55 **PLENARY LECTURES –VII** *(Chair: B.N. Semenov)*

09.00–09.45 ***D. Indeitsev,*** *Yu. Mochalova, D. Vavilov.* Non-stationary problems of solid mechanics. Problem of diffusion. Phase-structural transformations under dynamic loading.

09.45–10.20 ***M.A. Guzev,*** *A.V. Ustinov.* The thermomechanical characteristics of molecular dynamics and summation formulae.

10.20–10.55 ***V.A. Babeshko.*** Block element forms and factorization methods in cylindrical coordinate systems.

10.55–11.15 **COFFEE BREAK**

11.15–13.00 **PLENARY LECTURES –VIII** *(Chair: D.A. Indeitsev)*

11.15–11.50 ***B.N. Semenov.*** Deformation and fracture of graphene containing defects.

11.50–12.25 ***A.E. Gorodetskiy.*** Smart ElectroMechanical Systems (SEMS).

12.25–13.00 ***U. Nackenhorst.*** Stochastic Finite Element Methods for Non-Linear Solid Mechanics.

LUNCH BREAK

14.00–16.00 **MECHANICAL AND CIVIL ENGINEERING APPLICATIONS** *(Chairs: L.A. Nazarova, L.A. Nazarov)*

14.00–14.20 ***R.V. Guchinsky.*** Damage Accumulation-based and FEA-aided Fatigue Life Evaluation of Tubular Structures.

14.20–14.40 ***L.A. Nazarov.*** Evolution of geomechanical fields and technogenic seismicity of natural objects.

14.40–15.00 ***L.A. Nazarova.*** Methane emission and adsorption-induced deformation of coal beds: Direct and inverse problems.

15.00–15.20 ***O.N. Malinnikova.*** Formation and development of methane filtration waves in stressed coal seams.

15.20–15.40 ***V. Kolykhalin.*** Investigation of the noise reduction effect of ventilating systems.

15.40–16.00 *A.R. Arutyunyan,* ***R.A. Arutyunyan.*** Experimental and theoretical studies of the processis of aging and fracture of polimer materials.

16.00–16.20 **COFFEE BREAK**

16.20–18.50 **MOLECULAR AND PARTICLE DYNAMICS** (*Chair: A.M. Krivtsov*)

16.20–16.50 Key-note lecture. ***V.A. Kuzkin,*** *A.M. Krivtsov.* Oscillations and non equipartition of energies in two- and three-dimensional harmonic crystals.

16.50–17.10 ***A.D. Sergeyev.*** Mechanism of nonlinearity phenomena in longitudinal-and transversal oscillations of a graphene strip.

17.10–17.30 ***A.Yu. Panchenko,*** *E.A. Podolskaya, A.M. Krivtsov.* Determination of the Gruneisen function for 2D crystal lattices.

17.30–17.50 ***M.B. Babenkov,*** *A.M. Krivtsov, O.S. Loboda, D.V. Tsvetkov.* Non-stationary heat transfer equation for a chain of coupled harmonic oscillators.

17.50–18.00 ***A. Sokolov,*** *A.M. Krivtsov.* Localized heat impulses in 1D crystals. solutions for non-fourier heat equation.

18.00–18.10 ***M.V. Simonov,*** *A.M. Krivtsov.* Heat propagation in non-linear one dimensional crystal.

18.10–18.20 ***A. S. Murachev,*** *A. M. Krivtsov.* Non-equilibrium thermal effects in finite one dimensional crystals.

18.20–18.30 ***K.V. Matsyuk,*** *A.M. Krivtsov.* The discrete and continuum approaches to solution the dynamic problems of pin-load action.

18.30–18.50 *N.F. Morozov, P.E. Tovstik,* ***T.P. Tovstik.*** Continual model of multilayer nano plate bending and free vibrations.

20.00 BANQUET

Day 4 – Thursday

ROOM II

14.20–16.00 **MINISYMPOSIUM "STOCHASTIC FINITE ELEMENT TECHNIQUES FOR NON-LINEAR SOLIDS AND STRUCTURES"** *(Chair: U. Nackenhorst)*

14.20–14.40 ***A. Fau,*** *M. Bhattacharyya, D. Néron, U. Nackenhorst.* Proper generalized decomposition for stochastic computations.

14.40–15.00 ***K. Dees,*** *A. Fau, U. Nackenhorst.* Analysis of structural safety under mixed uncertainty assumptions.

15.00–15.20 ***R.L. Gates,*** *M.R. Bittens, U. Nackenhorst.* Combining multilevel and adaptive collocation approaches for the efficient solution of parametric problems.

15.20–15.40 ***M. Grehn,*** *A. Fau, U. Nackenhorst.* A Stochastic Finite Element Approach on Creep of Rock Salt.

15.40–16.00 ***U. Nackenhorst,*** *F. Loerke.* A Discontinuous Galerkin approach for higher dimensional Fokker-Planck equations in non-linear structural dynamics.

16.00–16.20 **COFFEE BREAK**

16.20–18.20 **SOLIDS AND STRUCTURES** *(Chair: N.V. Banichuk)*

16.20–16.40 ***S. Aizikovich,*** *A.S. Vasiliev, S.S. Volkov, B.I. Mitrin.* Semi-analytical solutions for plane contact problems for isotropic and transversely-isotropic half-plane with functionally-graded coating.

16.40–17.00 ***I.D. Breslavskyi,*** *M. Amabili, M. Legrand.* Hyperelastic ring under internal and external pressure.

17.00–17.20 ***N.V. Banichuk,*** *S.Yu. Ivanova.* Deformation and divergence of the moving beams made from thermoelastic materials.

17.20–17.40 ***D. Andreeva,*** *W. Miszuris.* Transmission conditions for thin curvilinear low conductive interphases in composite materials.

17.40–18.00 ***A.N. Fedorova,*** *M.G. Zeitlin.* Veselov-Marsden invariant discrete variational approach and Harten'smultiresolution framework in beam dynamics.

18.00–18.20 ***M.G. Zeitlin,*** *A.N. Fedorova.* Invariant calculations in beam physics: dynamics on semi-direct products and CWT.

20.00 BANQUET

Day 5 – Friday

ROOM I

09.30–11.50 **PLENARY LECTURES –IX** *(Chair: V. A. Eremeyev)*

09.30–10.05 ***M.A.S. Quintanilla.*** The legacy of Antonio Castellanos' work in granular materials.

10.05–10.40 *A. Castellanos, F. Ruiz Botello,* **E. Grekova,** *M.A.S. Quintanilla, V. Tournat.* Acoustic waves in solid-like powders at low and medium consolidation.

10.40–11.15 ***E.C. Aifantis.*** Coupled Gradient Nanomechanics & Applications.

11.15–11.50 ***T. Kitamura,*** *T. Sumigawa.* Challenge to the fracture mechanics in nanometer Scale.

11.50–12.10 **COFFEE BREAK**

12.10–13.55 **PLENARY LECTURES –X** (*Chair: A.B. Freidin*)

12.10–12.45 ***V. Erokhin.*** Nanoengineered organic systems for neuromorphic networks and smart drug carriers.

12.45–13.20 ***V.A. Eremeyev.*** Surface metamaterials: On effective properties of materials at the nano and micro-scales taking into account surface effects.

13.20–13.55 ***W.H. Müller,*** *W. Weiss, E.N. Vilchevskaya.* Assessing deformation due to self gravitation - Treacherous pathways of continuum mechanics.

LUNCH BREAK

15.00–16.40 **NANO-AND MICROMECHANICS** (*Chair: E. Grekova*)

15.00–15.20 **S.V. Bobylev,** I.A. Ovid'ko. Micromechanism of transition from intergrain to intragrain deformation in nanocrystalline materials.

15.20–15.40 *A.K. Abramyan, N.M. Bessonov,* ***L.V. Mirantsev,*** *N.A. Reinberg.* Behavior of mixtures of polar and nonpolar liquids in carbon nanotubes.

15.40–16.00 ***D.Yu. Skubov,*** *O.V. Privalova, L.V. Shtukin.* Some of nano- and micro nonlinear electromechanical tasks.

16.00–16.20 *A.L. Kolesnikova,* ***M.Yu. Gutkin,*** *A.V. Proskura, N.F. Morozov, A.E. Romanov.* Wedge disclinations axially piercing bulk and hollow elastic spheres.

16.20–16.40 ***K.E. Aifantis.*** Nanoporous-micropyramid anode Si for Li-ion batteries.

16.40–17.00 **CLOSING CEREMONY**

SURPRISE FROM THE ORGANIZERS

17.30 PICNIC

Day 5 – Friday

ROOM II

15.40–16.40 **MINISYMPOSIUM "GENERALIZED CONTINUUM THEORIES"**
(Chair: W.H. Müller)
15.40–16.00 *C. Liebold,* ***F.A. Reich****, W.H. Müller*. Modified strain gradient theory and Timoshenko beam assumptions - a direct approach.
16.00–16.20 *B.E. Abali,* ***W.H. Müller***. Comparison of different methodologies leading to a generalized elasticity theory for modeling the size effect.
16.20–16.40 *W.H. Müller,* ***G. Ganzosch***. Experimental techniques applied to generalized continuum theories - A state-of-the-art report.

SURPRISE FROM THE ORGANIZERS

17.30 PICNIC

Day 6 – Saturday

10.00 EXCURSION TO PETERHOF

Information about the Co-Chairmen and Plenary Speakers is available at the end of the Book (see p. 134)

Poster Session

1. **<u>Argunova T.S.</u>, Lim J.H., Gutkin M.Yu., Lyapunova E.A.** Three-dimensional study of cracks in human dentin using synchrotron phase-contrast imaging and microtomography
2. **<u>Arutyunyan A.R.</u>** Influence of aging on fatigue fracture of specimens made of polyurethane
3. **<u>Atroshenko S.A.</u>** Effect of electron beam processing on the characteristics of tool steels
4. **<u>Boltachev G.Sh.</u>, Chingina E.A., Gashkov M.A., Kochurin E.A.** Influence of particle size distribution on processes of cold compaction of oxide nanopowders
5. **<u>Eremeyev V.A.</u>, Sikorska-Czupryna S.** On the elastic properties of coatings constisting of net of polymeric chains
6. **<u>Eremeyev V.A.</u>, Kut S., Ryzińska G.** On the experimental and theoretical study of the elastomer under tension and bending
7. **<u>Evlampieva S.E.</u>** Structural and effective properties of damaged systems
8. **<u>Fedorovsky G.D.</u>** About optimization of an experimental research of thermal deformation, creep and interlayer viscosity of destruction of the reinforced layered plastics. Mathematical modelling and forecasting of defining properties
9. **<u>Frolov P.V.</u>, Ilyina V.P., Orlov I.V., Frolov V.P., Frolova K.P.** On the potential use of high-Mg mineral products from karelia in tribo-engineering
10. **<u>Garishin O.K.</u>, Lebedev S.N.** Determination of nanoscale mechanical properties of rubbers under uniaxial stretching by means atomic force microscopy
11. **<u>Guzev M.A.</u>, Dmitriev A.A.** The resonance criterion for the model of molecular dynamics
12. **<u>Ivanova Yu.E.</u>, Ragozina V.E.** The system of evolution equations for the one-dimensional problem of variable shear loading on the boundary of an inhomogeneous incompressible half-space
13. **Soldatov I.N., <u>Klyueva N.V.</u>** Nondestructive testing of protective coating of layered elastic plates
14. **<u>Komar L.A.</u>, Svistkov A.L.** Mathematical modelling of drug release kinetics through the surface of new generation endoprosthetics
15. **<u>Lurie S.A.</u>, Qi Chengzhi, Belov P.A.** On correctness of gradient plasticity theory
16. **<u>Mantcybora A.A.</u>** Modeling moution of melt particles under the gravity
17. **Dudko O.V., <u>Mantcybora A.A.</u>** The flat self-similar problem about the fall of plane shock wave on the fluid-solid interface
18. **<u>Morozov I.A.</u>** Structural-mechanical AFM mapping of overstressed zones in stretched filled natural rubber
19. **<u>Petrov V.E.</u>** Construction of solution forced quasi 2D turbulence with large-scale dissipation mechanisms on inverse cascade
20. **<u>Potianikhin D.A.</u>** Mathematical simulation of iron reduction from industrial waste with aluminothermic method
21. **<u>Prozorova E.V.</u>** Effects of dispersion and structure molecules on time relaxation
22. **Abramyan A.K., Bessonov N.M., Mirantsev L.V., <u>Reinberg N.A.</u>** Modeling of fluid confined in system of reservoirs connected by means of single-walled carbon nanotube and multi-walled nanotube connection
23. **<u>Sevodina N.V.</u>, Oshamarin D.A., Yurlova N.A.** Finite-element algorithm for numerical implementation of the problem of natural vibrations of electroviscoelastic bodies with external electrical circuits
24. **Garishin O.K., <u>Shadrin V.V.</u>, Gerasin V.A., Guseva M.A.** Experimental research and computer modeling of the mechanical behavior of polymer/clay nanocomposites under large deformations
25. **<u>Shishkin E.V.</u>, Kazakov S.V.** Vibratory crusher forced oscillations near the resonance
26. **<u>Shumova M.A.</u>, Korolev D.V., Smolyanskaya O.V., Chivilikhin S.A.** Investigaton of the sedimentation magnetic nanoparticles on the walls of vessels
27. **<u>Skiba N.V.</u>, Ovid'ko I.A., Sheinerman A.G.** Plastic deformation mechanisms in nanotwinned materials
28. **<u>Svijazheninov E.D.</u>** Dual-purpose resonant supercharger for internal combustion engine

29. **Yakubovich V.I., Shimanovsky A.O.** Mesomechanical analysis of the composite reinforced by grains
30. **Yurkevich K.S., Geis-Gerstorfer J.** Assessment of tooth alveolus damage during occlusion forces action: effect of implant materials
31. **Zahaf A., Djari A., Revo S., Hamamda S., Boubertakh A.** Dilatometry of polyethylene nanocomposite containing 5% of multiwall carbon nanotubes

Young Scientists Session

1. **Alekseev D.V., Bosiakov S.M., Shpileuski I.E., Silberschmidt V.V.** Post-resection load-bearing capacity of human femur: finite-element study
2. **Anisimova M.A.** Formation of the transition zone between the matrix and the inclusion during the casting process under pressure
3. **Antonov I.D., Porubov A.V.** Generation of desired localized nonlinear wave by feedback control
4. **Balobanov V., Niiranen J., Khakalo S.** Isogeometric Analysis of Gradient-Elastic Beams
5. **Bobyl E.A., Gutkin M.Yu., Kolesnikova A.L., Romanov A.E.** Stress fields of a radial disclination loop in an elastic cylinder
6. **Bondarenkov R.S., Porubov A.V.** Feedback control for suppression scheme dispersion
7. **Cherkasova M.K., Mukhamedyarova I.I., Chivilihin S.A.** Crack formation during drying of a dispersed system
8. **Rossikhin Y.A., Shitikova M.V., Duong T.M.** Modeling of the dynamic response of a viscoelastic plate by a viscoelastic spherical shell
9. **Emelianova E.S., Skripnyak N.V., Sergeev M.V., Zinovieva O.S.** On improvement of strength and plasticity of Fe-Cr alloys
10. **Evgrafova A.V., Sukhanovskii A.N., Popova E.N.** The characteristics of steady-state convective cyclonic vortex
11. **Ezhenkova S.I., Chivilikhin S.A.** Finding the distribution density of settling nanoparticles in a liquid with regard to their Brownian diffusion using the boundary layer theory
12. **Fedotov A.V.** Biomorphic approach in application to vibration control of distributed systems
13. **Galanin M.P., Gliznutsina P.V., Lukin V.V., Rodin A.S.** Lagrange multiplier method implementations for two-dimensional contact problems
14. **Golovina D.S., Chivilikhin S.A.** Estimation of the pore size distribution in inhomogeneous nanoporous media
15. **Grigoreva P., Vilchevskaya E.** Influence of stress-dependent diffusion coefficient and chemical affinity on chemical front kinetics under mechanical loads
16. **Grigoriev A.S., Shilko E.V., Skripnyak V.A., Psakhie S.G.** The development of the discrete elements formalism to simulate the mechanical behavior of brittle materials under dynamic loading
17. **Grishchenko A.I., Semenov A.S., Guetsov L.B.** Creep model parameter identification of single crystal superalloys with account of I, II and III stages
18. **Rossikhin Yu.A., Shitikova M.V., Guadalupe Estrada Meza M.** Modeling of the dynamic response of a Timoshenko-type viscoelastic beam by a viscoelastic sphere
19. **Rossikhin Yu.A., Shitikova M.V., Kandu V.V.** Free and force driven vibrations of a nonlinear thin plate embedded into a fractional derivative medium
20. **Khakalo K.A., Puisto A., Tighe B.P, Baumgarten K., Alava M.J.** Modelling of coarsening in foams and its influence on foam rheology
21. **Khakalo S., Balobanov V., Niiranen J.** Variational formulation and isogeometric analysis of second strain gradient elasticity with surface effects of nano-structures
22. **Kalinina M.A., Kolchanov N.V., Kolchanova E.A.** Convection of ferrofluids and carrier fluids in a horizontal layer
23. **Kolchanova E.A.** Double-diffusive convection in superposed fluid and porous layers under high-frequency vibrations
24. **Konakov Ya.V., Ovid'ko I.A., Sheinerman A.G.** Influence of nanoinclusions on grain boundary migration in nanocomposite materials
25. **Gutkin M.Yu., Krasnitckii S.A., Smirnov A.M.** Boundary-value problem in the theory of elasticity for a long cylinder with an eccentric inclusion of rectangular cross section
26. **Rossikhin Yu.A., Shitikova M.V., Krusser A.I.** The simplest fractional derivative models of viscoelasticity and their correctness in problems of thin body dynamics
27. **Kucher D.A., Chivilikhin S.A**. Modelling early steps of hydrothermal nanoparticle synthesis using OpenFOAM
28. **Kuzniatsova M.G., Shimanovsky A.O.** Influence of the internal friction, viscous and turbulent dissipation of liquid cargo transported in closed tanks on the internal friction and cargo properties
29. **Begun A.S., Kovtanyuk L.V., Lemza A.O.** Creep and plastic flow of the cylindrical layer of a material at changing rotation velocity of a boundary surface

30. **Lukin A.V., Skubov D.Y., Popov I.A.** On the pull-in instability of ferromagnetic membranes and electrostatic MEMS
31. **Markov N.S., Kuzkin V.A.** Thermal expansion of quasi one-dimensional chain with angular interactions
32. **Martynov S.A., Balokhonov R.R., Romanova V.A.** Numerical simulation of stress concentration in deformed materials with a curvilinear modified surface layer - base material interface
33. **Mosheva E.A., Mizev A.I., Kostarev K.G.** Convective instability driven by a neutralization reaction
34. **Mostovaya K.S., Maksimkin A.V., Kaloshkin S.D., Nyaza K.V., Zadorozhny M.Yu.** Shape memory effect in an oriented ultra-high molecular weight polyethylene
35. **Mostovaya K.S., Kaloshkin S.D., Maksimkin A.V., Chukov D.I., Senatov F.S.** Multiwall carbon nanotubes reinforced nanocomposites based on ultra-high molecular weight polyethylene
36. **Mukhamedyarova I.I., Cherkasova M.K., Chivilihin S.A.** Calculations of colloidal solution microdrop drying
37. **Dmitriev A.I., Nikonov A.Yu.** Molecular dynamics study of the relative sliding mechanisms in amorphous silica and carbon
38. **Nikonov A.Yu., Dmitriev A.I., Sharkeev Yu.P.** Molecular dynamics study of the influence of the parameters of the crystallization process during selective laser sintering of alloy Ti-Nb
39. **Eliseev V.V., Oborin E.A.** Statics and harmonic oscillations of springs as rods of arbitrary spatial shape
40. **Osokina A., Michelitsch T.** Local and nonlocal constitutive laws generated by matrix function for the case of 2d square lattices
41. **Parfenova E.S., Knyazeva A.G.** Mathematical modeling of ion implantation process with account the diffusion and mechanical waves interaction
42. **Petrenko S.E., Freidin A.B.** Spherically-symmetric problem of mechanochemistry with visco-elastic reaction product
43. **Gubaidullin A.A., Pyatkova A.V.** Nonlinear effects in acoustic streaming in cylindrical cavity
44. **Bessonov N.M., Golovashchenko S.F., Reinberg N.A.** Modeling of elasto-plastic deformation of aluminium alloy on the base of Voronoi cells mesh
45. **Abramyan A.K., Bessonov N.M., Mirantsev L.V., Reinberg N.A.** Modeling of fluid confined in system of reservoirs connected by means of single-walled carbon nanotube and multi-walled nanotube connection
46. **Rzhavtsev E.A., Gutkin M.Yu.** The formation of low-angle grain boundaries during shock loading of metals and alloys
47. **Arutyunyan A.R., Arutyunyan R.A., Saitova R.R.** Application of mechanical methods for solving the problem of high-temperature creep and long-term strength of metals
48. **Pyatkova A.V., Semenova A.S.** Acoustic streaming in a rectangular cavity
49. **Kostyrko S.A., Shuvalov G.M.** Morphological stability of thin film materials during annealing
50. **Gutkin M.Yu., Krasnitckii S.A., Smirnov A.M.** Misfit dislocations in the parallelepipedal core of a core-shell nanowire
51. **Sokolov A.K., Svistkov A.L., Komar L.A., Shadrin V.V., Terpugov V.N.** Features of simulation of the tire in the conditions movement of the car with acceleration
52. **Wildemann V.E., Staroverov O.A., Lobanov D.S., Belonogov N.S.** The effect of cyclic pre-loading to the residual static strength of composite materials samples
53. **Tiwari A.K., Kumar N.** A neural network model to investigate the effect of frequency and time on loading induced osteogenesis
54. **Vinogradova O.A.** A qualitative analysis of the dynamics of a cylinder on a harmonically oscillating plane with friction
55. **Wang L., Wang J., Xu J.** Peridynamic Thermoelasticity based on non-fourier heat conduction
56. **Zaccagnino F., Cox S.** Numerical simulation of the relaxation of a two-dimensional foam
57. **Zinoviev A.V., Balokhonov R.R., Romanova V.A., Zinovieva O.S.** Influence of the substrate grain size on the mechanical properties of the composition “ceramic porous coating – steel substrate”
58. **Zinoviev A.V., Zinovieva O.S., Ploshikhin V., Romanova V.A., Balokhonov R.R.** Modelling of the microstructure evolution during laser additive manufacturing of steel

Abstracts

THE ROLE OF THERMOMECHANICAL TREATMENTS IN REVERSIBILITY OF SHAPE MEMORY ALLOYS

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Shape memory alloys have a peculiar property to return to a previously defined shape when they are subjected to variation of temperature. These alloys are plastically deformed in low temperate martensitic phase region, and recover the original shape on heating after deformation. These alloys cycle between the deformed and original shapes on cooling and heating, respectively. Shape memory alloys exhibit another property called superelasticity (SE), which is performed in only mechanical manner. These alloys can be deformed in parent phase region just over austenite finish temperature, and recover the original shape on releasing the stress in superelastic manner. Shape memory effect (SME) and superelasticity (SE) is observed in bulk level in shape memory materials, and these properties are facilitated by a solid state phase transformation, martensitic transformation which occurs as twinned martensite in crystallographic level on cooling from high temperature parent phase region, and the twinned structures turn into the detwinned structures with deformation of the alloys in martensitic state.

Shape memory effect is performed thermally in a temperature interval, with successive martensitic transformations; thermal induced martensitic transformation on cooling, and stress induced martensitic transformation by stressing the material in low temperature product phase condition. However, superelasticity is performed mechanically with stress induced martensitic transformation at a constant temperature in the parent austenite phase region of the material.

Both SME and SE is associated martensitic transformation. SME is a result of thermally induced martensitic transformation and deformation of material in the product martensite region, whereas SE is the result of stress-induced martensitic transformation, which occurs by only mechanical stress at a constant temperature. With this stress, parent austenite phase structures turn into the fully detwinned martensite. Superelasticity exhibits rubber like behavior, but it is performed in non-linear way, unlike normal elastic materials. Loading and unloading paths are different, and hysteresis loop reveals energy dissipation.

Martensitic transformations occur with cooperative movement of atoms by means of lattice invariant shears which occur, in two opposite directions, <110 > -type directions on the {110}-type basal planes.

Copper based alloys exhibit this property in metastable β - phase region, which has bcc-based structures at high temperature parent phase field. Lattice invariant shear and twinning is not uniform in copper alloys, and they give rise to the formation of unusual layered complex structures with lattice twinning following two ordered reactions on cooling.

In the present contribution, x-ray diffraction (XRD), transmission electron microscopy (TEM) and differential scanning calorimetry (DSC) studies were carried out on two copper based CuZnAl and CuAlMn alloys. X-ray diffraction profiles and electron diffraction patterns reveal that both alloys exhibit super lattice reflections inherited from parent phase, due to the diffusionless character of transformation.

References

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COUPLED GRADIENT NANOMECHANICS & APPLICATIONS

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A combined theoretical/numerical/experimental program is outlined for extending the Internal Length Gradient (ILG) approach to consider time lags, stochasticity and multiphysics couplings with emphasis at the nanoscale. Through this extension it is possible to discuss the interplay between deformation internal lengths (ILs) and ILs induced by thermal, diffusion or electric field gradients. Size-dependent multiphysics stability diagrams are obtained, and size-dependent serrated stress-strain curves are interpreted through combined gradient-stochastic models. When differential equations are not available for describing material behavior, Tsallis non-extensive thermodynamic formulation is employed to characterize statistical properties. Examples are chosen for ultrafine grain (UFG) nanocrystalline (NC), and bulk metallic glass (BMG) materials. Experiments are suggested for determining ILs through novel laboratory tests by employing specimens with fabricated gradient micro/nano structures. The extension of ILG to consider fractional derivatives and fractal media is explored.In particular, three apparently different emerging research areas of current scientific/technological/biomedical interest are discussed: (i) Plastic instabilities and size effects in NC/ UFG and BMG materials; (ii) Chemomechanical damage, electromechanical degradation, and photomechanical aging in energetic materials; (iii) Brain tissue and neural cell modeling. Finally, a number of benchmark problems is considered in more detail. They include gradient chemoelasticity for Li-ion battery electrodes; gradient piezoelectric and flexoelectric materials; elimination of singularities from crack tips; derivation of size-dependent stability diagrams for shear banding in BMGs; modeling of serrated size-dependent stress-strain curves in micro/nanopillars; description of serrations and multifractal patterns through Tsallis q-statistics; and an extension of gradient elasticity/plasticity models to include fractional derivatives and fractal media.

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NANOPOROUS-MICROPYRAMID ANODE SI FOR LI-ION BATTERIES

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New types of Si patterned surfaces are presented that have a double microstructure as they are comprised of micropyramids that are nanoporous. The pyramid diameter ranges between 1-6mm, while the pores are 50-100nm in diameter and ~100-400nm deep. When used as anodes in Li-ion batteries these nanoporous-micropyramids can accommodate the ~400% expansion that Si experiences upon lithiation, and minimize the formation of the solid electrolyte interface (SEI) that forms upon decomposition of the electrolyte. Particularly, scanning electron microscopy after twenty-five electrochemical cycles reveals that no fracture occurs in either high (1C) or low (0.1C) current densities. This is a unique and significant observation as similar experiments, at 0.1C, on solid Si micropyramid anodes indicate severe fracture [1]. Introducing, hence, a nanostructure on the pyramids allows the patterned Si anodes to retain their morphological and mechanical stability during the Li-insertion and de-insertion process. It can therefore be concluded that inducing a secondary nanostructure can significantly enhance the electrochemical performance of micro-scale configurations [1].

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SEMI-ANALYTICAL SOLUTIONS FOR PLANE CONTACT PROBLEMS FOR ISOTROPIC AND TRANSVERSELY-ISOTROPIC HALF-PLANE WITH FUNCTIONALLY-GRADED COATING

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The paper focuses on the development of the bilateral asymptotic method of solving a class of dual integral equations appearing in the wide range of the contact problems of solid mechanics. Method is extended to a case of transversely-isotropic bodies. Plane contact problems on indentation of a rigid flat-based or cylindrical punch into a surface of an isotropic or transversely-isotropic elastic half-plane with a functionally-graded isotropic or transversely-isotropic coating are considered. Specially designed analytical approximation for the kernel transform of the dual integral equations is used to construct approximated analytical solutions of the contact problems, effective for both small and big values of the characteristic geometrical parameter of the problem. Influence of type of changing of the elastic properties in the coating on the solution of the problem is studied for a whole range of values of the geometrical parameter of the problem (relative coating thickness). Cases of a hard and soft coating (in terms of value of Young's modulus in the coating compared with the Young's modulus of the substrate) are considered. It was shown how the sufficient difference of the value of Young's modulus in the coating and in the substrate redistributes the contact stresses appearing under the punch, especially near the edge of the contact area.

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POST-RESECTION LOAD-BEARING CAPACITY OF HUMAN FEMUR: FINITE-ELEMENT STUDY

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The main method of treatment of benign tumors and metastatic lesions of long bones is a surgical removal of the affected area within an unmodified tissue (surgical resection). After surgery, a sectorial defect of rectangular shape is formed in the bone. Current practical recommendations on compensation of the loss of bone's strength and prevention of pathological fracture after a sectorial resection (load limitation, bone reinforcement or external immobilization) are entirely descriptive. The aim of this study is to develop finite-element-based tools capable to predict post- resection damage in femur caused by resection notches acting as stress concentrators.

This study considers a defect placed in a middle section of a femur on its medial surface. In the first stage of analysis, an experiment study of femur fracture was performed. A resection defect was cut in the middle section of the femur on its medial surface using a special cutting tool, replicating conditions of a real-life surgery. After resection mutually perpendicular notches were formed in each corner of the defect. For the experiments, the femur with a post-resection defect was fixed rigidly with epoxy in a cylindrical base. A bone's position was aligned along a load direction from an upper pole of the femoral head to a middle of an interval between the end points of lower divisions of femoral condyles. A direction of crack propagation coincided with the position of the horizontal (transversal) cut, located closer to the femur's head.

In the second stage, finite-element (FE) modeling of loading of the same femur was implemented; the FE model was developed using computed tomography. A bone tissue was modeled as a homogeneous isotropic linear-elastic medium [1]. Damage assessment of the post-resection bone defect was carried out with the use of ANSYS Damage Status Tool. It was assumed that if a damage variable was equal to 0, then the bone was intact; damage in the range between 0 and 1 signified its evolution; the bone's failure corresponded to a case when damage attained the value of 1.

The highest level of damage in our FE simulations was observed near the notches, from which the crack started propagating in the experiment. The obtained simulation results indicate that pathological fracture after a sectorial resection would not arise only under the static effect of the person's own weight. It could be caused by a dynamic effect of a jump or a fall, or turning or bending of the operated limb. A reasonable agreement between the results of FE simulations and experimental measurements indicates a possibility for using the developed model of the femur with the notches as a basis for recommendations on prevention of pathological fracture after a surgical resection. When the calculated level of damage is equal to zero, the unloading regime can be recommended to a patient. For damage greater than zero (but less than unity), bone reinforcement (stabilization) can be recommended to a patient. Levels of damage reaching unity mean that routine activities of the patient (walking, posture on one (operated) leg, etc.) can lead to pathological fracture of the femur. In this case, complete immobilization or a plaster cast should be advised to a patient.

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TRANSMISSION CONDITIONS FOR THIN CURVILINEAR LOW-CONDUCTIVE INTERPHASES IN COMPOSITE MATERIALS

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We consider the problem of heat transfer in a composite material of cylindrical shape. The structural elements are bonded to the matrix with a closed curvilinear adhesive interphase (precise shapes may vary). This interphase is significantly thinner than the characteristic sizes of the other components and is also characterised by much lower thermal conductivity and exhibits essential nonlinear properties. Direct use of numerical techniques, FEM in particular, leads to computational inaccuracy and even instability[2], whereas asymptotic methods prove to be useful for this kind of problem, as we can use the small thickness of the interphase as an asymptotic parameter. With this technique, we replace the thin interphase with a zero thickness object (imperfect interface) modelled by the evaluated nonlinear transmission conditions[1]. The latter preserve the main physical features of the original interphase. Appropriate numerical simulations verify the validity of this approach and highlight the drawn conclusions. We consider cases of different geometries of the interphase and analyse the influence of the interphase curvature on the accuracy of the transmission conditions.

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FORMATION OF THE TRANSITION ZONE BETWEEN THE MATRIX AND THE INCLUSION DURING THE CASTING PROCESS UNDER PRESSURE

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Liquid-phase methods of preparation of composite materials allow producing of complex shape products with minimal further processing. The process of forming a composite by casting with crystallization under pressure is used to increase density of casting and improve uniformity of particle distribution in the metal matrix.[1]
Of particular interest is represented the processes at the phase boundary, defining the physical and mechanical properties and performance characteristics of the product. The inclusions are coated previously to improve the interphase bonds. During the crystallization process the transition layer with a new chemical compound is formed between the matrix and the inclusion. Similar composites are widely used and analyzed in the literature.[2,3]
In this paper we analyzed numerically the spherically-symmetric problem about formation of the transition zone between the coated particle and the matrix. The model takes into account diffusion and formation of the phase in the transition zone. The aim is to study the influence of technological parameters on the thickness and composition of this zone.

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GENERATION OF DESIRED LOCALIZED NONLINEAR WAVE BY FEEDBACK CONTROL

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Recently [1,2] there were found some feedback algorithms of control that allow us to suppress oscillations on the localized wave fronts and to achieve desired velocity of the wave. The aim of the control was to get the wave that is described by exact or asymptotic solution of the equation under study. A natural extension is in a development of the algorithm that results in obtaining of rather arbitrary localized wave of desired shape and velocity.
We consider the sine- Gordon equation. This equation arises in several mechanical problems. It is known its exact traveling wave solution having a smooth kink shape. We develop a feedback speed-gradient algorithm with the aim to get a localized wave with prescribed velocity. We perform simulations demonstrating appearance of the wave whose shape is not described by any analytical solution. The code is designed in the Wolfram Mathematica program. Various profiles are checked whose shape contain both bumps and holes before or after the front of the wave.

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BOUND KINK STATES IN A MODEL FOR A CATION LAYER

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One peculiarity of the mineral mica muscovite is the presence of dark tracks of magnetite in the cation layer, some due to swift particles and some along the lattice directions due to some kind of lattice excitation called *quodons*. See Ref. [1] for a recent review. Recently a model with realistic interactions for the cation layer of the silicate muscovite mica has been developed [2,3], one of their findings was the existence of a supersonic lattice kink also called a crowdion. This lattice kink have a constant velocity and a constant energy of 26 eV. This energy was of particular interest because it is smaller than the recoil energy of the beta decay of ^{40}K, which is the probably source of *quodons*, but also larger than the energy to eject an atom from the lattice, which is about 8 eV as demonstrated experimentally [4]. It was observed that only positive particles were able to leave a dark track in the mineral, which led to the conclusion that most of quodons also have a positive charge [5]. This property connected with lattice kinks, because they include the transport of an ion K^+ and therefore of a positive charge, which is produced by the emission of an electron during beta decay [6]

The lattice kinks have a structure of a double kink or if described in the distances between particles of a double soliton. This is a particular case of bound solitons who have been described and analyzed in previous publications [7]. In this article we analyze which other multi-kinks can appear in the realistic model for the cation layer of mica muscovite, we analyze their energies and their possible role in the production of tracks in muscovite mica. We also study which is the role of the three potentials involved: repulsive electrostatic potential, short-range nuclear repulsion and on-site potential produced by the rest of the lattice in the appearance of the different lattice-kinks.

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THREE-DIMENSIONAL STUDY OF CRACKS IN HUMAN DENTIN USING SYNCHROTRON PHASE-CONTRAST IMAGING AND MICROTOMOGRAPHY

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Highly incompressible solids are of great interest in many areas including biomimetic which imitates systems and elements of nature to solve human problems. Bio-composites have complex hierarchical structures. In some of them, empty space may occupy up to 20% of volume. Nevertheless, they exhibit the combination of unique strength properties. It is known that endurance, fracture toughness and crack resistance of bio-composites are defined by their complex structural hierarchy. However, factors determining these properties are not clear, because the mechanisms of their deformation behavior are not yet understood. Hard tissues of living organisms represent good model materials for the study of stress relaxation in bio-composites.

Deformation behavior of natural human dentin was an objective of this study. Synchrotron-based phase contrast techniques allow obtaining images of empty cavities in solids with a minimum size from a fraction to a few microns. When a photon energy of synchrotron light is larger than 10 keV, a phase shift per unit path length in a solid object changes a wave field up to 100 or more times faster than absorption.

In-line phase-contrast x-ray imaging and microtomography were used to study deformation-induced cracks in human dentin. Dentin specimens were made of human teeth freshly extracted from patients according to a medical diagnosis. Cut out by a diamond saw, they had a shape of cuboids of different orientations

and sizes. Damaged layer was removed by polishing. Some of the specimens were subjected to compression, tension, bending and shear tests. Different orientations and sizes were prepared for examination of size and shape effects[1].
In the dentin specimens deformation and fracture were investigated in detail. The geometry of cracks was displayed in three dimensions. The trajectories of cracks were found to depend on the type of mechanical loading. A theoretical model of plastic deformation under compression was suggested in which the dentin behaved like a biopolymer.

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INFLUENCE OF AGING ON FATIGUE FRACTURE OF SPECIMENS MADE OF POLYURETHANE

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Polymers and composite materials based on them are widely used in engineering, medicine, aircraft building, etc. At the same time physical and mechanical characteristics of these materials after long-term exploitation are significantly changed caused by the aging process [1-3]. So the investigation of aging processes in these materials is needed. In this work as a model material is used polyurethane, in particular, round reinforced polyurethane drive belt by brand Continental ContiTech with diameter equal to 4 mm. From this belt the specimens with working lengths of 2.5-4.5 mm were cutted out.
Fatigue experiments under repeated tension (the coefficient of asymmetry of a cycle is equal to 0) at a given amplitude variation of displacement and loading frequencies equal to 10 and 5 Hz were carried out. The tests were conducted on a desktop servo-hydraulic fatigue testing machine Si-Plan SH-B. The fatigue curves under these loading frequencies are plotted. The considerable (within one order) frequency dependence of fatigue curves is observed.
Experiments for alternation of cyclic loadings and climatic aging during one year of the unloaded specimens are carried out. Results of tests have shown the effect of considerable hardening and embrittlement during the process of aging. So the number of cycles to fracture for the aged specimens was increased on average more than by 3 times.

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EXPERIMENTAL AND THEORETICAL STUDIES OF THE PROCESSIS OF AGING AND FRACTURE OF POLIMER MATERIALS

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The results of long-term tests of specimens made of polyurethane in tension, compression, cyclic loading, climatic and strain aging, as well as experiments carried out on the rubber samples in tension and climatic aging at room temperature are presented. In all experiments a significant effect of hardening and embrittlement of materials during long-term aging is observed. The tests on cyclic tension and climatic aging of thin circular samples of polyurethane at loading frequencies of 10 and 5 Hz shown that during the aging process the material damaged and losses its deformation characteristics. The obtained results allow formulating the general equations for aging elastic-viscous compressible medium. These equations are written in the scale of real and effective time [1, 2]. The experiments on cyclic loading were carried out on servo hydraulic fatigue testing machine Si-Plan SH-B at cycle tension at the variation of loading amplitude and frequency. In experiments the dissipative processes to change the hysteresis loops width were investigated and the energy dissipation for changing of the samples temperature is measured. Taking into account the aging effects the interconnected kinetic equations for the creep rate and damage parameters are formulated. The Maxwell equation, written in the scale of effective time, and the equation of the hereditary theory of visco-elasticity of Boltzmann-Volterra are used for the description of the degradation processes in polymer and composite materials. The analytical relations for creep, damage parameter and the criteria of long-term strength are obtained. Corresponding theoretical curves are constructed and their qualitative agreement with the experimental curves is shown.

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EFFECT OF ELECTRON BEAM PROCESSING ON THE CHARACTERISTICS OF TOOL STEELS

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One of the promising methods of energetic influences that have a significant impact on the structure, phase composition, physical and mechanical properties of metals and alloys is an electron beam processing (EBP). This method consists in treating the surface of the low-energy pulse high- current electron beams, providing adjustable over a wide range of energy density on the surface of the irradiated material. Ultrahigh heating speed to melting and subsequent cooling of a thin surface layer of material forms the limit temperature gradients. It is provides cooling of the surface layer due to heat transfer in the bulk material at a speed of 104 ... 109 K / s, which can significantly improve the characteristics of the surface material.
In this work it is used low-energy electron beam (20 KeV) [1], whereby hardened layer thickness of several tens of microns is heated by heat transfer. Using pulsed high-current electron beams with high-energy particles, it is possible to heat the surface layer of such thickness without heat transfer - as direct result of the energy of the electron beam. Experiments were conducted by electron-pulse treatment on the electron accelerator "Inus" (electron beam energy is E≈230 KeV, the duration of the current pulse is ≤7mks.
The electron beam treatment causes a change in the physicochemical properties of the metal surface layer that can be used to obtain protective and reinforcing coatings.
Investigation was carried out on 12Cr-V tool steel and speed steel R6M5 and P18. It presents data on the influence of EBP on structure characteristics and mechanical properties of these steels.

Work was financially supported by RFBR grants 16-01-00638, and by St. Petersburg State University (Project no. 6.39.319.2014).

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SELF-SYNCHRONISATION STABILITY OF LABORATORY BENCH VIBRATIONAL EXISTERS DURING WORKLOAD MODELLING

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The presentation states the results of the experimental tests carried out on the oscillatory system with the use of the laboratory vibration bench.
Special attention was paid to the exploration of the workload stability of the so-called preserved self-synchronisation of vibration transport machines with three vibroexciters (VE). This phenomenon involves preserving (under certain conditions) of the synchronous rotation mode in three VE after turning one or two of them off.
In the progress of the tests we placed extra load on the working element of the vibration bench, which changed sufficiently the position of the mass centre. In case of three VE this didn’t lead to the loss of preserved self-synchronisation. This type of VTM was proved to be stable under all tested loads.
Under some restrictions, a similar phenomenon is present in the machines with two VE, but it is not stable under workload.

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NON-STATIONARY HEAT TRANSFER EQUATION FOR A CHAIN OF COUPLED HARMONIC OSCILLATORS

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Non-Fourier heat conduction processes in ideal crystal structures have been intensively studied in the recent decades. The literature is surveyed in the review papers [2, 3]. In this work we consider a one-dimensional crystal in the form of a chain of identical particles with mass *m* that are connected by linear springs with each other and with a fixed base, described by the following equations of motion:

$$\ddot{u}_n = \omega_0^2 (u_{n-1} - (2+\varepsilon) u_n + u_{n+1}), \quad \varepsilon = C_1 / C_0, \quad \omega_0 = \sqrt{C_0 / m} \quad (1)$$

where u_n is the displacement of the *n*-th particle, *m* is the particle mass, C_0 is the stiffness of the interparticle bond, C_1 is the stiffness of the bond between a particle and the fixed base, and dots denote partial time derivatives. The crystal is infinite: the index *n* is an arbitrary integer.

The initial conditions for (1) are $u_n|_{t=0} = 0$, $\dot{u}_i|_{t=0} = \sigma(x)\,\rho_n$, where ρ_n are independent random values with zero expectation and unit variance; $\sigma^2(x)$ is a variance of the initial velocities, which is a slowly varying function of the spatial coordinate $x = na$, where *a* is the lattice constant. These initial conditions correspond to an instantaneous temperature perturbation, which can be induced in crystals, for example, by an ultrashort laser pulse.

We adopt an approach based on the covariance analysis [5, 4] for the velocities $\dot{u}_i$ to obtain a closed equation system determining unsteady thermal processes. The nonlocal temperature $\theta_n(x)$ is introduced as [1, 4]:

$$k_B (-1)^n \theta_n(x) = m \langle \dot{u}_i \dot{u}_j \rangle, \quad (2)$$

where k_B is the Boltzmann constant, $n = j - i$ is the covariance index, $x = \frac{i+j}{2} a$ is the spatial coordinate, *a* is the lattice constant. If $n = 0$ then $i = j$ and quantity θ_n coincides with the kinetic temperature *T*: $\theta_0(x,t) = T(x,t) = \frac{m}{k_B} \langle \dot{u}_i^2 \rangle$, where $i = x/a$. The use of the correlation analysis [1, 4] and the long wavelength approximation allows to formulate the initial value problem for kinetic temperature *T(x,t)* in a simple form:

$$\ddot{T} + \frac{1}{t}\dot{T} = c_*^2 T'', \qquad T|_{t=0} = T_0(x), \qquad \dot{T}|_{t=0} = 0, \quad (3)$$

where $c_* = \frac{c}{2}\left(\sqrt{\varepsilon+4} - \sqrt{\varepsilon}\right)$ is the velocity of a heat wave propagating in a harmonic crystal with a substrate potential, $c = \omega_0 a$ is the sound velocity in a simple harmonic crystal.

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BLOCK ELEMENT FORMS AND FACTORIZATION METHODS IN CYLINDRICAL COORDINATE SYSTEMS

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This work shows that being constructed, the block elements have several stages, where they may have different opportunities and functions. It was established that some stages are more opportune for the research aims and for the construction of new block structures. This stage is called packing up the block element and the element is called packed. At another stage, which is called unpacking, the block elements are more opportune for the performing calculations and clear research of solutions. It is shown that analyses of boundary-value problems by existed methods of variable separation, integral transformations and different insertions from the view of the developed theory are aimed at the analysis specifically in the form of the unblocked element. Exactly this restrained the use of these methods in the boundary problems in no classical fields, that didn't correspond to the framework of space transformation groups [1-6]. The method of the block-level element is convergent not only because it unites several approaches but also because it increases opportunities in research of boundary-value problems in no classical fields [7,8].

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ISOGEOMETRIC ANALYSIS OF GRADIENT-ELASTIC BEAMS

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In the present contribution, static and dynamic beam problems based on the high-order strain-gradient linear elasticity theories [1, 2] are analysed by using isogeometric methods [3]. Both Bernoulli-Euler and Timoshenko beam models are considered. Typically, the aim of the gradient theories of elasticity is to model size-dependent effects arising in micro- and nano-objects as well as to take into account the effect of the microstructure of the material on its mechanical behaviour by introduction the length scale parameters as additional material constants [4]. Such theories enrich the classical energy expressions by new components increasing the order of the corresponding governing partial differential equations [5, 6]. In our approach, the problems are first formulated in a Sobolev space setting and then implemented by utilizing an isogeometric NURBS based discretization providing C^{p-1}-continuity. A modified Timoshenko model is proposed in order to avoid possible shear locking effects.

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DEFORMATION AND DIVERGENCE OF THE MOVING BEAMS MADE FROM THERMOELASTIC MATERIALS

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The problem of stability and out-of-plane deformation analysis is considered for an axially moving elastic web modelled as a beam (undergoing cylindrical deformation). The beam is under homogeneous pure mechanical in-plane tension and thermal strains corresponding to the thermal tension and bending. In accordance with the static approach of stability analysis the problem of out-of-plane thermomechanical divergence (buckling) is reduced to an eigenvalue problem which is analytically solved. This problem corresponds to the case of in-plane thermomechanical tension and zero thermal bending. The general case of deformations induced by combined thermomechanical bending and tension is reduced to nonhomogeneous boundary-value problem and analyzed with the help of Fourier series.

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STATISTICAL ANALYSIS OF INTERFACE FRACTURE AND DELAMINATION FAILURE OF COMPOSITES

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A methodology for measuring the interface fracture toughness of a crack between two isotropic, homogeneous materials and a delamination between two laminae of unidirectional composite materials of differing directions is presented. Four cases are considered. Two isotropic material pairs are described: glass/epoxy and two ceramic clays. Similar studies are presented for two cross-ply laminates: $0^0/90^0$ and $+45^0/-45^0$.

The Brazilian disk specimen was used to carry out mixed mode fracture tests. The load and crack or delamination length at fracture were measured and used in a finite element analysis to determine the displacement field. An interaction energy or *M*-integral was used to determine the stress intensity factors at failure. These in turn were employed to obtain the critical interface energy release rate G_{ic} and one phase angles ψ in two dimensions or two phase angles ψ and ϕ in three dimensions which measure the mode mixity. For the *M*-integral and for each interface crack or delamination, the first term of the asymptotic solution of the field quantities is required. For two isotropic materials, these solutions are well known. For the laminates described here, they were determined by the Stroh and Lekhnitskii formalisms. A failure criterion determined from first principles is presented. The values of G_{ic} and ψ in two dimensions or ψ and ϕ in three dimensions are used to specify the criterion for each material pair. A statistical analysis is presented. Two approaches are taken; one uses the t-statistic to predict a 10% probability of failure; the second uses a standard normal variate to predict a 10% failure probability with a 95% confidence.

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NUMERICAL SIMULATION FOR THE DEFORMATION BEHAVIOR OF ALUMINUM POLYCRYSTALS IN TERMS OF CRYSTAL PLASTICITY

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Aluminum alloys are widely used in up-to-date industry. Prediction of the deformation and fracture behavior of aluminum components and structures has significant research and practice value.

Along with experimental research, computational materials science methods are applied. Numerical modeling calls for construction of constitutive models which adequately describe the material behavior under the load. An advanced method of computational materials science implies the material microstructure to be included in calculations of the boundary-value problems in an explicit form [1]. In the framework of crystal plasticity approach [2], an aluminum polycrystal is treated as a set of single crystals with different crystallographic orientations relative to a global coordinate system. Constitutive equations of grains are developed with account for the elastic and plastic anisotropy on the microscale. The elastic response is defined by the generalized Hook’s law written for an FCC crystal lattice. To simulate the plastic behavior of grains, use is made of the crystal plasticity theory, according to which components of the plastic strain rate tensor are calculated as a sum of plastic shear strains over the active slip systems. The slip system is activated when the critical resolved shear stress reaches its critical value.

The polycrystalline constitutive model has been implemented in the finite-element software ABAQUS/Explicit through a User Subroutine to solve the boundary-value problems in the dynamic formulation. The model was verified by a comparison of the calculation results with experimental data. The single crystal orientation effect on the plastic strain localization has been investigated.

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HYDRAULIC FRACTURE PROPAGATION IN INHOMOGENEOUS POROELASTIC MEDIUM

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Hydraulic fracturing is an important part of modern technologies for intensification of hydrocarbon production. The propagation of the hydraulic fracture is stimulated by the pumping of viscous fluid which creates pressure on fracture's walls high enough to overcome the rock closure stresses and cause the rock failure. Process of the hydraulic fracture growth is governed by several factors: flow of viscous fluid in a narrow fracture's gap, elastic reaction of the fracture's walls, and filtration of fluid from the fracture to the reservoir, rock failure and advance of the fracture tip. Recent progress in the mathematical modelling of hydraulic fracture dynamics is described in review papers [1], [2].

In present work we extend the poroelastic model proposed in [4] to the case of propagating fractures. The model allows determining the porous pressure and the rock deformation coupled with the fracture disclosure and the pressure of the fracturing fluid. The material of the formation is observed as an inhomogeneous permeable medium governed by Biot poroelasticity equations [3]. The advantages of this approach in comparison with the classical approaches based on the KGD and PKN models (see [1], [2]) are the correct account for the interaction of the pore fluid with the fracturing fluid, finiteness of fluid pressure in the fracture's tip, ability for modelling of reservoirs with inhomogeneous physical properties under non-uniform closure stresses. In order to account for the rock failure during fracturing, we adopt the cohesive zone model [5] as the fracture propagation criterion.

The numerical solution of the problem was carried out by the finite element method with the use of a modification of the algorithm proposed in [4]. We demonstrate the numerical convergence of the algorithm and possibility for computation of problems within the scale of engineering practice with a satisfactory accuracy. In the series of numerical experiments, we demonstrate the influence of non-uniform closure stress and inhomogeneous reservoir physical properties to the fracture dynamics. It is shown that the symmetry of fracture wings is essentially sensitive to the inhomogeneity of the reservoir.

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POD-BASED REDUCTION METHODS, THE QUASICONTINUUM METHOD AND THEIR RESEMBLANCE

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Large mechanical simulations are computationally inefficient, because they come with
1. large numbers of degrees of freedom (and hence, the solution of large sys-tems), and
2. large numbers of integration points that need to be visited to construct these large systems.

These two issues are especially problematic for nonlinear problems, because they both occur for each increment, for each iteration. Parallel computations on clusters can be used to speed up large nonlinear simulations. Alternatively, numerical strategies can be employed. In this presentation, two numerical reduction approaches will be considered, including their resemblance. The first category consists of reduced order modelling approaches based on proper-orthogonal-decomposition (POD). The second is the multiscale quasicontinuum (QC) method.

Both methods aim to reduce the large number of degrees of freedom by interpolation (avoiding issue (1)). They also select only a few integration points to sample the contributions of all integration points (avoiding issue (2)). POD methods are broadly applicable, but require many full-scale computations to be performed before they can be applied. Furthermore, relatively few procedures to select the reduced integration points exist [1-2], although we have recently made some contributions in this field [3]. The multiscale QC method on the other hand does not require full-scale computations to be performed a-priori. Also, the application of Dirichlet boundary conditions is more straightforward and the selection of reduced integration points is studied more extensively [4-7]. An important disadvantage of the QC method is that it can only be used for regular lattice computations up till now.

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ELASTIC NETWORKS MODEL TO PREDICT EFFECTIVE AUXETIC PROPERTIES OF CELLULAR MATERIALS

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Materials with periodic cellular microstructure presented as a set of elastic spring of two types: longitudinal and torsional. Different microstructures were considered including triangular, rectangular, regular honeycomb and re-entered honeycomb lattices proposed in [1, 2]. Effective properties of the lattices were determined as the functions of only two elastic parameters of the springs. The qualitative analysis showed that some structures could demonstrate both auxetic and regular properties whereas the inverted honeycombs are auxetics at any values of the springs' stiffness. It was found that two—parametric spring-lattice model can successfully describe the isotopic materials; however can bring some error for higher anisotropy.

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STRESS FIELDS OF A RADIAL DISCLINATION LOOP IN AN ELASTIC CYLINDER

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Radial disclination loops (RDLs), called also Somiliana dislocation loops or ring dislocations, attract much attention [1-6] due to their applicability for theoretical modeling of various three-dimensional (3D) imperfections, such as cylindrical cracks, broken or truncated fibers and fiber-matrix debonding in fiber-matrix composites [1], and for using as virtual defects in the virtual surface defect method of solving 3D boundary value problems in the theory of elasticity [3, 4]. The elastic fields of RDLs are known for the cases when RDLs lie in an elastic infinite space [1-6], in an elastic half space [2, 6] and in two perfectly bonded dissimilar half spaces [2], with the RDL plane parallel to the interface.
The aim of the present work is to find the stress field of a RDL which is symmetrically placed in an elastic cylinder with free surface. To this end, the RDL stress field is considered in the form σ $\sigma()$ + $\sigma(v)$, where the first term is the stress field of a RDL placed in an infinite space, while the second one is an extra stress field which provides the fulfillment of boundary conditions on the free surface of the cylinder. Following the calculation procedure described in [7], we find the extra term $\sigma(v)$ and make sure that the sum stress field σ satisfies the boundary conditions. Our solution is given analytically by the Fourier transforms of the Lipschitz-Hankel integrals, which are convenient for numerical calculations. It is analyzed by means of stress maps and discussed in detail. The strain energy of the RDL in a cylinder is also calculated and discussed.
As an application of the found solution, we consider the stress field of a cylindrical inclusion of finite length, which is symmetrically embedded in a cylinder. The inclusion is characterized by a radial dilatation eigenstrain and is modeled as a dipole of RDLs of the same radius, spaced by a distance equal to the inclusion length. The stress maps of the inclusion are demonstrated and discussed with special attention to stress concentration and possible mechanisms of plastic relaxation.

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MICROMECHANISM OF TRANSITION FROM INTERGRAIN TO INTRAGRAIN DEFORMATION IN NANOCRYSTALLINE MATERIALS

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A micromechanism of the transition from intergrain sliding to intragrain glide is proposed and described theoretically. It represents the ultrahigh-stress-driven splitting of a gliding grain boundary dislocations into gliding lattice dislocations and a sessile grain boundary dislocations. Various dislocation reactions are considered, such as: nucleation of isolated partial lattice dislocations, nucleation of pairs of partial lattice dislocations (dislocation multiplication), sequential splitting of grain boundary dislocations resulting in deformation twins generation. The energy characteristics of these processes are calculated. It is shown that they are energetically efficient and can occur athermally (without the energy barrier) under conditions of the action of ultrahigh mechanical stresses. The critical stresses required for the athermal nucleation and emission of dislocations are calculated. Our theory is consistent with the experimental data [1] on observation of high-density ensembles of dislocations in nanocrystalline nickel after laserdriven deformation.

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INFLUENCE OF PARTICLE SIZE DISTRIBUTION ON PROCESSES OF COLD COMPACTION OF OXIDE NANOPOWDERS

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The processes of cold compaction of nanopowders are simulated in 2D geometry by the granular dynamics method [1, 2], which also known as the discrete element method (DEM) [3]. Model systems, which correspond to the oxide nanopowders having weak and strong tendency to agglomeration, are investigated. The interactions of the particles, in addition to commonly used contact interactions such as Hertz law and Cattaneo-Mindlin law, involve the dispersion forces of attraction and the possibility of the formation/destruction of solid bridges between particles. The solid bridges result from strong pressing of particles to each other which is initiated an action of high dispersive interactions or the compaction process. The influence of particle size distribution on processes of powder cold compaction is analyzed. Processes being simulated are the uniaxial compaction and the uniform pressing. Model systems being studied are monosized systems with particle diameter of 10, 20, and 30 nm; bi-sized systems with different ratio of 10 nm and 30 nm particles; polydisperse systems, which is described by log-normal size distribution with different width. The presence of interparticle dispersion forces and solid bridges is the crucial distinction from the investigation [3] and results to quite different properties of powder body being compacted.

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FEEDBACK CONTROL FOR SUPPRESSION SCHEME DISPERSION

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Correct numerical description of shock waves in mechanical systems requires utilization of schemes with higher-order approximation. An important problem in utilization of the higher-order shock capturing schemes is their ability to maintain the total Variation Diminishing (TVD) condition. In other words, the shock profile should not contain oscillations caused by the dispersion features of the scheme. The second-order schemes, e.g., the Lax-Wendroff and Warming-Beam, are not the TVD schemes, and an improvement of the numerical algorithm is needed. One of such modification is utilization of the so-called limiters whose role is to act as a nonlinear switch between numerical methods applied for an equation under study. Another method concerns addition of artificial viscosity in the scheme. Both methods possess some disadvantages and are not universal for various schemes.

Recently [1,2] there were found some feedback algorithms of control that allow us to suppress oscillations on the wave fronts. Such oscillations also arise in numerical solutions due to use of the higher-order schemes. Therefore, an extension of the method may be suggested to avoid parasitic oscillations caused by the dispersion of the schemes.

We start with the simplest advection equation. A new distributed speed-gradient feedback control algorithm is developed that allows us to suppress scheme dispersion of the Lax-Wendroff and Warming- Beam schemes in a universal manner. As a result stable propagation of a smooth shock wave with desired steepness and velocity is achieved.

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HYPERELASTIC RING UNDER INTERNAL AND EXTERNAL PRESSURE

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In this study we compare the deflection of circular ring made of physically linear and nonlinear materials under pressure. Three versions of Neo-Hookean hyperelastic material are considered, namely the incompressible material [1] and Ogden's [2] and Bower's [1] forms of compressible material. Both cases of external and internal pressures are analyzed and the pressure itself is considered in two different forms: first is the simple radial force (dead load) and the second is deformation-dependent pressure (follower load) [3]. In some cases the analytical solutions are obtained, the rest are solved by combined analytical-numerical approach. An interesting and unexpected feature is observed. While it is well-known that the rod made of Neo-Hookean material under uniaxial load behaves in a manner that is quite close to the behavior of linear material, the Neo-Hookean ring under pressure exhibits a pattern of deformation that is resembles the linear material's reversed pattern, i.e. the load-deflection curve for Neo-Hookean ring under external pressure is close enough to the such a curve for linear material under internal pressure and vice versa. Some mathematical reasoning explaining this type of behavior are provided. The analytical findings are verified with few different finite elements codes.

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FUNCTIONALLY INVARIANT SOLUTIONS OF THE NONLINEAR NONAUTONOMOUS KLEIN-FOCK-GORDON EQUATION

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We develop methods of finding of exact analytical solutions of the nonlinear nonautonomous Klein-Fock-Gordon equation

$$\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}-\frac{1}{v^2}\frac{\partial^2 U}{\partial t^2}=p(x,y,t)F(U)\ . \quad (1)$$

Here $p(x,y,t)$ and $F(U)$ are arbitrary functions. These methods are based on finding of functionally invariant solutions of the partial differential equations. For the first time functionally invariant solutions were used by H.

Bateman for the theory of propagation of electro-magnetic waves [1]. Later, the authors generalized it for some nonlinear equations of mathematical physics [2-5]. Solutions are received in the form of some arbitrary function $U = f(W)$ with W is depending on one or two specially certain functions $\alpha(x, y, t)$, $\beta(x, y, t)$ which are called as ansatzes. Methods of creation of the ansatzes are developed. The offered methods allow to find exact analytical solutions of the equation (1) for partial, but large number of analytical expressions of functions $p(x, y, t)$ and $F(U)$. The general methods of the solution are illustrated by examples of finding of the partial solutions.

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GRAHPENE-LIKE CARBON LATTICES - OPTIMAL SEARCHING FOR NEW STABLE NANOSTRUCTURES

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Carbon has many allotropes such as diamond, graphite and amorphous phase, as well as numerous synthetic structures like graphene and nanotubes. This phenomenon is caused by existence of carbon atoms in various hybridization states, i.e. atoms of carbon with different electronic configurations, which determine types of bondings, angles between them and spatial arrangement of neighboring atoms. Two dimensional graphene-like materials can be considered as periodic, flat atomic networks, made of stable configurations of carbon atoms in certain hybridization states. Depending on arrangement of the considered structure, rectangular or triclinic unit cell of given size and atomic density can be identified. Since the stable configurations of atoms correspond to the global (or local – in the case of isomers) minima on the Potential Energy Surface (PES), such a task can be considered as an optimization problem. However, searching for the global minimum on the PES is a non-trivial, NP-hard problem, because the number nanostructure. Searching for new two dimensional, graphene-like structures can be performed in the same manner, however needs more sophisticated interatomic interaction model, so called bond-order potential, should be applied. The bond-order potential is able to handle various hybridization states of carbon atoms, allowing creation of bondings with proper, neighborhood-dependent geometry. Additionally, in opposite to the isolated for environment atomic clusters, new algorithm should impose periodicity of the created structure.

The optimization of new graphene-like structures allows us to obtain new stable nanostructures with unique material properties. The goal of the paper is to describe a methodology, which can be used to solve topology optimization problem in nano-level by defining optimization objectives and constraints imposed on design variables.

The proposed methodology is based on a hybrid algorithm, which combines the parallel evolutionary algorithm prepared by the authors, and the classical conjugated-gradient minimization of the total potential energy of the optimized atomic system. Since the processed structure is considered as a discrete atomic model, the behavior and the potential energy of carbon atoms are determined using the Adaptive Intermolecular Reactive Empirical Bond Order (AIREBO) [2] potential developed for molecular dynamics simulations of hydrocarbons.

In order to validate the accuracy of the obtained numerical results of the topology optimization, certain arrangements of carbon atoms already known from literature have been examined, e.g. the supergraphene and the graphyne. Since all the tests yield promising results, the proposed optimization algorithm has been applied to search for new stable configurations of a given number of carbon atoms in a unit cell of given size and periodic boundaries [1]. New stable carbon networks found by proposed methodology are presented.

The considered problem can be reformulated and applied to searching for nanostructures with predefined material properties, not only in the case of carbon-based structures.

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SHAKEDOWN STATE IN POLYCRYSTALS: A DIRECT NUMERICAL ASSESSMENT

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It is well known that in high cycle fatigue (HCF), macroscopically, structures undergo elastic shakedown and the stress level (shear amplitude and hydrostatic pressure) commonly determines the lifetime. In this domain, the fatigue phenomenon is due to local plasticity at the grain scale. Therefore, some multiscale HCF multiaxial fatigue criteria were proposed, among them the well-known Dang Van criterion [1]. This criterion supposes that in a polycrystal, some misoriented grains can undergo cyclic plasticity (plastic shakedown), which conduct to crack initiation.
The objective of this work is to validate this assumption by conducting numerical simulations on polycrystalline aggregates. As it is necessary to estimate the stabilized state in each grain of the polycrystal, classical incremental simulations are not the best way as it will be highly time-consuming because of the size of the aggregate. In the recent years, Pommier proposed a method called Direct Cyclic Algorithm to obtain the stabilized response of a structure under cyclic periodic loading, which it is shown to be more efficient compared to an incremental analysis in such situation [2]. However, errors can be obtained in certain case with respect to the incremental solution.
In this work, Crystal Plasticity FEM models, based on dislocation densities and large deformation [3], were used. As a first step, an aggregate of 20 grains of AISI 316L stainless steel under strain controlled cyclic loading was studied. Precise comparisons were conducted with incremental analysis and the results show that DCA seems to be an efficient solution in order to estimate the shakedown state of polycrystalline aggregates. Extensions to notches and gradient areas are also studied.

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CRACK FORMATION DURING DRYING OF A DISPERSED SYSTEM

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In this work the process of crack growth in the monolayer, represented as a set of spheres in the number of m×n pieces is considered. This kind of model would represent a single-layer substance - dispersed system. The system is in equilibrium in the initial moment of time, all forces are compensated. Next, a perturbation of the system is created and mechanical stresses appear between the particles, which result in the rupture of the connecting bridges.
To calculate the force acting between particles connected by bridges of solvent, it is necessary to find the form of the bridge from the solvent, i.e. dependence of R(z) - the equation of the surface lathe object.
Excess (over atmospheric) pressure at a point of a surface of any kind depends on the mean curvature at this point and is given by the Laplace formula (1):

$$\sigma H = p \qquad (1)$$

Here σ – is the surface tension coefficient, H – is the scalar curvature, p – is the excess pressure at the point. After the mathematical transformations, taking into account the values at the border bridge, the differential equation (2) is got.

$$\frac{R''(z)}{(1+R'^2(z))^{\frac{3}{2}}} - \frac{1}{R(z)\sqrt{1+R'^2(z)}} = -\frac{p}{\sigma} \qquad (2)$$

A layer of interconnected particles is considered. The grid consisting of m×n of particles is introduced for this purpose. In this system all extreme nodes are fixed, and the inner able to move in any direction under the action of forces. Each particle can interact only with its immediate neighbors.
One particle is chosen and deviated from the equilibrium position. We will consider changes occurring in the system at various timepoints, to detect patterns of crack formation. At each time step there is the recalculation of all forces, then each particle moves in the direction of its resultant force.
Using the function ode45 in MATLAB mathematical package the numerical solution of the differential equation (2) for further calculation of force operating on particles is received. It is unique and depends on the initial data.
The rupture moment of the connecting bridge is also investigated, that is the critical interparticle distance. When $R_0 = 3.78 \cdot 10^{-6} m$ - the radius of the particle, $V = 0.57 \cdot 10^{-10} m^3$ - volume of solvent, it is $7.65 \cdot 10^{-6} m$.
The dependence of interaction forces between particles on the distance between them is found.
Two-dimensional model of a monolayer of nanoparticles, illustrating the process of formation and propagation of cracks in a disturbed system has been constructed. As a result of simulation a series of images showing the

process of cracks formation has been received.

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DYNAMICS OF HIGH-VISCOSITY FLUID DROPLET ON A SOLID SURFACE

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The two-dimensional Stokes flow isolated volume of viscous fluid under the action explicit surface forces and the potential volume forces described in [1]. In this paper we investigate the problem with mixed boundary conditions. Part of the liquid surface is free. Surface forces here are given explicitly. Another part of the liquid surface is adjacent to a solid wall. Surface forces on this part of boundary are unknown. They are determined by a known and equal to zero velocity point of this part of the surface.

The pressure in the region is represented as an expansion in the complete system of harmonic functions. The resulting pressure of the expansion allows us to calculate the speed of the free part of the surface using methods, close to the ideas of linear elasticity theory [2].

The general theory illustrated by deformation droplet on a solid surface by capillary and gravitational forces. Separately studied loss of drops stability under the force of gravity, directed from a solid wall.

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NONLOCAL APPROACH FOR SIMPLE MODES OF VIBRATION IN CUBIC CRYSTAL NANOPLATES

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The purpose of this presentation is to investigate problems of the thickness-shear vibrations in cubic crystal nano-plates, face-shear and thickness-twist waves in nano-plates.

It has been experimentally observed and established that almost all materials and elastic repetitive structures show a dynamical response with strong dependency on the length and time scales. However, classical continuum theories do not possess an intrinsic length and are insufficient to predict the behavior at variable spatial and temporal scales. In particular, it has been shown that the classic elasticity theory does predict dispersion spectrum of Rayleigh-surface waves motions at any wave length (any wave number in the first Brillouin zone) [1-2]. In contrast, dispersion phenomena at very high frequency can be described from strain or stress gradient enriched continuum models [3-4] provided of characteristic lengths (weak nonlocality and strong nonlocality). These enriched continuum theories, are able to bridge the gap between classical continuum models and lattice dynamic approaches.

Because of their growing potential applications, a particular attention has been given recently devoted to mechanical behavior of nano-structures (beam, plate, shell). Among advanced continuum theories, the Eringen's nonlocal theories have been adopted widely for capturing the length scale effects in ultra-thin nanostructures. In the majority of recent researches, the classical stress gradient Eringen's formulation is postulated as a phenomenological model without systematic arguments supported by molecular dynamics, first principle or experimental results (for eg: phonon dynamics). Some exceptions can be found in the literature for the calibration of nonlocal kernels from with respect to one and two-dimensional lattice dispersion relations (Eringen, Lazar). The calibration of nonlocal models of structural elements (beam and plates) in bending from specific lattice representations is more recent (Challamel et al). Despite of these efforts, the calibration for dynamics problems of non-local kernels, remains to still nowadays a key problem.

In this research one is mainly interested, in the analysis of the propagation of shear horizontal waves in an ultra-thin plate-like with nano-scale thickness (some ten atomic layers). The nonlocal model selected is a simplified version of an anisotropic Helmholtz model (Lazar et al). In particular, the real dispersion spectrum, obtained analytically, shows in contrast to the classical case, that

all modes are dispersive.
The calibration of the only nonlocal coefficient is obtained by matching to exact analytical results concerning the dispersion spectrum, from two-dimensional lattice which include central force interactions between nearest and next-nearest neighbors. It is shown that this parameter depends on the mode considered and the thickness of the plate (number of atomic layer).

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THE MULTISCALE CHALLENGE IN MODELING FRACTURE OF METALS

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Energy dissipation by dislocation plasticity in metals provides the resistance against crack growth that makes metals tough engineering materials. However, homogenized plasticity constitutive laws must fail at a singular crack tip, one consequence of which is that the conditions for crack growth are typically calibrated using experimental data rather than computed from fundamental mechanics. This issue, along with the size-dependence of plasticity and the need to address chemical aspects of fracture, dictates that plasticity and fracture be studied at smaller scales – from the dislocation level down to the atomistic and quantum levels. The severe challenges in simultaneously capturing the macroscopic plasticity and the nanoscale behavior at the crack tip, and doing so on time scales appropriate to real materials, are first discussed.
Emerging multiscale methods for addressing some of these challenges are presented here, including the Coupled Atomistic/Discrete-Dislocation (CADD) model, its extension to Quantum Mechanics, its extension from plane strain to full 3d problems, and the Coupled Discrete-Dislocation/Crystal-Plasticity model, which taken together bridge from quantum to continuum scales of plasticity. Examples of successes are shown and limitations identified.
These advanced multiscale methods, i.e. those that go beyond the basic coupling of atomistics to a hyperelastic continuum (e.g. the Quasicontinuum model), are highly algorithmic, or recipe-based. The coupling is accomplished through ideas akin to domain decomposition but, because the different domains have different constitutive descriptions, the "boundary conditions" at the domain interfaces are non-standard and often non-local. Thus, while these methods preserve important fundamental physics and mechanics with demonstrated high and often controllable accuracy, putting such methods on a firm mathematical foundation appears to be very difficult. However, finding alternative new methods that are derived from a more-formal structure is also a huge challenge because the loss of degrees of freedom (electrons, atoms, dislocations) with increasing scale of description precludes the development of, for instance, a single energy functional from which the mechanics emerges naturally.

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ANALYSIS OF STRUCTURAL SAFETY UNDER MIXED UNCERTAINTY ASSUMPTIONS

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A challenge of engineers is to guarantee a faultless service of structures even under uncertain and changing conditions, for example material parameters or loading conditions may be not precisely known. These uncertainties can be categorized into epistemic or aleatory uncertainties, i.e. imprecise knowledge and probabilistic models, respectively.

The classical approach merges the different sources of uncertainty into a unique probability distribution for the uncertain parameters, which introduces artificially some modeling restrictions. We propose to describe uncertainties using imprecise probability, and particularly a range of probability distributions called probability box [1]. The first part of this presentation will focus on presenting how to describe epistemic uncertainties using probability boxes and how mixed uncertainties are propagated during the computation.
Because of missing mathematical theories suitable to describe epistemic uncertainties, engineers have to design structures to cope with risk, uncertainty and economical costs [2,3]. This requires computational methods providing decision makers clear charts for quantifying the risk based on the available information and accurate computations. Thus, the second part of this presentation deals with reliability analysis based on mixed uncertainties. For illustrations, the methods will be demonstrated on a simple engineering structure.

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PANTOGRAPHIC SECOND GRADIENT CONTINUA: THEORY AND APPLICATIONS

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It is presented the mechanics of pantographic structures: these structures are constituted at microlevel by arrays of beams interconnected by pivots which do not interrupt the continuity of the beams they constrain. Using Cauchy first gradient continuum model we can model this mechanical system at microlevel. However the numerical computations involved in the study the behaviour of these lattices at such a detailed level is too large for being viable. There is therefore space for the study of so-called reduced order models, which, as already suggested by G. Piola, involve generalized continuum theories. Indeed by introducing a non-linear second gradient theory (which generalizes the Kirchhoff-Love theory) it is possible to describe efficiently the experimental behaviour observed in pantographic structures. The number of constitutive parameters needed to completely describe the global behaviour of pantographic sheets reduces to only 4: this thing implies a relevant economy of thought considering the great complexity of the structure. The pantographic structures open the way to more serious problems involved in the technology of composite materials constituted by fibers reinforced matrices: by the way we can also now suggest some of the many applications of pantographic lattices.

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SHOCK WAVE AS A RESULT OF INCREASING NONSTATIONARY COMPRESSION AT THE BOUNDARY OF A PERFECTLY ELASTIC POROUS HALF-SPACE

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Nonlinear dynamic processes of propagation of reversible deformations in porous materials with different strengths properties are studied. The description of the mechanical behavior of porous material is held in the framework of the mathematical model of a perfectly elastic porous medium [1], for which the diagram of a uniaxial deformation is given by a piecewise linear function with a non-zero singular point in the area of compression. Such dependence can be obtained by specifying the two different sets of elastic modules (Lame parameters), each of which corresponds to a separate part of the diagram. As a result, in the different strengths medium the characteristic speed of the motion equations may take two different values, in the same way as in [2-4]. But in contrast to [2-4], in this case the characteristic speed can change its value without changing strain state and can happen, for example, due to application of increasing compressive force on the medium border. As an example, the solution of the nonstationary boundary problem about uniaxial compression of perfectly elastic porous half-space shown that such model feature leads to an occurrence of nonlinear effect – a shock wave. In this case the shock wave appears not at the initial time of loading, but at the time of passage through a singular point of the deformation diagram of a perfectly elastic porous medium. The nonstationary boundary conditions leading to the propagation of the one-dimensional plane shock wave with a constant speed, different from both the characteristic speeds, are shown. Thus, it is shown that the processes of occurrence of non-linear effects of dynamic deformation (shock waves) can be studied in the framework of the simplest piecewise linear models, without exceeding the frame of the small elastic deformation theory.

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MODELING OF THE DYNAMIC RESPONSE OF A VISCOELASTIC PLATE BY A VISCOELASTIC SPHERICAL SHELL

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Two approaches for studying the impact response of viscoelastic engineering systems have been recently overviewed in [1] by the example of the dynamic response of a viscoelastic Bernoulli-Euler beam transversely impacted by an elastic sphere. Following Rabotnov [2], it has been shown that the first approach assumes that Poisson's ratio is a constant, while under the second approach the bulk modulus is considered to be constant. If the contact force is treated via the modified Hertz law, then for investigating the impact response of any viscoelastic structure it is necessary to substitute the rigidity coefficient in the contact force formula in the Hertz contact law by the operator involving the operator representation of viscoelastic analogs of Young's modulus and Poisson's ratio.

In the present paper, the dynamic response of a viscoelastic plate impacted by a viscoelastic spherical shell is investigated using the wave theory of impact. The model developed here suggests that after the moment of impact quasi-longitudinal and quasi-transverse shock waves are generated, which then propagate along the plate and spherical shell. The solution behind the wave fronts is constructed by the theory of discontinuities under the assumption that the reflected waves approach the contact zone after the impact process termination. Since the local bearing of the materials of the colliding viscoelastic bodies is taken into account, then the solution in the contact domain is found via the modified Hertz contact theory involving the operator representation of viscoelastic analogs of Young's modulus and Poisson's ratio. The collision of two elastic spherical shells is considered first [3], and then tending the radius of the shell-target to infinity and using Volterra correspondence principle, according to which the elastic constants in the governing equations should be replaced by the corresponding viscoelastic operators, the solution obtained for elastic shells is extended over the case of the viscoelastic plate impacted by the viscoelastic shell, in so doing viscoelastic features of the impactor and target are described by the standard linear solid model with conventional integer derivatives. During the impact process there occurs decrosslinking within the domain of the contact of the colliding bodies, resulting in more freely displacements of molecules with respect to each other, and finally in the decrease of the material viscosity in the contact zone. This circumstance allows one to describe the behaviour of the materials of the colliding spherical shell and plate within the contact domain by the standard linear solid model involving fractional derivatives, since variation in the fractional parameter enables one to control the viscosity of the material.

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ON IMPROVEMENT OF STRENGTH AND PLASTICITY OF FE-CR ALLOYS

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New materials with a high strength, a corrosion resistance and ductility are necessary for design and manufacturing of the IV generation of nuclear reactors [1]. Fe-Cr alloys are attractive as promising materials for this purpose. The increasing of the strength and ductility can be achieved by the precipitate hardening [2] and texture formation in Fe-Cr. Studies of plastic deformation and fracture processes in Fe-Cr alloys over a wide range of strain rates will facilitate a creation of Fe-Cr alloys with improved properties. In this paper, the review of experimental and theoretical results on the problem of the increase of strength and ductility of new Fe-Cr alloys is presented.

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ON THE EXPERIMENTAL AND THEORETICAL STUDY OF THE ELASTOMER UNDER TENSION AND BENDING

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Elastomers are widely used in modern engineering, for example as elements of tools for metal forming. So, the expeimental and theoretical analysis of the material properties and proper choice of the constitutive equations is highly important. Here we discuss the determination of the proper model for certain relatively rigid elastomer used for metall forming engineering. Using tests on tension, compression and bending for various level of deformations we consider the fitting procedure for the following models of materials: Neo-Hookean, Mooney (with two elastic moduli), Mooney (with two elastic moduli), Signorini, Yeoh, Ogden (with the number of terms in series 1, 2 and 3), Arruda-Boyce, Gent and Marlow [1, 2]. Let us note that it is known that unlike linear elasticity performing of uniaxial tests is not sufficient for proper choice of the model [1, 2]. Thus, one needs to fit all data obtained from various tests to choose and to validate the model. On the other hand, knowing a priori characteristic regime of loading one can use more simple model of nonlinear elastic materials. Here we discuss which model can be used with assumed accuracy for which regimes of loading.

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ON THE ELASTIC PROPERTIES OF COATINGS CONSTISTING OF NET OF POLYMERIC CHAINS

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We discuss the surface elastic properties considering the discrete model of the elastic coating. The model consists of chains of rigid rods with elastic joints. Here we assumed the linear elastic interaction between neighboring elements of the same chain as well as the interaction between neighboring elements of different chains. The elastic energy is similar to used in the theory of polymers the Stockmayer potential. The latter is a Lennard-Jones potential with additional term responsible for dipole interactions between neighboring elements of polymeric chains. As a result, we have in the model transaltional and rotational interactions between chains. Using the homogenization approach proposed in [1] we obtain the elastic parameters used in the surface elasticity. In addition we consider similarities between the considered model of surface elasticity and more classic problems of micromechanics such as rough surface approximation using splines, digital image recognition and other geometrical problems appeared in the elasticity [2].

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SURFACE METAMATERIALS: ON EFFECTIVE PROPERTIES OF MATERIALS AT THE NANO AND MICRO-SCALES TAKING INTO ACCOUNT SURFACE EFFECTS

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Recently the interest grows to development of so-called metamaterials, which properties almost determine by complex inner structure, see for example [1]. Among such materials are superhydrophobic, selfcleaned coatings, etc. These coatings dramatically change the surface physical properties of the material and the material properties at all, see [2] and the references therein. These very promising materials can be called surface metamaterials since their properties are almost determined by inner microstructure and interaction forces acting between elements of the coating.

The aim of the lecture is to discuss new methods and techniques for modeling the behavior of nanostructured materials considering surface/interface properties, which are responsible for the main differences between nano- and macroscale, and to determine their actual material properties at the macroscale. Our approach is intended to study the mechanical properties of materials taking into account surface properties including possible complex inner microstructure of surface coatings.

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NANOENGINEERED ORGANIC SYSTEMS FOR NEUROMORPHIC NETWORKS AND SMART DRUG CARRIERS

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The applications of the molecular architecture methods for realizing systems for information processing and smart delivery/release of drugs will be discussed.

The presentation will be divided into 3 parts:

Neuromorphic systems: concept of "memristor" as electronic analog of synapses [1]; bioinspired circuits [2] and networks [3]; adaptive logic [4] and perceptron [5].

Interfacing with living beings: Physarum polycephalum based electronic systems [6, 7]; interfacing with nervous cells.

Nanoengineered drug containers: technological approaches [8]; targeted delivery [9], triggered release [10].

Current state of the art and perspectives of the further development will be discussed for each branch.

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THE CHARACTERISTICS OF STEADY-STATE CONVECTIVE CYCLONIC VORTEX

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Experimental study of the steady-state cyclonic vortex from isolated heat source in a rotating fluid layer is described. The structure of laboratory cyclonic vortex is similar to the typical structure of tropical cyclones from observational data and numerical modeling including secondary flows in the boundary layer [1-3]. Different constraints of the steady-state hurricane-like vortex were studied. The three main dimensional parameters that define the vortex structure for a fixed geometry - heating flux, rotation rate and viscosity were varied independently. Characteristics of the steady-state cyclonic vortex were measured experimentally for different values of kinematic viscosity (from 5 to 25 cSt), rotation rate (from 0.04 to 0.17 s-1) and heat fluxes (from 2 to 9.2 kWtm2). The crucial importance for the vortex formation has angular momentum exchange in the viscous boundary layer. It was shown that viscosity is one of the main parameters that define steady-state vortex structure. Increasing of kinematic viscosity value may lead to the total suppression of cyclonic motion for fixed values of buoyancy flux and rotation rate. Strong competition between buoyancy and rotation provides the optimal ratio of the heating flux and rotation rate for achieving cyclonic vortex of maximal intensity. It was found that relatively small variation of the rotation rate in the case of low kinematic viscosity leads to the remarkable change of the cyclonic vortex structure and intensity.

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STRUCTURAL AND EFFECTIVE PROPERTIES OF DAMAGED SYSTEMS

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The influence of damage on the structural stresses and strains was verified by studying the behavior of regular and random ensembles of absolutely rigid inclusions enclosed in a soft incompressible matrix. The matrix was loaded at infinity by a unit tensile stress acting along the X-axis. The boundary value problem was solved by the iterative method in the framework of the theory of complex variable functions [1, 2].
A new approach was proposed to estimate the damage effect on the system. According to this approach, actual discontinuities are modeled by changing absolutely rigid inclusions to very soft inclusions with a low value of Poisson's coefficient (ν = 0,25). Damage was introduced in the system according to the following criterion: detachment of the matrix from the inclusion occurs at the time when the maximal value of the average tensile hydrostatic stress at the periphery of the inclusion reaches the value of Young' modulus of the matrix. The dependence of the relative Young modulus on the number of detachments was determined for the case when the volume of matrix filling with solid inclusions was 60%. The load–extension curves of the systems under deformation were obtained. It was shown that in high-filled materials the maximum damage does not exceed 30%, i.e., a considerable number of inclusions in the real systems remain tightly adherent to matrix up to the moment of specimen fracture.
The work was supported by RFBR grant No 15-08-03881-a.

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FINDING THE DISTRIBUTION DENSITY OF SETTLING NANOPARTICLES IN A LIQUID WITH REGARD TO THEIR BROWNIAN DIFFUSION USING THE BOUNDARY LAYER THEORY

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In this work we consider the gradient medium formed by particles settling in a liquid.
Sedimentation process of nanoparticles is investigated in detail in [1, 2], diffusion is investigated in [3-6].
As object of research we take glassful with liquid, which contains particles of different sizes. More heavy particles settle to the bottom, a lighter particles stay at the surface, and thus it is distributed over the depth and creating a gradient medium.
The equation of convective diffusion:

$$\frac{\partial f}{\partial t} + v(R)\frac{\partial f}{\partial x} = D(R)\frac{\partial^2 f}{\partial x^2}, \quad (1)$$

where $v(R)$ is the velocity of sedimentation, f is the particle distribution function, D is the coefficient of diffusion, x is the coordinate, t is the time of sedimentation, R is the radius of nanoparticle.
The initial conditions:

$$f|_{t=0} = f_0(R)\Theta(x), \quad (2)$$

where $\Theta(x)$ – the Heaviside step function.
The boundary conditions:

$$j|_{x=0} = 0 \quad (3)$$
$$j|_{x=L} = 0,$$

where $j = v(R)f - D\frac{\partial f}{\partial x}$ — the particles flux density, L – the depth of liquid.
The solution of this equation (which we describe in [4]) contain only one arbitrary constant, whereby it is impossible to satisfy two boundary conditions (3).The second boundary condition manifested in a rather small coordinate interval (a boundary layer) adjacent to the coordinate $x=L$.
Let use D = 0 in equation (1). Then we get a first order differential equation in tne next form:

$$v(R)\frac{\partial f}{\partial x} + \frac{\partial f}{\partial t} = 0 \quad (4)$$

To find the solution inside the boundary layer we are reduce (4) to a dimensionless form:

$$\varepsilon^{1-2\lambda}\frac{\partial^2 f}{\partial \xi^2} + \varepsilon^{-\lambda}\frac{\partial f}{\partial \xi} - \varepsilon^0\frac{\partial f}{\partial \bar{t}} = 0, \quad (5)$$

where **ε** is a small parameter
We produce cross-linking solutions $\bar{f}^p(\xi)$ inside the boundary layer with the solution $f^0 = Ae^{-\alpha R}$ outside the boundary layer and consider the behavior of individual parts of the equation for $\boldsymbol{\varepsilon \to 0}$.
The final formula for the particle size distribution was

obtained using the Newton polygon:

$$f = f_0(R)\Theta(1-\frac{tv(R)}{L})\left(1+\frac{D(R)}{D(R)+v(R)L}\mathrm{e}^{-\frac{v(R)}{D(R)}(L-x)}\right) \quad (6)$$

This equation is investigated analytically at the moment.

This work was financially supported by the Government of Russian Federation, Grant 074-U01.

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PROPER GENERALIZED DECOMPOSITION FOR STOCHASTIC COMPUTATIONS

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Most civil and mechanical engineering structures exhibits a large lack of knowledge, e.g. material parameters or loading conditions are not precisely known. To improve the predictability for such complex structures, sophisticated techniques based on the probability theory have been proposed. Nowadays, Stochastic Finite Element Method [1] has reached a maturity such that they can be applied to engineering problems. Their limitations lie on the complexity of the required solvers, and on the curse of dimensionality.

We will introduce a reduced order model based on the Proper Generalized Decomposition [2] for probabilistic framework. The gain of this strategy for deterministic parametric analysis has been established, it can reach the order of 25 in industrial examples [3]. To circumvent the curse of dimensionality, the approximation space will be optimized for the representation of random variables. We will overview the benefits and the drawbacks of our approach for accurate uncertain computations. The approach will be illustrated for a simple beam structure.

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VESELOV-MARSDEN INVARIANT DISCRETE VARIATIONAL APPROACH AND HARTEN'SMULTIRESOLUTION FRAMEWORK IN BEAM DYNAMICS

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We consider the applications of discrete wavelet analysis technique (Harten's calculus for maps) to maps, which comes from the discretization of continuous invariant nonlinear polynomial problems (Veselov-Marsden approach) in accelerator physics. Our main point is a generalization of wavelet analysis that can be applied for both discrete and continuous cases. We give explicit multiresolution representation for solutions of discrete problems, which is the correct discretization of our representation for solutions of the corresponding continuous cases.

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ABOUT OPTIMIZATION OF AN EXPERIMENTAL RESEARCH OF THERMAL DEFORMATION, CREEP AND INTERLAYER VISCOSITY OF DESTRUCTION OF THE REINFORCED LAYERED PLASTICS. MATHEMATICAL MODELLING AND FORECASTING OF DEFINING PROPERTIES

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At the development, designing, manufacturing and exploitation of products from the reinforced plastics which manufacture promptly grows, one of the major is the solution of the following problems: optimization, essential reduction of duration of the experimental studying of physicomechanical properties of materials (about one day and less); mathematical modelling and forecasting of properties on along times of operation (10 years and more). Many scientific researches [1-3, etc.] are devoted to the decision of these questions.

1) In the present work, developed by the author, the precision techniques of the express train-measurements on one sample of thermal deformation and creep during 120 minutes at uniaxial stretching in a transverse direction of unidirectional and bidirectional winding fibreglasses on the basis of epoxy binder, in an interval of technological temperatures 20-150 oC in the field of linear thermoviscoelasticity are analyzed. Experimental data are described. On the basis of themperature-time conformity the generalized compliance curves by duration more than 1010 minutes are plotted. Applicability of the non-stationary linear theory of thermoviscoelasticity is checked up experimentally. Laws of interrelation of thermomechanical characteristics of fibreglasses, fibres and binder among themselves are established. Experimental and analytical data have been applied to an estimation and optimization of technological stresses of winding products.

2) A technique of the correct and accelerated measurement of interlayer viscosity of destruction (crack resistance) of the layered reinforced plastics on the basis of glass and carbon fibres, epoxy and polimide thermoplasticity and thermoreactive binders, in an interval of temperatures 20-150 îÑ during deformation of flexible two-console beams with constant speed of moving of the ends is described. The data generalized on temperature are cited. Their mathematical analysis is executed. The experimental and analytical techniques and data have been applied by development of materials and products, and estimations and improvementof their quality.

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BIOMORPHIC APPROACH IN APPLICATION TO VIBRATION CONTROL OF DISTRIBUTED SYSTEMS

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One of important applications of the automatic control theory is suppression of vibrations of distributed systems, which have an infinite number of degrees of freedom [1-5]. The study investigates the modal (or biomorphic) approach to this problem [6,7]. The specified approach, unlike the local one, implies separate control of the eigenmodes of object, and requires appropriate setting of the control loops. The study analyses methods of identification of the object, which is necessary for correct mode separation in the control system.

The experimental part of the research is devoted to the comparison of local and biomorphic approaches to the problem of suppression of forced flexural vibrations of the metal beam. All control systems created use the same elements – piezoelectric sensors and actuators attached to certain locations on the beam [8,9]. It is shown that the created modal control system is more efficient than the local ones in cases where it is necessary to suppress vibrations in the frequency range that include several resonance frequencies of the object.

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THE ANALYSIS OF ENERGY FLUX IN THE INFINITE CYLINDRICAL SHELL FILLED WITH ACOUSTICAL FLUID

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The problem of oscillations of the systems containing pipelines filled with the liquid is one of the actual problems of modern techniques. It is important to estimate the parameters of vibrations and acoustical fields of such objects in order to provide the construction from damaging, but calculation of these complicated systems demands major computing resources. Therefore the consideration of simple model problems which have exact analytical solution [1] is actual. On these models it is possible to analytically explore main effects and also to use them as the test problems for computing packages.
The problem of joint oscillations of infinite thin cylindrical shell with ideal acoustical fluid inside it is considered. The propagating waves and energy flux are analyzed in the system shell-liquid. The comparison of different mechanisms of energy transmission in the shell and input of the energy flux in the water is fulfilled.

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CHEMICAL AFFINITY TENSOR AND KINETICS OF STRESS-ASSISTED CHEMICAL REACTION FRONTS IN SOLIDS

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Oxidation processes in silicon microscale parts of MEMS and in nanowires, lithiation of silicon in lithium ion batteries, intermetallic formation in solder joints are among important examples of stress-assist chemical reactions. The influence of mechanical stresses on the reaction front kinetics was examined by many researches. To take into account stress effects stress-dependent parameters such as oxidant diffusivity, oxide viscosity, a reaction rate parameter were proposed. Another type of models starts from the statement that the velocity of the reaction front is controlled rather by the reaction rate than by the diffusivity (see e.g. [1-3]). Our approach takes into account the fact that the reaction takes place at oriented surface elements and depends on the orientation of the element. The approach is based on a concept of the chemical affinity tensor allowing for a natural way to take into account the effect of a stress-strain state on the kinetics of the reaction front (see [4-6] and reference therein). We derive the expression of the chemical affinity tensor and formulate a kinetic equation in a form of the dependence of the reaction front velocity on the normal component of the chemical affinity tensor. We present solutions of boundary-value problems for solids with propagating chemical reaction fronts. We demonstrate accelerating and blocking the reaction by mechanical stresses and construct the forbidden regions formed by stresses at which the reaction cannot go.

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DETERMINATION OF THE SHEAR VISCOSITY OF SCLERA

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Modification of existing human eye models and creation of new ones, which take into account ever-increasing number of sclera parameters, allow medics to correct disorders of the eye brought on by trauma, disease or ageing more intelligently and qualitatively. Viscosity of sclera is ignored in the most existing models. The reason is that direct measurements of sclera viscosity cause technical problems. However, sclera has viscoelastic properties [1]. This work investigates a method for determination of the shear viscosity of sclera based on a comparison of results of the mathematical modeling and the experimental data on intraocular pressure (IOP) discrete measurements for several minutes after the intravitreal injection [2]. Experimental curves based on measurements of IOP for several minutes after the intravitreal injection have the IOP jump immediately after the injection and then goes down. Biomechanical properties of sclera play a leading role in problems of determining eyeball shape or volume under the IOP, therefore we can consider only sclera in the modelling of eye behavior after the intravitreal injection. We offer to explain IOP reducing by the fact of sclera viscosity existing. To solve the problem we consider viscoelastic spherical layer under the centrally symmetric load: external pressure is absent, displacement of the inner boundary are specified and take into account the intravitreal injection volume. Material of human sclera is linear transversally isotropic. We consider problem in the framework of 3D-dimensional linear viscoelastic theory. This work investigates equation system with two types of boundary conditions. In the former case we suppose that eyeball volume doesn't change during the time of experiment. Therefore we explain IOP reducing only by viscous properties of sclera. In the second case we take into account intraocular fluid outflow [3]. Therefore we explain IOP reducing by both facts: sclera viscosity existing and intraocular fluid outflow existing. Our investigation shows that it is necessary to take into account both of these facts to have the best concurrence between the theoretical results and experimental data. We found values of the shear viscosity of sclera for different cases of BCs, different values of Young's modulus and different numerical algorithms for Inverse Laplace transform [4,5] for IOP determination.

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ON THE POTENTIAL USE OF HIGH-MG MINERAL PRODUCTS FROM KARELIA IN TRIBO-ENGINEERING

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High-Mg rock, known as serpentinite, is now widely used in refractory, ceramic and other industries. One of the new applications of serpentinite is the production of serpentinite-based anti-friction solid lubricant coating used in machine building [1]. The high yield strength of this coating increases wear resistance and lengthens the service time of the rubbing metallic surfaces of the processed mechanisms.

The Republic of Karelia, located in Northwest Russia, has commercial minerals hosted by Mg-bearing and high-Mg rocks, such as serpentine-bearing rocks and serpentinites, recognized as complex mineral products

[2]. Reference samples of serpentine rocks from some Karelian deposits and the potential production of monomineral serpentine from these rocks were studied in the Institute of Geology at the Karelian Research Centre, RAS. Preliminary testing of Aganozero serpentine rock-based tribotechnical mixtures, conducted at Research Laboratory «Tribotech», LLC, has shown that addition of several grams of powder (serpentinite combined with pyroxenite), less than 40 μg in size, to the oil considerably decreases the friction coefficient of the contact surfaces. Furthermore, stable ceramic crust, which absorbs and retains the oil, is formed at increased wear sites. Microcrystalline magnetite ingrowths in serpentine scales increase its autohesion ability of magnetic origin. When in the friction zone, finely dispersed powder of this material, modifies the surface structurally and creates a protective quasi-liquefied layer. The use of this powder in internal combustion engines and other mechanisms can decrease the wear of units 2-3 times, friction loss 2-3 times and vibroactivity by 50-100%.

The application of tribotechnical mixtures results in the partial recovery of the worn surfaces of rubbing units ("non-disassembly repair"). In addition, mechanisms can work for a relatively long time without lubrication in emergency cases (e.g., an internal combustion engine in case of oil leakage). Tribotechnical mixtures, based on Karelian serpentine rocks, are revitalizers; nanopreparations of this class modify self-recovering anti-friction wear-resistant stationary and liquid-crystalline layers on the friction surfaces of machine units [3].

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ELASTIC WAVE PROPAGATION IN HIGHLY DEFORMABLE COMPOSITE MATERIALS

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Elastic waves have been treated in detail due to doubtless gravity for many fields, i.e. seismology, petroleum engineering, medicine applications, etc. Recently, a new class of fabricated acoustic metamaterials with periodic microstructures (referred as phononic crystals) has attracted considerable attention. The astonishing properties of the phononic crystals originate in their microstructure, a proper choice of which may result in negative elastic moduli, mass density and refractive index. Remarkably, even relatively simple homogeneous materials can be utilized to achieve acoustic functionalities such as disentangling of pressure and shear waves by application of the specific deformation field [1]. Moreover, *soft* metamaterials, due to their tolerance of large deformations, open the promising opportunities of manipulating the acoustic properties by deformation. The heterogeneity of the matter together with the deformations can stimulate the development of elastic instabilities [2, 3]. These sudden and reversible geometry transformations can be employed to change the acoustic characteristics [4]. On the other hand, mechanical stimulus applied to the inhomogeneous media influences elastic waves by the change in the local properties, for example, local softening/hardening. It is known that change in the media properties, stress-strain state and stiffening effects [5] can significantly transform elastic wave propagation. Thus, elastic waves can be tuned by designing microstructures, which can be further actively controlled by external stimuli, for example, by mechanical loading [4], electric or magnetic field.

To account for the finite deformation non-linear effects as well as for the material non-linearity, we analyse the wave propagation in terms of the incremental small-amplitude motions superimposed on a finitely deformed state. By utilizing an exact analytical solution for the finitely deformed incompressible composite materials, we derive explicit relations for the phase and group velocities in the finitely deformed composite materials. Moreover, based on the expressions of phase velocities for the finitely deformed compressible homogeneous materials, we estimate the phase velocities of pressure and shear waves propagating in the finitely deformed compressible composite materials.

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EXPERIMENTAL TECHNIQUES APPLIED TO GENERALIZED CONTINUUM THEORIES - A STATE-OF-THE-ART REPORT

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It is well known, that the miniuarizing of modern mechanical systems towards micrometer or even nanometer length scale require new mechanical and material behaviour equations. This was observed in several experiments [1, 2]. Classical/traditional elasticity theory of continuum mechanics can not explain material behavior in this length scales (size effect). This is why generalized continuum theories are used to overcome these limits [2, 3, 4]. Also, lower computing time can be achieved by using generalized continuum theories for simulation models.

There are different reasons why experiments have to be performed for generalized continua. On the one hand new parameters show up in generalized continuum materia equations. If there is a need to use these equations, for example in a simulation study, these parameters have to been measured and determined in experiments before [1, 2, 3, 8]. On the other hand, simulations using generalized continuum models can be validated by experiments, provided that all parameters are known [5]. Unfortunately experimental data in literature for size effect in elasticity is very rare. Some basic research on an euler-beam made out of epoxy is presented in [1, 7]. Other fundamental work was performed by [2] using atomic-force-microscopy and micro-Raman-microscopy on silicon nitride in a loading test.

In the recent past, new experimental techniques have been developed to use generalized continuum theories [3, 5, 6]. Different experiment setups, different materials and different structures were used [1, 3, 5, 6, 7, 8]. This state-of-the-art-report gives an overview of the different experimental techniques which have been applied to different generalized continuum theories. Also, an outlook for future investigations will be given.

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DETERMINATION OF NANOSCALE MECHANICAL PROPERTIES OF RUBBERS UNDER UNIAXIAL STRETCHING BY MEANS ATOMIC FORCE MICROSCOPY

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Atomic force microscopy (AFM) is one of the most promising instruments of materials nanostructure investigation [1]. AFM allows to obtain information not only on the morphology of the inner structure of matter at the nanoscale, but also on its local physical and mechanical properties (which, as experience shows, may differ significantly from what we see at the macro level). The successful development of modern nanotechnologies in materials science is not possible without this knowledge.

The basis of the AFM is the force interaction between the sample surface and the cantilever beam with a sharp silicon probe at the free end. Typically, this probe has the shape of a cone with a rounded apex. The radius of the probe tip (which determines the resolution of device) in modern cantilevers range from 1 to 50 nm. Knowing the relationship between the force acting on the probe, and its depth of indentation can be judged the local mechanical properties of the material.

Atomic force microscopy also allows to explore local strength properties of nanostructured materials. Appropriate experimental studies of the nanostructure of elastomers and elastomeric nanocomposites, pre-stretched at the macro level until prescission states were held in ICMM UB RAS [2]. Experiments have shown that the interaction of the AFM probe with previously deformed surface differs substantially from that observed in samples unloaded.

Most of the standard models used for interpretation of the results of AFM scanning, are based on the solution of the classical problem of Hertz contact between a rigid sphere and a flat linearly elastic half-space, which does not take into account the given factor.

Model studies of contact interaction between the AFM probe and the surface of uniaxially stretched polymer sample were carried out to assess emerging errors. Two types of materials have been considered: 1) neo-Hookean material; 2) real natural rubber NR0-799A (its mechanical properties were approximated by Ogden potential). Contact boundary problem on pressing of hard cone probe with a rounded tip (probe) in a nonlinearly elastic surface has been solved for this purpose. At calculations the sample was subjected to uniaxial tension before the probe indentation. Pre-stretching elongation ratio varied from 1 to 7. The problem was solved in a three-dimensional formulation, finite element method was used. As a result the dependencies between elastic reaction force on the indenter, the indentation depth of the AFM probe into the material and pre-stretching elongation ratio of the sample were built.

Calculations showed that the indentation force essentially depends on the pre-stretching of the sample, with the relationship between F and stretching the sample is nonlinear. The more deformed polymer is the more it manifests itself.

These results are planned further to use in the study of the destruction of polymers at the nanoscale level with the help of atomic force microscopy.

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COMBINING MULTILEVEL AND ADAPTIVE COLLOCATION APPROACHES FOR THE EFFICIENT SOLUTION OF PARAMETRIC PROBLEMS

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This work proposes a scheme for reducing the computational complexity of discretized problems involving the non-smooth forward propagation of moderately high dimensional uncertainty. It combines the adaptive hierarchical sparse grid stochastic collocation method (ASC) [1] with a cost-effective sparse multilevel hierarchy of successively finer discretization of the underlying deterministic problem, an idea borrowed from the multilevel Monte Carlo (MLMC) [2] and stochastic collocation methods (MLSC) [3]. As such, this work can be considered an elaboration on our previous efforts on multilevel adaptive stochastic collocation methods [4]. The multilevel hierarchy exploits the variance decay over differences of successively finer problem discretization in order to reduce, for the more costly deterministic computations, the number of adaptively-chosen collocation points needed to interpolate the parametric solution. The inclusion of adaptivity in stochastic collocation methods generally has two advantages: it extends their exponential convergence characteristics to problems non-smooth in the random parameter domain and is able to detect anisotropy in a reliable manner. In the present case it also aids in the purpose of profit optimization: as the stochastic error is controlled and the work is assumed constant for a given multi-index, the stochastic profit optimization for a single hierarchical difference can be handled entirely in the framework of adaptivity. The method is numerically tested on an academic problem of a parametrically-non-smooth partial differential equation. An approach for going beyond a single scalar quantity of interest is outlined, by which complete parametric vector-field solutions are computed. It is finally remarked that, due to its non-intrusive nature, the method is ideally parallel and can be used to compute stochastic problems using an arbitrary numerical framework for the deterministic sub-problem.

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EFFICIENT SIMULATION OF HYDRAULIC FRACTURES BY SOLVING DYNAMIC PROBLEM FOR P3D MODEL

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The work aims to increase the efficiency of solving hydraulic fracture (HF) problem when employing the conventional P3D model for so-called [3, p. 6-22] “non-equilibrium height growth”. In this case important for practice, the apparent stress intensity factor (SIF) depends on the speed of tips propagating in a considered cross-section. In a numerical scheme, this complication is usually accounted for by employing iterations in the speed at each time step. We develop an approach, which avoids iterations. It consists of solving the dynamic system of ODE obtained by adding the speed equation to the continuity equation averaged over a cross-section [2]. The resulting system is solved by well-developed methods like Runge-Kutta and Adams. Numerical realization of the approach has confirmed its high efficiency. The comparison with the benchmark solution for a three-layered system [1] shows that results are sufficiently close for the case of high toughness. The adequacy of the model for applications is verified by comparing results with the predictions of MFrac simulator.

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LAGRANGE MULTIPLIER METHOD IMPLEMENTATIONS FOR TWO-DIMENSIONAL CONTACT PROBLEMS

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Two-dimensional elastic contact problem is considered. Finite element method with bilinear shape functions is used. The Lagrange multiplier method for contact conditions implementation is used in three ways: node-to-surface method, mortar method and advanced mortar method. In the first method integration is performed with one point from master body and one point from slave body (for each finite element), in the second method integral over a segment of master body is evaluated. The third method is more like the second, except dividing each segment of master body on subsegments according to segments of slave body. Tests showed that the mortar method and the advanced mortar method are more accurate than the node-to-surface method. The advanced mortar method is able to smooth the stress field fluctuations, but only in limited number of problems. A plane problem of contact interaction of the metal rail and composite orthotropic shell in cross-cut section of the electromagnetic accelerator barrel (railgun) is considered. Parallel software package for sparse linear systems of equations solving with MPI technology is designed.

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ESTIMATION OF THE PORE SIZE DISTRIBUTION IN INHOMOGENEOUS NANOPOROUS MEDIA

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In recent years the properties and possible applications of nanoporous materials have been the subject of various researches. One of the problems in this field is the evaluation of the parameters of the inhomogeneous nanoporous media.

We propose a method of estimation of the pore size distribution in inhomogeneous nanoporous medium on the basis of liquid front propagation in it. The sought-for result can be obtained by successfully replicating the evolution of the liquid front profile in the medium.

For the reproduction of the liquid front propagation we use the numerical model which is based on the continuity equation for the incompressible flow and the approximation of Darcy's law [1]. Such model allows us to obtain the distribution of pressure in mediums part, which has been permeated by liquid, and, therefore, the transition of the liquid front.

From there the pore size distribution in the medium can be presented as a polynomial with unknown coefficients and the problem transforms in the problem of function minimization. In our case the function has been taken as the maximum difference between points of the experimentally obtained liquid front profile and the numerically reproduced one. The problem of function minimization has been solved by the variation of the Nelder-Mead method [2].

The program, which simulates the two-dimensional liquid front propagation in inhomogeneous nanoporous medium, has been written in C++. The comparison between modelled and reproduced liquid front profiles has been made for media with various pore size distributions.

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DAMPING OF FRICTION-INDUCED SELF-EXCITED VIBRATIONS APPLYING PARALLEL COMPENSATOR

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In many electromechanical systems a number of different frictional effects have to be taken into account. Here, if

the frictional load torque in the electric drive is determined by negatively sloped friction curve, self-excited oscillations may occur [1]. These oscillations decrease the operational performance and often lead to mechanical breakdowns. Their occurrence has been reported in different areas, e.g. rail transport, bridge cranes, metal-working machinery, drilling systems [2].
In order to solve the described problem several approaches have been proposed [2, 3]. All of them are based on designing a complex control law. However, nowadays the majority of electric drive systems are equipped with power converters, which have their own software and conventional drive control system. In this case implementing a new control laws is difficult and thus increases costs considerably.
In this contribution a new damping approach of friction-induced self-excited vibrations is presented. The main idea is to extent the conventional drive control systems with an additional parallel compensator. In a first step, a simple two degree-of-freedom electromechanical system with a nonlinear friction curve and classical cascade drive control system is investigated.

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THE PREDICTION OF REGIMES OF STABLE STEADY-STATE CRACK PROPAGATION IN BRITTLE SOLIDS BASED ON DISCRETE MODEL

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The problem of dynamic crack propagation in solids has been fascinating a lot of researchers for a long time. The experimental observations reveal several phenomena which are not observed in case of quasi-static crack movement such as radiation of elastic waves from the crack tip, oscillations of crack speed, etc. There is a particular interest in estimation of the intervals of crack speed within which no instability in crack movement is registered, i.e. when then crack path stops to follow a "straight" line.
Among numerous of methods to study the problem we used a technique, developed by Slepyan [1], to study steady-state crack propagation in a structured media. We present theoretical results for the steady-state crack propagation in one-dimensional chain of oscillators with non-local interactions. The neighbouring oscillators are connected by linear springs while the non-local interactions are presented by linear springs between next to closest neighbour interactions. The analysis was based on the recent works of Slepyan and his colleagues [2-3].
The obtained results show that the regimes of stable crack propagation can not be estimated based on the considerations of energy release rate only but the analysis of the solution at the crack tip is required as well. Moreover, the variation of parameters of the problem can significantly effect the solutions [4].

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SMART ELECTROMECHANICAL SYSTEMS (SEMS)

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The development of modern robotics is currently one of the most urgent and rapidly developing areas of fundamental research, which largely determines the future trends for a wide range of applications and practical usage. Special attention in this process is attracted by the relationship between the general laws of technical systems development and the fundamental laws of nature development that characterize world evolution [1,2]. Using SEMS modules in the construction of new classes of robotic systems allows us to assign them to a new class of information cybernetic systems - Cyber Physical Systems (CPhS). Distinctive features of CPhS is to bring together heterogeneous components in a single integrated environment, actively interacting with the external factors of purposeful behavior in achieving the targeted control functions for group interaction [3].
SEMS have been widely employed since 2000 in parallel robots, or so-called parallel kinematic machines. They provide good opportunities in terms of accuracy, rigidity and ability to manipulate heavy loads. Currently, SEMS are widely used not only in intelligent robots, but also in astronomy, machine tools, medicine, and other fields. SEMS modules are based on the principles of

adaptability, intelligence, biomorfizma parallel kinematics and overlap in the information processing and computation of control actions; these modules are equipped with a wireless interface for group interaction [4].

Currently, the main directions of development of SEMS is to develop new methods and algorithms for solving problems of group interaction based on fuzzy mathematical modeling and optimization of the methods of mathematical programming in an ordinal scale and generalized mathematical programming. In addition a lot of attention paid to the development of hardware and software implementation of the produced by the central nervous system of SEMS. At the same time the following tasks: development of logical-interval, logical-probabilistic and logical-linguistic models of group interaction; the development of algorithms for group interaction based on mathematical programming techniques in an ordinal scale and generalized mathematical programming; development of methods of making and planning behavior in a group using the cortege algebra; development of software and hardware modules of the central nervous system of SEMS.

The focus of the report will be given to the most important new scientific results obtained by the laboratory team SEMS: analysis and synthesis of structures and modules of SEMS; analysis and synthesis of structures of automatic control systems, SEMS; develop the principles and techniques of fuzzy mathematical modeling SEMS; develop the principles and methods of optimization of SEMS ACS under no complete certainty

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MODELING OF SELF-LUBRICATION EFFECT IN FRICTION INTERACTION OF MULTICOMPONENT ALLOYS

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Multicomponent antifriction alloys are widely used for increasing the working capacity of frictional units. Such alloys are composite materials containing a matrix (hard phase) and inclusions of a softer materials (soft phase) arranged at the grain boundaries of the hard phase. The antifriction effect of the alloys is based on squeezing the soft phase out, which leads to the formation of a surface film protecting the friction surfaces against seizure and scoring (self-lubrication effect) in critical regimes of friction in which the contact pressure and temperature are high, whereas the amount of liquid lubricant is not sufficient for hydrodynamic lubrication [1,2].

The model based on the multiscale analysis of the stress/temperature distributions inside the alloy in contact interaction, is developed to study the influence of the composition of an antifriction alloy on the amount of the solid lubricant appearing on the surface under given loading/velocity conditions. As an examples, two [3] and three phases compositions of aluminum alloys are analyzed to predict the film formation at the friction surface under given load/velocity conditions.

The model constructed makes it possible to determine the conditions under which the solid film formed on the surface of the alloy, ensures the self-lubrication and protects the friction surfaces against seizure and scoring. On the basis of the analysis performed, the recommendations can be given for creating new wear- and score-resistant alloys.

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NUMERICAL ANALYSES OF MACROSCOPIC INSTABILITIES IN SOFT DIELECTRIC ELASTOMERS

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Dielectric elastomers (DEs) can convert electrical energy into mechanical work. DEs are highly promising materials because of their light weight, fast response and simple principles of work. However, these materials are limited by the extremely large electric fields that they require for meaningful actuation. An approach to solve the problem is to consider heterogeneous DEs by combining an elastomer with a high dielectric or even conductive material [1]. Loss of stability is an important

aspect of DE behavior which should be incorporated in robust design of composite DE. Traditionally, instabilities were considered as a limiting factor, associated with failures, which should be predicted and avoided. However, the phenomenon can be used to achieve new functionalities such as tunable band gaps [2].
In this study, we specifically focus on the identification of critical condition for onset of macroscopic electromechanical instabilities. More specifically, we study the response of periodically distributed circular particles embedded in soft matrix. The corresponding unit cells are analyzed numerically by means of the finite element code [3]. The applied electromechanical loadings are imposed in terms of periodic boundary conditions. To determine the onset of electromechnical instabilities, the general condition is applied [4]. We identify the unstable domains in terms of material and microstructure parameters and electromechanical loading. We show that the stability of the unit cell can be decreased or even increased by applying proper electric field. The dependence between critical stretch and electric field is presented. We also find out how to reduce extremely large electric fields required for meaningful actuation.

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A STOCHASTIC FINITE ELEMENT APPROACH ON CREEP OF ROCK SALT

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Old salt domes are used as reservoirs for toxic and nuclear waste in Germany. Nuclear waste has a long half-life time, so the mechanical stability of salt domes has to be guaranteed for a long period. In the last decades, a large expertise in the mechanical behavior of rock salt was gained in Germany. This led to a variety of material models to describe the mechanical behavior of rock salt.
In general, a deterministic approach to describe the material behavior for rock salt is suggested. However, from experimental data [1] it can be seen that the material properties are subject to large variation. This has been the motivation for the development a stochastically motivated material model for rock salt.
A first goal is to predict numerically the response of the rock salt during creep tests and reproducing the variety of mechanical response exhibited during the experimental campaign [1]. Our approach is based on an additive split of the strain tensor in a viscoelastic part and a creep part. The viscoelastic part is described by an approach introduced in [2] and the creep part is modeled by Norton's law. Rock salt's Young modulus is considered as a random field described by a polynomial chaos expansion, i.e. an approximation by a set of multi-dimensional Hermite polynomials [3].
We will present the validation of our model and particularly how the stochastic model can offer the thermos-dynamical consistency required to ensure numerical stability for long term predictions. We will demonstrate the models efficiency and robustness on the example of an salt dome which is under observation during several decades.

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ACOUSTIC WAVES IN SOLID-LIKE POWDERS AT LOW AND MEDIUM CONSOLIDATION

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We perform different experiments on wave propagation in fine powders at low and medium consolidation. Powders are difficult to investigate experimentally and theoretically since they change easily their structure under usual loads, and, therefore, they change their properties. Apart from that, even if the structure of the material is maintained, the contacts between grains or agglomerates are nonlinear. Also, grains or aggregates have other degrees of freedom apart from translational ones that may influence the dynamics and stability of the medium. Granular materials have a high capacity of attenuation.

One way to overcome these difficulties is to subject a powder to the very high pressure [1]. In this way the packing becomes dense, the contacts are not so easily destroyed, and it starts to behave as a nonlinear solid. However, the case of low or medium consolidation is very difficult.

We use three experimental setups. One of them, developed by us, is a cylinder with a layer of powder of 1 – 2 cm, put vertically, with emitter on the upper part and receiver at the bottom. We use vibration for the sample preparation to improve the reproducibility of the experiment. We measure the velocity of the wave propagation via "time of flight" of the emitted signal, depending on the pressure applied at the top of the sample. We use two ranges of frequencies: 45 – 55 kHz and 95 – 105 KHz. We see that when increasing the pressure, cohesive powders drastically change at some critical values of load its structure and have jumps in their properties at these critical values. On average, the velocity depends on the pressure according to the logarithmic law, with higher velocity for less cohesive powders.

Another experimental setup, also developed by our group, is a modification of Sevilla Powder Tester. We put the powder into a parallepiped cell, with transducers embedded into its vertical walls, and use the sine swept signal with the frequency changing between 1 and 50 kHz. To improve reproducibility, we fluidize the powder with a gas flow that goes in the vertical direction, let it settle down, and then measure the wave velocity. We use Helholmtz coil to apply the magnetic field when we investigate magnetic powders. Analyzing our experimental results, we see that the external magnetic field, applied when the powder is in the sedimentation process, changes the structure of the powder and influences in this way its acoustic properties. This experimental cell allows us to investigate powder at very low consolidations.

The third experimental setup consists of a rectangular parallepiped box where the powder is placed after inicialization by means of a grid placed at the bottom of the box. The transducers (emitting swept-sine signal from 1 to 80 kHz) are embedded into vertical walls and we measure the velocity of the wave propagation by the frequency (resonance) method. For low frequencies (2 – 20 kHz)we use the flight method. We see that the medium is dispersive. We measure transfer function and analyze how acoustic properties depend on the particle properties.

Our experiments show that investigated solid-like granular material under low and medium consolidation do not behave as classical elastic solids even in the domain of elasticity. We suggest some theoretical interpretations of our results.

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INFLUENCE OF STRESS-DEPENDENT DIFFUSION COEFFICIENT AND CHEMICAL AFFINITY ON CHEMICAL FRONT KINETICS UNDER MECHANICAL LOADS

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The problem of the thermal silicon oxidation nowadays is one of the most important problems in chemistry, due to the importance and large use of silicon integrated-circuit technology. Since the volume of a molecule of silicon dioxide is much larger that of a silicon atom, silicon oxidation is accompanied by a large increase in volume, this produces stresses and strains. In addition, chemical reactions in deformable solids often go under external mechanical loads. All that means that this problem belongs to field of mechanochemistry, which looks at the chemical reactions when subjected to mechanical loads.

Nowadays two main theoretical approaches to the solution of mechanochemical problems are developed. The influence of mechanical loads could be taken into consideration through the dependence of chemical affinity on mechanical loads, as it was done, for example, in [1] or through dependence of diffusivity coefficient on mechanical loads, see [2]. In this work, we combined these two approaches for the simplest geometrical forms of the body and obtained range of the values, for which we can neglect the dependence of diffusivity coefficient on stresses.

Two forms of the body were studied: with axial symmetry and rectangular block. It was supposed that reaction goes on the bottom side of the block and on outer surface of the cylinder, all relations between stresses and strains are a linear-elastic and Hookean. We do not solve heat problem and consider a quasi-static case. Mechanical loads were prescribed as displacements or as stresses. Dependence of diffusivity coefficient on stresses was taken according to [3].

It was obtained that for the rectangular block accounting of non-constant diffusivity retards oxidation rate, but we can neglect the difference between kinetics with constant and non-constant diffusivity. For the case of cylinder body results depends on the value of diffusion coefficient, but still non-constant diffusivity retards the rate. In addition, the dependence of kinetics on diffusion constant was examined: the bigger the constant is, the smaller is the difference between kinetics with constant and non-constant diffusivity.

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THE DEVELOPMENT OF THE DISCRETE ELEMENTS FORMALISM TO SIMULATE THE MECHANICAL BEHAVIOR OF BRITTLE MATERIALS UNDER DYNAMIC LOADING

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The material properties are determined not only by the features of the internal structure, but greatly depend on the load type and strain rate as well. The effect of strain rate on the experimental results is observed even at low rates, while under the dynamic impact the influence of strain rate becomes determinative. Numerical simulation is an efficient way to reveal the influence of strain rate on the features of material behavior under dynamic loading and material mechanical properties.
Discrete elements methods (DEM) are widely used to study the features of the deformation response and fracture of heterogeneous brittle materials. The movable cellular automata (MCA) method relates to these methods. It combines the main advantages of DEM and cellular automata method, and has already established itself as an effective engineering tool for the numerical simulation of the behavior of heterogeneous brittle materials of different nature.
However, despite the widespread use of DEM to simulate the deformation response of brittle materials, their mathematical formalism is limited by quasi-static models of the deformation response of a material. This limits the field of DEM application by strain rate interval < 10 1/s.
The realization of the dynamic model of material deformation response is proposed with use of the MCA method formalism. The proposed model is the dynamic extension of the Nicolaevsky's plasticity model where the non-associated plastic flow law is used to take into account the plastic deformation and dilation of material [1].The dynamic model is based on the assumption that any inelastic deformation of a material is the result of relaxation of instantly applied (elastic) stress. Moreover, the relaxation process is not instantaneous, but it takes a finite time T. In this case, the current value of T is determined by the acting stress value and material properties. Note that this parameter is an analogue of the characteristic degradation time of a material, which appears in the works of such authors as the Zhurkov, Petrov and Morozov.
The verification of the developed dynamic model was carried out to confirm its adequacy. The uniaxial compression tests of concrete and sandstone samples of size 6x9 mm were simulated. The simulation results showed good agreement with the experimental data [2] in the strain rate range from 0.001 1 / s to 1 000 1 / s.

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CREEP MODEL PARAMETER IDENTIFICATION OF SINGLE CRYSTAL SUPERALLOYS WITH ACCOUNT OF I, II AND III STAGES

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A creep process of *polycrystalline* nickel-based superalloys is characterized by the presence of three stages. The second (steady state) stage of creep is dominant (more 50% time up to the failure). However, *single crystal* nickel-based superalloys demonstrate domination of the third stage of creep (more than 80% time before the failure), whereas the first stage takes less than 5%. Therefore the standard Norton's phenomenological model, which describes only the second creep stage, is insufficient to describe correctly behavior of such materials. Adequate description and simulation of the creep processes in the single crystal structures requires taking into account of all three creep stages. The correct description of third stage of creep is based on the taking into consideration of the damage accumulation process.
Coupled creep-damage model has not trivial form and identification of the it's parameters 1 leads to the optimization problem of finding the global minimum of a functional, having a complex, non-linear structure and a large number of local minimums. The solution to this problem is not trivial. When we using the Newton's method, the Gradient descent method we have not received theresult. In this works for solution of this problem was use Nelder–Mead method [1]
The aim of the research is to create coupled visco-elasto-damage model for the single crystal nickel-based superalloys with taking into account of all creep stages and to propose a procedure for the model parameter identification. The results of the parameter identification and the proposed model verification for several single

crystal nickel-based superalloys (VZhM4, VZhM5Y, ZhS36 and VIN3) [2], [3] are presented and discussed.

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MODELING OF THE DYNAMIC RESPONSE OF A TIMOSHENKO-TYPE VISCOELASTIC BEAM BY A VISCOELASTIC SPHERE

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Recently [1] the problem of low-velocity impact of an elastic sphere against a viscoelastic Timoshenko-type beam has been studied considering the extension of its middle surface. In the present paper, the approach proposed in [1] is extended for the case of modeling the dynamic response of a viscoelastic target by a viscoelastic impactor. The viscoelastic features of the beam out of the contact domain are governed by the standard linear solid model with derivatives of integer order, while within the contact domain the fractional derivative standard linear solid model is utilized, in so doing rheological constants of the material in both models are the same. However the presence of the additional parameter, i.e. fractional parameter which could vary from zero to unit, allows one to vary beam and sphere's viscosity, since the structure of the material of colliding bodies within this zone may be damaged, resulting in the decrease of the beam and sphere's material viscosity in the contact zone. Consideration for transient waves (surfaces of strong discontinuity) propagating in the target out of the contact zone via the theory of discontinuities and determination of the desired values behind the surfaces of discontinuities upto the contact domain with the help of ray series, as well as the utilization of the Hertz theory in the contact zone allow one to obtain a set of two integro-differential equations,which govern the desired values, namely: the local bearing of the target and impactor's materials and the displacement of the beam within the contact domain.

The main goal of this paper is to bring to light the physical sense of the fractional parameter in problems on impact, since one and the same question arises very often, namely: Why is it needed to introduce a fractional derivative in problems of mechanics? The authors have tried to answer this question at least for the problems of impact by connecting the fractional parameter with the changes in microstructure of beam's material within the contact zone. For this purpose we have assumed that viscoelastic features of the beam outward the contact zone is determined by the conventional standard linear solid model, while the contact force is also viscoelastic and its features are governed by the fractional derivative standard linear solid model, in so doing relaxed and non-relaxed moduli and relaxation and retardation times coincide with the corresponding moduli and times for the viscoelastic medium out of the contact zone, and the fractional parameter varies from zero till unit controlling the viscosity within the contact domain. This is connected with the fact that during the low-velocity impact there could occur decrosslinking within the domain of the contact of the beam with the sphere, resulting in more freely displacements of molecules with respect to each other, and finally in the decrease of the beam material viscosity in the contact zone without discontinuity of the target medium within this zone.

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DAMAGE ACCUMULATION-BASED AND FEA-AIDED FATIGUE LIFE EVALUATION OF TUBULAR STRUCTURES

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Fatigue assessment of tubular structures in various applications according current design codes is based on S-N criteria with uncertain characterization of the damage. In case the crack is detected residual service life may be estimated by applying the Linear fracture mechanics techniques, again, with incomplete defining the exhaustion of life. An approximate procedure based on application of the Strain-life criterion for fatigue failure and of the finite element modeling of successive damage accumulation is implemented for evaluation of fatigue life of tubular components under the cyclic loading. The procedure allows assessment of fatigue life from the moment structure is put into service up to the through crack development in the shell, or alternatively, up to the onset of fast fracture conditions. Efficiency of the approach is illustrated in example of fatigue life evaluation of the pipeline component subjected to internal pulsating pressure.

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WEDGE DISCLINATIONS AXIALLY PIERCING BULK AND HOLLOW ELASTIC SPHERES

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The wedge disclination (WD), which is the linear defect of rotational type in deformable media, is the object of great interest for mechanicians, physicists and materials scientists. For mechanicians, the first big challenge is to cope with long-range divergence and strong short-range singularities in elastic fields and strain energies of individual straight WDs when considered in infinite media within the classical linear theory of elasticity [1,2]. The second big challenge is to correctly incorporate WDs in mechanistic models of strain relaxation, plastic deformation and fracture in various materials containing WDs as real structural features [3]. For physicists and materials scientists, WDs represent important elements in real structure of many types of condensed media, from soft matter, i.e. biological structures, liquid crystals, polymers, etc., to amorphous and crystalline solids, i.e. metallic glasses, small particles, poly- and nanocrystalline solids, severely deformed metals and composites, some heteroepitaxial systems, etc. [4]. Theoretical examination and description of behavior and role of WDs in the structure of these materials again face the aforementioned difficulties.

In the present work, a linear elasticity problem for a straight WD, which axially pierces a spherical layer, is solved analytically. The WD displacements, stresses and dilatation are given in the form of series with Legendre polynomials. The related elasticity problems for WDs axially piercing a bulk elastic sphere and a spherical pore in an elastic medium are addressed as well. It is shown that the found solutions satisfy the boundary conditions on spherical free surfaces of the bodies under consideration including the WD emerging points. The divergence of the WD elastic fields is eliminated everywhere in the elastic bodies with the exception of the WD line. On the free surfaces, the WD induces characteristic displacements which depend on the WD strength and the radii of the surfaces. The distribution and the magnitude of the WD elastic fields in spherical bodies strongly depend on the presence and the size of the inner cavity. Nevertheless, the regions adjacent to the lines of positive (negative) WDs are always hydrostatically compressed (stretched), while the regions distant from these lines are always hydrostatically stretched (compressed). For the correct treatment of elasticity for a WD penetrating through a spherical pore, it is necessary to take into account the boundary conditions on remote external boundaries of the elastic body.

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THE THERMOMECHANICAL CHARACTERISTICS OF MOLECULAR DYNAMICS AND SUMMATION FORMULAE

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In [1] we considered a one-dimensional system of mutually interacting harmonic oscillators, which simulates behavior of a one-dimensional crystal, and studied the thermo-mechanical characteristics of the system at different levels of scale at a uniaxial deformation. It was supposed that the particles are in equilibrium in the initial state at the same distance a from each other. Coordinate of j-particle is equal to xj = ja+uj where the function uj determines the displacement of a particle. Fixing coordinate xn+1 of the last particle and assuming xn+1 = vt where v is a constant speed, we obtain the model of the one-dimensional crystal at its uniaxial deformation.
The thermomechanical characteristics of the crystal were calculated in the framework of the kinetic theory, the use of which requires knowledge of the function uj. Exact solution of uj constructed in [1] is the sum of monotonic and periodic, functions, the latter one is a linear combination of the normal modes of the discrete model. Since the final state of the system is not fixed, then averaging over the fast oscillations modes was performed under the condition of slow speed deformation. The problem of determining the averaged values results in necessity of calculating the sums that determine the behavior of thermo-mechanical characteristics at different scales.
In the present article we show that using the methods of the theory of numbers [2], it is possible to calculate sums for the respective characteristics exactly.

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THE RESONANCE CRITERION FOR THE MODEL OF MOLECULAR DYNAMICS

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In work [1] we constructed an analytical solution for the one-dimensional harmonic crystal at a uniaxial deformation for constant speed of action, and the thermo-mechanical characteristics of the system at different scales were studied. In the present article we show how to obtain the analytical solution in the case of arbitrary external deformation.
As application of the result we calculated the thermomechanical characteristics of the crystal in the framework of the kinetic theory for the harmonic displacement of the last particle. It was shown there are the resonance conditions which define internal time scale. Then the stress state of the material depends on the width of the resonance.
The further analysis of the non-linear effects demands consideration of strong chaos for particles and usage of the Chirikov criterion of resonance overlapping [2].

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INFLUENCE OF THE TREATMENTS ON THE BEHAVIOR AND THE DAMAGE IN TENSILE AND WITH THE SHOCK OF THE RECOVERY ALLOY ALSI12: APPLICATION TO THE RECYCLING OF WASTE

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Our goal is to make a direct contribution for the study of mechanical strength, hardness, micro hardness, resilience and structural properties of the alloy foundry AlSi12 used in sand casting and metal shell both mechanical and manual.
The reference state is designated as cast, noted: F. To try to increase over the strength characteristics of the state F and obtain substantially high stress elasticity, rigidity of large modules with small deformations, the material of 44000 numerical designation is subject to specific treatments T46.
To determine the behavior of the material deal with various stresses it may encounter during use, these solicitations are reproduced using static or dynamic tests, usually performed on standard specimens in order to know the characteristics Figures of the material. Four techniques are used, namely: the tension to identify the

various constraints, micro hardness and Brinell hardness HB for the stress field, the Kcv resilience us about the mode of fracture, fragility and resistance to shock and to identify metallography structures.

We will describe in more detail and present in the main mechanical characteristics of the material obtained from chemical composition by AlSi12 purpose of this study.

Non-alloy aluminum with mechanical properties very reduced, leading to add two items of very low density with 12% silicon and traces of magnesium less than 0,1% which is the lightest of all stable metals susceptible of industrial employment to improve their properties and obtain a super light alloy AlSi12. The addition of a high percentage of silicon to aluminum are the main vectors and improving agents largely mechanical.

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ON HOMOCLINICS AND HETEROCLINICS OF LAGRANGIAN SYSTEMS IN A NON-STATIONARY FORCE FIELD

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During the last two decades many authors studied connecting (homoclinic and heteroclinic) orbits of Lagrangian systems by use of variational methods and critical points theory [1]-[4]. The existence of such trajectories usually leads to chaotic dynamics of a system. In the present work we study a natural Lagrangian system on a complete Riemannian C^3-manifold M under action of a non-stationary potential force field. The Lagrangian of such a system can be written in the following form $L(x,x',t)=K(x, x')-U(x,t)$, where the kinetic energy K is a positive definite quadratic form in velocity x' and the potential energy $U(x,t)$ has special representation $U(x,t) = f(t)V(x)$. Such systems often arise in mechanical applications. In particular, this work was inspired by [1], where the authors considered the Kirchhoff problem. To formulate the main result we assume that the factor $f(t)$ satisfies two conditions: 1. there exists time t_0 such that $f(t_0) =0$, i.e. at the moment t_0 the system motion becomes free and 2. $|f(t)|$ is monotonic on both intervals $t> t_0$ and $t< t_0$. Let X_+, X_- denotes the set of critical points of $V(x)$ at which $U(x,t)$ distinguishes its maximum for $t> t_0$ and $t<t_0$, respectively. Under nondegeneracy conditions on points of $X_\pm$ we prove the existence of doubly asymptotic trajectories connecting X_+ and X_-. One may note that the sets X_+, X_- do not necessarily coincide what may lead to connection between different regions of the configuration space. It also can be shown that number of such trajectories is at least $cat\ \Omega(M)$, where $\Omega(M)$ is the loop space of M.

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THE SYSTEM OF EVOLUTION EQUATIONS FOR THE ONE-DIMENSIONAL PROBLEM OF VARIABLE SHEAR LOADING ON THE BOUNDARY OF AN INHOMOGENEOUS INCOMPRESSIBLE HALF-SPACE

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A large number papers [1-3] are devoted to the mathematical modeling of nonlinear dynamic processes in solids. They show that the volume deformation and forming are interlinked and arising shock waves are quasilongitudinal waves or quasitransverse waves. At the same time shear deformation has not analogy to the hydro and gas dynamics, so the transverse and quasi-transverse shock waves are less studied than the longitudinal waves. General nonlinearity of boundary value problems with shock waves leads to the impossibility of obtaining of exact solutions. Therefore there is a necessary to construct of generalized approximate analytical and numerical solutions. One of the most effective analytical methods for solving problems of nonlinear dynamics is a small parameter method [4]. Earlier application of the matched asymptotic expansions method in one-dimensional plane problems with a single wave process has led to the analysis of a single evolution equation. It was a Cole-Hopf equation for longitudinal waves in inhomogeneous medium [4], it was a Cole-Hopf equation for the square of intensity of wave the process for transverse waves [5]. In medims with weak inhomogeneity the transition to the evolution equation is done by a recurrent chain of internal problems with the change of all dependent variables [6]. In this paper we consider the generalization of techniques to the case of presence of several shock wave. One-dimensional plane wave process caused by variable load on the boundary of incompressible nonlinear elastic half-space, leads to the formation of a plane polarized shock wave and shock wave of circular polarization. An additional factor influencing on the deformation, we consider the inhomogeneity of properties of the medium in the direction of shock wave motion. By making these assumptions, we simultaneously take into account the non-linearity of the model describing the shock waves, and the inhomogeneity occurring in solids of large sizes. Using the method of matched asymptotic expansions, we reduce the problem to a system of evolution equations describing the solution at large distances from the loaded boundary. We received a general solution of this system in the case of propagation of a common front of wave processes. As an example, we have constructed a particular solution with irrational boundary condition on the boundary of the half-space.

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MICROSTRUCTURES OF "IRREGULAR" GEOMETRY AND THEIR QUANTITATIVE MODELING: TOWARDS LINKING MECHANICS AND MATERIALS SCIENCE

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In micromechanics, that considers materials with multiple inhomogeneities (pores, cracks, inclusions) almost all available results assume that their shapes are ellipsoidal. However, in actual microstructures the shapes are typically "irregular" and do not resemble ellipsoids. This creates a gap between quantitative methods of solids mechanics and materials science. A related issue is that anisotropies caused by preferential orientations of inhomogeneities usually have approximate character, whereas the usual solid mechanics models assume that they are exact. We review the progress in quantitative description of "irregular" microstructures that has been made in our recent works.

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FREE AND FORCE DRIVEN VIBRATIONS OF A NONLINEAR THIN PLATE EMBEDDED INTO A FRACTIONAL DERIVATIVE MEDIUM

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Dynamic behavior of a nonlinear plate embedded in a fractional derivative viscoelastic medium and subjected to different conditions of the internal resonances has been studied in [1]. Nonlinear equations, the linear parts of which occur to be coupled, were solved by the method of multiple time scales. A new approach proposed in [2] allows one to uncouple the linear parts of equations of motion of the plate, while the same method, the method of multiple time scales, has been utilized for solving nonlinear equations. The new approach enables one to solve the problems of vibrations of thin bodies more efficiently.

In the present paper, nonlinear free and force driven vibrations of thin plates in a viscoelastic medium are studied, when the motion of the plate is described by a set of three coupled nonlinear differential equations in the case when the plate is subjected to the conditions of the 2:1 and 2:1:1 internal resonance, resulting in interaction of two and three modes, respectively, corresponding to the mutually orthogonal displacements, which are determined in terms of eigen functions of linear vibrations of a free supported elastic rectangular plate. To describe the non-linear damped vibrations of the thin plate under consideration, the fractional derivative

Kelvin-Voigt model is used, since this model has an advantage over the conventional Kelvin-Voigt model, because its prediction is in a good compliance with experimental data.
For each type of the resonance initiated when the order of viscosity equal to ε, where ε is a small dimensional value, the non-linear sets of resolving equations in terms of amplitudes and phases have been obtained. The resulting set of six nonlinear equations has been solved analytically by the method of variation of arbitrary constants. Force driven vibrations resulting in the internal and external resonances have been studied by the method of multiple time scales.
If the external force is of order of ε^2 and the viscosity coefficients are of order of ε, then it has been possible to obtain the approximate analytical solutions for the generalized displacements, wherein the solution for the vertical displacement involves two parts: the first corresponds to the damping vibrations with damping coefficients and nonlinear frequencies dependent on the fractional parameters and describes the transient process, while the second one is nondamping in character and describes the steady-state regime, i.e., forced vibrations with the frequency of the exciting force and with the phase difference depending on the fractional parameter. The solution for the in-plane displacement consists only from one term describing the transient process with the damping coefficients and the frequencies of nonlinear vibrations depending on the square of the exciting force amplitude.

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MODELLING OF COARSENING IN FOAMS AND ITS INFLUENCE ON FOAM RHEOLOGY

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Foam is a typical example of soft jammed material. However, the gaseous nature of foams distinguishes it from other jammed systems. Gas can diffuse through bubble walls and this leads to coarsening. If a foam is watched over time, the small bubbles shrink and disappear, and the larger bubbles grow. This leads to a polydisperse distribution of bubble sizes, which turns out to have a universal form [1]. The average bubble radius changes as t^{α}, and the coarsening exhibits scaling behaviour.
In our research we are modelling foams using particle-based dynamics approach (Durian bubble model [2]). According to the model two types of forces are acting in the system. The first one is the repulsive force between neighbouring bubbles and the other one is the drag force proportional to the velocity of the flow. Due to the gas exchange between neighbouring bubbles its radii constantly change and the whole system evolves. The speed of foam ageing depends on many parameters of the system. The most critical one is the gas volume fraction. Undoubtedly, volume fraction also has a tremendous effect on the whole foam rheology. Thus we are modelling coarsening for systems with different volume fractions and study how it influence the foam rheology. Our results show good agreement with the experiments.

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VARIATIONAL FORMULATION AND ISOGEOMETRIC ANALYSIS OF SECOND STRAIN GRADIENT ELASTICITY WITH SURFACE EFFECTS OF NANO-STRUCTURES

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In the present contribution, isogeometric methods [1, 2, 3] are used for analysis of second strain gradient elasticity problems [4, 5]. Here, we distinguish two forms of Mindlin's second strain gradient elasticity theory and propose a simplified model of Form II with four additional material constants [4, 6]. Admissible parameter sets [7] as well as material macroscopic stability conditions are studied and analysed. The proposed simplified second strain gradient model is implemented as user elements in a commercial finite element software [3], verified by benchmarks and used for numerical simulations.
Within the second strain gradient elasticity, the continuum model is governed by (at least) 6-th order partial differential equations replacing the corresponding 2-nd order ones based on the classical elasticity, which demands C^2 continuous conforming Galerkin methods [2, 3]. NURBS based isogeometric analysis provides a C^{p-1} continuous approximation for one patch domains, where p is the NURBS order, and hence offers a natural framework for solving higher-order problems.

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CHALLENGE TO THE FRACTURE MECHANICS IN NANOMETER SCALE

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In order to inquire the cracking mechanics in nanometer scale materials, we develop an experimental system combining a transmission electron microscopy and a well-controlled small loading device. A cantilever specimen composed of Si, Cu (thickness of 20nm), Si_3N_4 and C layers is loaded by a tip and the cracking from the upper edge of Si/Cu interface is observed *in situ*. The FEM based on the critical load elucidates that the crack is initiated by the interface stress concentrated in $r < 20$ - 30 nm. Several specimens with different size show similar behavior, and these confirm the availability of the fracture mechanics concept.
We can control the stress at the cracking position designing the shape of specimen. We will show novel testing in the presentation including a torsion/bend experiments used for the investigation of the mixed-mode cracking at Cu/Si interface edge. The specimen has a three-dimensional structure with the shape of "]" consisting of three arms. These nano-scale specimens with special shapes can be carved out precisely by the FIB processing as designed.
We can introduce a slit-like notch in the SiN layer controlling the location. This technique enables us to introduce a high stress concentration in an arbitrary position of any interface in a multi-layered cantilever specimen and we can evaluate the strength of targeted interface in multi-layer specimen. The interface crack is initiated at the interface where the initial slit makes the stress concentration.
The result signifies that "stress", the concept of which is based on continuum mechanics, is still applicable to the fracture phenomenon as the governing parameter while the size approaches the atomic scale. We are challenging to create the concept of fracture mechanics such as cracking under the single-digit nanometer-scale deformation field using our unique experimental techniques.
We also show the experimental results in detail on fatigue cracking and environmental effect of nano-meter scale components in the lecture.

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NONDESTRUCTIVE TESTING OF PROTECTIVE COATING OF LAYERED ELASTIC PLATES

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Nondestructive testing of protective coating of multilayer elastic plates and pipes is an important task of ultrasound evaluation. The coating being of a different material than the basic elastic layers of waveguide has also a visco-elastic properties. Often it is necessary to control five or more parameters of coating: the thickness, the elastic modules, the density, volume and shear coefficients of internal friction. Surface long wave propagation in an elastic layer coated on an isotropic half-space are studied in [1,2]. In our case visco-elastic protecting layers (or layer) coated basic laminate waveguide. We propose to use guided modes for evaluating material properties of protective coating. If the protective layer is thin (ratio the thickness of the coating to the thickness of basic waveguide is very small), frequency of wave is not equal cut-off frequencies of basic waveguide and waveguide with coating layer than we can use the perturbation method to obtain formula for change in phase velocity and coefficient of wave attenuation due to the influence of the protective layer. Derived expressions for the phase velocity and attenuation coefficient for several guide modes allow to define the parameters of the coating.

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MODELING OF HIGH TEMPERATURE SYNTHESIS OF THREE LAYER CERAMIC COMPOSITE UNDER LOADING

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The model of ceramic composite synthesis is suggested. It is assumed that powder mixture behaviour can be described similarly to viscous liquid. In the chamber we have three layers of powders with different compositions and properties. The contact between layers is assumed as ideal, in a first approximation. Macroscopic thermal stresses are small. Friction with walls is negligible small too. The dependencies of the properties on porosity are taken into account. In turn, the porosity changes during the heating and loading. Heat exchange of powder mixture with the walls leads to the appearance of nonuniform temperature field and can be the cause for nonuniform composition change in the layers. The chemical reactions can proceed in each layer. The kinetical equations correspond to them. The problem is solved numerically. Special numerical algorithm is based on the conservation of number of mesh points in the each layer of composite. As a result we obtain the porosity, temperature field, final composition, mechanical stresses for different synthesis conditions. This work develops the idea used in the papers [1-9].

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DOUBLE-DIFFUSIVE CONVECTION IN SUPERPOSED FLUID AND POROUS LAYERS UNDER HIGH-FREQUENCY VIBRATIONS

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The work deals with the onset of double-diffusive convection in a two-layer system consisting of a binary fluid layer and a porous layer saturated with the same fluid in the presence of imposed vertical temperature and concentration gradients. The system is under the conditions of the gravity field and vertical high-frequency vibrations. The vibration effect on the excitation of convection in layers is more pronounced for porous media with high permeability, which is a measure of the resistance of porous matrix to the fluid flow within it. The results of the research can find its application in various industries. Depending on the properties of the fluid and porous medium as well as directions of temperature and concentration gradients, vibration can weaken or strengthen convective heat and mass transfer in layers. Management of convective motions in layers can improve production efficiency.

Investigation of the stability of the mechanical equilibrium (ME) in the system was carried out in the framework of the averaging approach. The problem was solved numerically using the shooting method. The stability boundary corresponding to the threshold of the excitation of the convective flow averaged over the period of vibration was defined for various amplitudes and frequencies of vibrations. The different heating conditions for a model system of a binary solution layer and a saturated porous layer consisting of packed balls were considered. The peculiarity of the problem is that there are two types of perturbations of the ME in layers: short-wave perturbations, which are localized mainly in the fluid layer and long-wave perturbations covering both layers. Due to the different role of inertial effects in the fluid and porous layers, the vibrations have a greater impact on the short-wave perturbations in contrast to the long-wave ones.

It was shown that, as in the case of thermal convection [1], the vertical vibrations stabilize the ME in the system heated from below. At the same time the large-scale long-wave perturbations penetrating both layers become most dangerous as the vibration intensity increases, with short-wave perturbations localized in the fluid layer being stabilized by vibrations. When the system is heated from above and has the unstable compositional stratification of the density (the heavier impurity is at the top of the cavity), vertical vibrations decrease the threshold of the ME stability. They have a destabilizing effect, especially, on the short-wave perturbations. Thus the vibrations primarily cause convection in the form of rolls in the fluid layer. It was shown, that the vibrations have a greater impact on the binary fluids with small Prandtl numbers, i.e., for example, liquid metals. To significantly influence the convection in the binary solution and saturated porous medium, one should use large amplitudes and frequencies of vibrations.

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CONVECTION OF FERROFLUIDS AND CARRIER FLUIDS IN A HORIZONTAL LAYER

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The research is devoted to an experimental study of the gravitational convection in a horizontal cylindrical layer filled with transformer oil or magnetic colloids based on kerosene and undecane. Previously conducted experiments revealed a regular oscillatory regime near the threshold of the stability of mechanical equilibrium in the 3 mm layer of the kerosene-based magnetic colloid [1]. The presence of this regime can be explained by two competing mechanisms: the sedimentation of clusters and the thermal diffusion of magnetite particles. In this regime temperature perturbations move along specific directions with the velocity of about 5 cm/h.

In present study we used a cavity of 2.4 mm in thickness and 58 mm in diameter. Thermocouple and thermal imaging measurements were carried out. In accordance with the obtained data we plotted the Nusselt number versus the Rayleigh number. Threshold values of the temperature difference, at which the convection was excited, were determined by means of temperature fields at the fluid surface, detected by the thermal imaging camera. For magnetic colloidal fluids based on kerosene and undecane they were equal to 6 and 7.5 °C, respectively. Near the threshold of the stability of mechanical equilibrium in the supercritical region these magnetic fluids behave differently. It can be explained by different properties of their carrier liquids.

Regimes of convection for the transformer oil were observed in work [2]. Authors also plotted the Nusselt number versus the Rayleigh number. The obtained dependence qualitatively agrees with the one presented for the kerosene-based magnetic fluid. Both kerosene and transformer oil are multicomponent molecular hydrocarbon mixtures. Therefore thermal diffusion properties of mixture components should be considered near threshold of convection excitation. Similar conclusion was made in work [3] devoted to the study of the thermal convection of magnetic fluid in narrow channels.

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INVESTIGATION OF THE NOISE REDUCTION EFFECT OF VENTILATING SYSTEMS

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The well known magnetostrictive effect of electric motors results the nonlinear dependence of magnetic noise components in the wide sound range from infrasonic frequencies. In the open ventilating pipe the electric motor with the fan impeller and the fan impeller without the electric motor on a quarter length wave distance of electric network frequency are installed. On the same distance the same series identical a pair of elements is set up but two electric motors on half length wave distance of electric network frequency are fixed and through the phase-shift device are switched on. The compensatory effect of the basic component of magnetic electric motor noise is considered. The theoretical and experimental data of the ventilating systems noise reduction are commented on.

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MATHEMATICAL MODELLING OF DRUG RELEASE KINETICS THROUGH THE SURFACE OF NEW GENERATION ENDOPROSTHETICS

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A mathematical apparatus to describe the kinetics of swelling and drug release through the polymer film on the surface of the prosthesis that is implanted into a living tissue of a patient. The easiest way of administration of the drug in the polymer film due to swelling is achieved when the polymer is placed in a solvent saturated with the required amount of drug. The mathematical model is able to monitor kinetic processes while maintaining optimum flow rate.

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INFLUENCE OF NANOINCLUSIONS ON GRAIN BOUNDARY MIGRATION IN NANOCOMPOSITE MATERIALS

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It is well known that the stress-driven athermal migration of grain boundaries (GBs) is recognized as one of deformation modes effectively operating in nanocrystalline (NC) and ultrafine-grained (UFG) metals. We suggest a model that describes migration of low-angle tilt boundaries in composite solids containing nanoscale inclusions. Recently, such migration processes were experimentally observed in aluminum alloys containing Al_3Sc and Al_2O_3 nanoparticles [1-3]. Using the method of two-dimensional dislocation dynamics [4-6] we considered the cases of incoherent and coherent nanoinclusions.
Within our model we considered the migration of low-angle symmetric tilt boundaries under the action of an applied stress τ in the presence of several nanoinclusions. We modeled the GB in its initial state as a wall of perfect lattice dislocations of the edge type. We calculated the evolution of dislocation ensembles composing the migrating GB in the composite material containing nanoparticles and composed GB profiles. The analysis of the data obtained revealed two GB migration modes (limited and unlimited) intrinsic to the cases of both incoherent and coherent nanoinclusions. In the limited migration mode, all the dislocations of the migrating GB eventually approach their equilibrium positions. In the unlimited migration mode, some dislocations stop either at the nanoinclusion boundary or in its interior region, while others move unrestrictedly far away from the nanoinclusion. The transition from limited to unlimited GB migration occurs at some critical value τ_c of the applied shear stress. We calculated the dependence of τ_c on different geometrical parameters of the system and revealed that the critical stress significantly increases with increasing the volume fraction of inclusions. Also,

the rise of the distance between nanoinclusions and the initial GB position can either increase or decrease the critical stress τ_c.

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METAMORPHOSE OF NEAR CRACK TIP STRESS DISTRIBUTION IN ELASTIC MEDIUM WITH MICROSTRUCTURE

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According to linear elastic fracture mechanics (LEFM) the stress at the crack tip obeys the well-known formula (see, for instance, [1]). As the derivation of the formula implies using a continuum medium model one may ask a question what happens if the presence of some medium microstructure is taken into account. Clearly, the proper answer to the question depends on the actual type and strength of the interaction between strains and microstructure degrees of freedom.
In the talk one considers the general problem in crystalline materials. It is shown that if the stress intensity factor K < K* microstructure degrees of freedom are not activated and the conventional stress distribution is still valid while in the opposite case K > K* this distribution is modified. The latter modification is due to the appearance of a disturbed microstructure domain which is localized at the crack tip. The value K* is written through a set of measurable material parameters. The spatial domain structure is obtained in the explicit form near the threshold K* for both stationary and propagating with a constant velocity crack. It is shown that the existence of the disturbed microstructure domain leads to the appearance of a viscous drag force acting on the tip. The force modifies Freund's equation. The modified equation admits discontinuity of the crack velocity and what's more its terminal value turns out to be below the Rayleigh velocity [2].

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BOUNDARY-VALUE PROBLEM IN THE THEORY OF ELASTICITY FOR A LONG CYLINDER WITH AN ECCENTRIC INCLUSION OF RECTANGULAR CROSS SECTION

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It is well-known that radially inhomogeneous nanowires have excellent electronic and optical properties [1, 2]. Physical properties of nanowires depend on shape, size and types of crystalline lattices of the composite components as well as on presence of various defects in their structure. In particular, the shape effects can be tightly related with peculiarities in misfit stress distribution over the nanowires and with the mechanisms of misfit stress relaxation in them. However, in theoretical description of these mechanisms, they commonly use the model of cylindrically symmetric core-shell nanowires [3, 4] as it is much simpler for analytical modeling. It excludes the glide of straight misfit dislocations along the flat areas of the core-shell interface that is sometimes observed in experiments [5, 6]. It is worth noting that flat interface regions often form in radially inhomogeneous nanowires [7-8].
It seems that the simplest case of a core with flat faces is the core in the form of a long parallelepiped. To our best knowledge, today there is only one analytical solution which describes the elastically strained state in an elastic cylinder with parallelepiped inclusion placed symmetrically with respect to the free surface [9]. The solution was found in the model case of plane strain through the complex potentials method and illustrated by stress maps in Cartesian coordinates. The lack of the work [9] is that the authors did not demonstrate the evidence of the boundary condition fulfillment. Moreover the case of plane strain is obviously quite far from the case of three-dimensional mismatch of crystalline lattices in real core-shell composites.
We have obtained an analytical solution to the boundary-value problem in the classical theory of elasticity for a core-shell cylinder with the core in the form of a long parallelepiped of a rectangular cross section. The core is placed in an arbitrary position in the cylinder. The stress field caused by a dilatational eigenstrain is given by a sum of the stress field created by the core in an infinite medium [10], and an extra stress field which is needed to satisfy the boundary conditions on the shell free surface. The extra stresses are found through the complex potentials method in a concise and transparent form of trigonometric series. We show the analytical formulas for the stress components applicable for practical use in theoretical modeling of misfit stress relaxation processes and demonstrate their distribution in the composite cross section, from which the fulfillment of boundary

conditions on the shell free surface is evident. In the limiting case of a core of square cross section centered at the cylinder axis, we come to the solution given in [11].
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UNSTEADY THERMAL PROCESSES IN HARMONIC CRYSTALS

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An analytical approach for exact analysis of unsteady heat processes in harmonic crystals is presented [1-3]. The approach allows analytical description for fast nonequlibrium thermal processes [2] and relatively slow anomalous heat transfer processes [3] inherent to harmonic crystals. The obtained results are relevant to high purity nanostructures and confirm such phenomena as ultrafast heat transfer [4] and thermal superconductivity [5], already observed in recent experiments.

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THE SIMPLEST FRACTIONAL DERIVATIVE MODELS OF VISCOELASTICITY AND THEIR CORRECTNESS IN PROBLEMS OF THIN BODY DYNAMICS

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The question on applicability of the simplest fractional derivative viscoelastic models [1,2], namely: Kelvin-Voigt model and standard linear solid model, for describing the dynamic behavior of such thin viscoelastic bodies as beams and plates is discussed. It is shown that the utilization of the fractional derivative Kelvin-Voigt model in conjunction with the time-independent Poisson's ratio for the description of the dynamic behavior of viscoelastic Kirchhoff-Love plate results to the fact that the given problem is reduced to an equivalent problem about the dynamic behavior of an elastic Kirchhoff-Love plate in a viscoelastic medium, damping features of which are described via fractional derivatives. If the fractional derivative Kelvin-Voigt model is utilized together with the time-independent bulk extension-compression coefficient for solving the same problem, what seems to be more logical from the point of view of experimental data, then such a model occurs to be completely inapplicable. However the standard linear solid model involving fractional derivatives remains to be correct in both cases: when considering or ignoring the bulk relaxation.
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MATHEMATICAL AND EXPERIMENTAL SIMULATION OF THE ASCENDING TWISTING FLOWS

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The results of theoretical and experimental studies of the

ascending twisting flows encountered in nature in the form of tornadoes and tropical cyclones [1-3] are represented.
Theorems on the existence and the uniqueness of the solutions to specific initial-boundary value problems that, in particular, set the rotation direction of tornadoes, tropical cyclones and fire vortices are proved for the system of gas dynamics equations and the complete system of Navies-Stokes equations.
There are the constructed numerically the solutions of indicated systems of partial differential equations that model the gas flow from the simple planar spiral currents to the three-dimensional nonstationary flows in general. The calculation results are consistent with both the data of natural observations and the results of laboratory experiments.
Results of laboratory experiments on the vertical upwards motion of air along the pipe, which confirmed the occurrence of the twisting in the near-bottom and the vertical parts of the flow in the appropriate direction are given in this investigations.

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PHASE TRANSITIONS IN TITANIUM ALLOYS AT HIGH-SPEED MECHANICAL EFFECT

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TEM, SEM- technique and X-ray diffraction analysis are used to investigate the structural and phase changes occurring in a material of chip after turning treatment of blanks from alloys on a base of titanium VT-6 in speed range of cutting 2…275 m/mines and plane targets - samples from the VT-6 ($\alpha+\beta$) titanium alloy, tested within impact velocity range of 400…600 m/s. were investigated.
The microhardness measurements were made on microslices of the chip, prepared in a longitudinal plane, in share and transversal its directions with an interval 50 microns and plane targets - samples at load 50. The test results had undulating character. The maximal values of microhardness had on places of chip segments articulation, in which with the help of transmission electron microscopy the localization plastic deformation on the mechanism of formation of narrow bands of secondary dislocation substructures detected.
Is shown, that on an input the loading wave resulting in decomposition β- phases and enrichment by a vanadium of α- phase up to formation soft orthorhombic of $a^{//}$-phase, braking a shock wave was formed. The shock wave was reflected in an output from the back party and the unloading wave was formed. Here there was a change of the mechanism of plastic deformation, from shift to rotational.
Thus there was an intensive heat-generating and return phase transformation, at which soft β-phase enriched with vanadium, inclined to decomposition down to formation of a brittle ω-phase was formed. Than the more the quantity of soft β-phase, the microhardness of opposite side material was less. From the moment when β-phase turned in brittle ω-phase, the hardness of sample material was raised. In this place the crack was formed.
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MODELLING EARLY STEPS OF HYDROTHERMAL NANOPARTICLE SYNTHESIS USING OPENFOAM

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Despite the fact that hydrothermal technology has decades of history in science, there is no common definition to describe what a hydrothermal process is. Typically, this definition refers to any heterogeneous reactions in the presence of aqueous solvents or mineralizers at high pressure and temperature [1]. Morey and Niggli (1913) defined hydrothermal synthesis as "…in the hydrothermal method the components are subjected to the action of water, at temperatures generally near though often considerably above the critical temperature of water (~370°C) in closed bombs, and therefore, under the corresponding high pressures developed by such solutions."[4]. Lobachev (1973) defined it as a group of methods in which crystallization is carried out from superheated aqueous solutions at high pressures [2]. Yoshimura (1994) proposed the following definition: reactions occurring under the conditions of high-temperature–high-pressure (>100°C, >1 atm) in aqueous solutions in a closed system [3].

Using OpenFOAM for modelling CFD problems

To simulate the process of hydrothermal synthesis is convenient to use computational fluid dynamics (CFD) package OpenFOAM (Open Field Operation And Manipulation). According the name of the package it is an open source tool with the mathematical apparatus for the operation and manipulation of the fields. Since the solution of hydrodynamic problems is based on the operation with fields of temperature, pressure, speed - OpenFOAM is the most convenient tool for building your own models[4].

Also OpenFOAM open source package includes tools for working with graphical representation of data called ParaView. Together, these two tools are software system for mathematical modeling of hydrodynamic phenomena.

Mathematical model

Since the process of hydrothermal synthesis takes place at high temperatures in the force of gravity, one of the main components of its effects is the convective motion of the fluid. This process defines on of the main parameters of system – distribution of temperature. Experimental setup allows manipulating the initial conditions of temperature distribution. To achieve the most effective results of synthesis needed to find relations between initial distribution of temperature and final distribution of nanoparticles. The first step to find these relations is modelling convection inside autoclave.

Modelling of free convection inside autoclave convenient make using system of Navier-Stokes equations under Boussinesq approximation. OpenFOAM provides standard solver for this problem buoyantBoussinesqPimpleFoam. The mathematical mode of problems describes following equations [5]:

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial x}=0$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial x}=-\frac{1}{\boldsymbol{\rho}}\frac{\partial p}{\partial x}+\eta\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial x}=-\frac{1}{\boldsymbol{\rho}}\frac{\partial p}{\partial y}+\eta\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+F_b$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial x}=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)$$

According to Boussinesq approximation Fb is:

$$F_b = g\beta(T - T_c)$$

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OSCILLATIONS AND NON-EQUIPARTITION OF ENERGIES IN TWO- AND THREE-DIMENSIONAL HARMONIC CRYSTALS

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We consider relaxation to thermodynamic equilibrium in two- and three-dimensional harmonic crystals [1]. Two processes are investigated: (i) equilibration of kinetic and potential energies [2] and (ii) distribution of kinetic energy among spatial directions. Deterministic Cauchy problem describing both processes is formulated using the correlation analysis [2, 3]. For a triangular lattice it is shown that, in general, temperature is a non-spherical tensor [4] even at equilibrium. Anisotropy of the tensor temperature is uniquely expressed in terms of the initial conditions. Equilibration of kinetic and potential energies is accompanied by oscillations. Amplitude of the oscillations decays inversely proportional to time. Analytical results are supported by numerical simulations.

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INFLUENCE OF THE INTERNAL FRICTION, VISCOUS AND TURBULENT DISSIPATION OF LIQUID CARGO TRANSPORTED IN CLOSED TANKS ON THE INTERNAL FRICTION AND CARGO PROPERTIES

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At moving along the roads tanks can have different conditions of driving. At city traffic jams there is a need to move at small distances some amount of times. It can lead to sloshing of liquid cargo in the reservoir and affect the controllability, stability of road car and the rheological features of liquid cargo either [1]. The temperature of transported liquid can change due to the internal forces at liquid sloshing (liquid cargo energy dissipation) at tank transient movement modes. Essential temperature change of liquid cargo can lead to its viscosity change and as a result to changes in the dynamic behavior of the transported liquid and its relative movement, velocities and accelerations. Liquid temperature can be increased after cargo sloshing due to the viscous and turbulent liquid energy dissipation caused by internal forces and turbulent effects of cargo oscillations accordingly.

To analyze the necessity of taking into account thermal processes for simulations of liquid cargo sloshing in closed reservoirs there were carried out computations for road tanks of different shape at transient movement modes partially-filled by liquid cargoes of different viscosity and density. The obtained results showed that increase in liquid density leads to the increase of viscous dissipation due to the transition of liquid particles mechanical energy to heat caused by the internal friction. The values of viscous dissipation for low-viscous liquids (under 1 Pa·s) increase in the directional proportion with the viscosity and density but then this dependence is not linear. After viscosity increases to significant values it begins to decrease due to smaller relative velocities of liquid particles. Generally viscous dissipation of liquid cargoes at their oscillations in closed reservoirs reaches less than 5-10 % from the summarized liquid dissipation.

Previous results showed that road tank stops at emergency braking after 4.2 seconds [2]. So further simulations were performed considering this fact. To estimate the influence of liquid internal forces at its sloshing there were carried out computations for liquid cargoes of 0.001–300 Pa·s dynamics viscosities. The obtained results showed that at road tank braking the temperature of liquid cargo changes not significantly (0–10 %), so for computations of liquid sloshing in closed road tanks the values for temperature and viscosity changes of cargo can be neglected if not considering the external conditions of transportation process.

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CREEP AND PLASTIC FLOW OF THE CYLINDRICAL LAYER OF A MATERIAL AT CHANGING ROTATION VELOCITY OF A BOUNDARY SURFACE

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Cold forming because of slow regime of creep is the most perspective technology of material processing and producing of a finished work. Nevertheless, local areas of plastic flow, which have significant influence on a deforming process, can be found both at common ways of working and at cold forming. Therefore, the construction of a mathematical model of such a process requires a researcher to pay attention to the creep of a material and the development of plastic flow in it. Intensive forming of the deformed material causes necessity of applying the theory of large deformations. Thus, an investigation of cold forming processes should be based on a model of large strains which considers elastic, plastic and viscous properties of the material.

This study considers a boundary value problem of deforming of an incompressible material with nonlinear elastic, viscous and plastic properties. We assume that the material is placed between two rigid cylindrical surfaces and deformed at the rotation of the internal cylinder. Viscous properties of the material are taken into account both before the stage of plastic flow and during this stage. The solution is constructed in the context of the model of large deformations [1, 2]. Components of reversible and irreversible strain tensors are determined by the integration of the system of partial differential equations constructed on the base of constitutive relations of the theory used. At some instant, due to an increase of the rotation velocity of the internal cylinder, in its neighborhood the stress state reaches the yield point, and an area of viscoplastic flow begins to extend. In areas where the stress state has not yet reached the yield surface or plastic flow has stopped, the dissipation mechanism is set in the form of the Norton creep law. When the stress state has reached the yield surface, the dissipation mechanism is determined by the associated plastic flow rule. The generalized Tresca yield criterion is used to consider viscous properties of the material. The deforming process is studied at increasing, constant, decreasing and zero rotation velocity of the internal cylindrical surface.

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DETONATION COMBUSTION IN A SUPERSONIC GAS FLOW IN A PLANE CHANNEL

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Using a detailed chemical kinetics the possibility of a control of detonation propagation in a stoichiometrical hydrogen-air mixture flowing at a supersonic velocity into a plane channel of a special form was investigated. In particular conditions that provide detonation stabilization in the flow (without any energy input) were detected.
The possibility of stabilization of formed detonation in the combustible gas mixture flowing into the plane channel with narrowing cross-section has been determined in [1]. Advancing the research [1] the stability of the flow with stabilized detonation in the channel with narrowing to strong disturbances was examined. It has been established that the flow under consideration with stabilized detonation is stable to those disturbances (excited by an energy input) that do not initiate a new detonation wave upstream some (critical) cross-section of the channel. At such disturbances detonation wave remains in the divergent part of the channel and the flow with stabilized detonation restores with time. Otherwise the detonation wave appears in the convergent channel part and wave moves upstream from the channel.
The possibility of a control of a stabilized detonation wave location in the high-velocity gas mixture flow was investigated. So the influence of increase of the incoming flow Mach number and of dustiness of the incoming combustible gas mixture to detonation stabilization in the flow in the plane channel with narrowing was studied. In particular it has been obtained that in the channel the form of which provides detonation stabilization in case of incoming flow Mach number of 5.2, dustiness of the incoming combustible gas mixture leads to transferring of a stabilized detonation wave location in the downstream direction.
For some Mach numbers of the incoming flow the method of determination of the channel shape, which gives detonation initiation and its stabilization in the flow without any expenditure of energy, is proposed.

This research has been partly supported by the Russian Foundation for Basic Research (14-01-00742a), by the President Grant for Support of Leading Science Schools of Russian Federation (NSh-5436.2014.1), by the Presidium of the RAS (the program No. 24). The study of the stability of the flow with stabilized detonation in the channel with narrowing cross-section and the investigation of detonation stabilization in the dustiness combustible gas mixture have been supported by the Russian Science Foundation (14-19-01759 and 14-11-00773, respectively). This research has been supported by the Supercomputing Center of Lomonosov Moscow State University [2].

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THE MODIFIED THEORY OF HYDRAULIC FRACTURING AND ITS APPLICATIONS

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Hydraulic fracturing (HF) is widely used for engineering purposes. Despite of many studies, there are still difficulties in its understanding and modeling (see, e.g. [1,11]). The work aims to present the latest findings and new results, based on the modified theory, which improve the theory and computational means.
In contrast with the conventional formulation (e.g. [1]), the modified theory [2,3,9,6] employs (i) the particle velocity instead of the flux, (ii) the speed equation (SE) instead of the global mass balance, and (ii) the universal asymptotic umbrella [6]. It provides theoretical, analytical and computational gains.
In the *theoretical aspect*, the modified theory, firstly, removes the confusion, caused by using the flux, which made inapplicable the classical methods [10] of tracing a propagating surface. Secondly, it reveals the fundamental significance of the SE [6]. Thirdly, it discloses the fact [2,3] that, when neglecting the lag and fixing the front, the problem becomes ill-posed. Fourthly, it suggests ε-regularization to overcome this difficulty. Fifthly, it suggests useful normalizing of variables [7,8]. It has also

resulted in *simple analytical solutions* [3,4,11].
In the *computational aspect*, the modified theory makes applicable the classical methods [10]. One of ways consists of using ε-regularization. Its efficiency is confirmed by accurate solutions of plane [2,9,11] and axisymmetric [7] problems. The second way consists of complementing the system of ODE, resulting after spatial discretization, with the SE. Its efficiency is confirmed by solving classical plane problems [9,8].
The modified theory has also provided *practical conclusions.* It reveals that the influence of strong perturbations in initial conditions dies away with time [8]. This smooths over the uncertainty of initial conditions. Furthermore, formulae are derived for assigning the apparent viscosity of thinning fluids [5,7]. The theory also provides easy evaluation of the lag. Further progress is expected when the second approach is used for developing truly 3D simulators of HF.

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MODELING OF NONLINEAR BEHAVIOR OF COMPOSITE MATERIALS

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Three mathematical models for characterization of different types of nonlinearity of composites behavior under deformation are proposed. The physical nonlinearities of composite materials are usually defined by heterogeneous nature, mechanical properties of constituents, the presence of initial defects caused by imperfections of manufacturing technologies and others. The corresponding approach is proposed, where two types of physical nonlinearity are taken into account, one of which is the stress state dependence of material properties (or their susceptibility to the loading conditions) and the second one is concerned the nonlinearity of stress – strain curves under conditions of shear loading, while the diagrams are approximately linear when the load acts along reinforcement. The corresponding constitutive relations are proposed to describe the considered types of physical nonlinearities of composite materials. To describe the first type of physical nonlinearity in the behavior of composite materials, the stress state parameter is introduced into constitutive relations [1, 2]. To take into account the nonlinear shear behavior of a material, the parameter that represents the degree of shear stresses or deformations is formulated and an additional tensor is introduced in constitutive relations, which can be considered as an additional structural parameter characterizing the anisotropic properties of a material. The method for the determination of anisotropic material functions is proposed and its effectiveness in characterization of behavior of composite materials is demonstrated on the base of experimental data for laminate made of the glass cloth and polyether matrix. Several experimental tests show a successful application of proposed model to conventional glass/carbon – epoxy laminate composites.

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ON THE PULL-IN INSTABILITY OF FERROMAGNETIC MEMBRANES AND ELECTROSTATIC MEMS

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The so-called “pull-in” instability as an inherently nonlinear and crucial effect which continues to become increasingly important for the design of electrostatic MEMS and NEMS devices. In systems where an applied voltage is used to actuate or move mechanical components, it is observed that when the applied voltage exceeds a critical value, electrostatic forces become dominant over elastic forces and the mechanical components “pull-in” of collapse into one another. The same phenomenon appears in large-scale electro-mechanical systems which contain ferromagnetic bodies and operate in magnetic fields. In this work we consider the named effect in a circular membrane subjected to electrostatic and magnetic fields of various configurations. Analytical and numerical results were achieved for forms of radially symmetrical equilibrium positions, their stability and bifurcations. Also the question of existence of radially nonsymmetrical equilibrium positions is investigated.

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NONLOCAL DIFFERENTIAL CALCULUS, HELMHOLTZ TYPE THEORY OF ELASTICITY AND THEIR APPLICATIONS TO SINGULAR PROBLEMS IN MECHANICS OF SOLIDS

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The classic differential calculus, based on the analysis of infinitely small quantities, is the foundation of the modern solid mechanics. The traditional system of equilibrium equations of linear elasticity theory is built on its base, using the assumption of uniform distribution of stress on the faces of small element.
In this work, we develop a nonlocal differential calculus for use in the problems, the traditional solution which has high gradients and singular points. Singularity of solutions has no physical nature and is generated by the incorrectness of the model [1]. It is therefore desirable to clarify the mathematical models at the points where the classical solution is singular. Nonlocal models can be used for this goal (as one of example see [2,3]). In contrast to the traditional differential calculus, based on an analysis of the behavior of an infinitely small changes in argument, we introduced a generalized function and its derivative, which describe the behavior of functions in a small, but finite interval of variation of the argument, called the structural parameter of the medium.
As a result, such a generalization the new non-local generalized theory is developing that takes into account the heterogeneity of the distribution of stresses on the representative fragment (non-locality) [4,5]. For generalized theory of elasticity operators balance equations written in terms of displacements, rises to fourth and have the form of the product of classical operator of balance equations and the Helmholtz operator [6].
In general, we consider arbitrary processes (for example the thermal conductivity problem), for which the balance equation and the theory as whole are generalized. Generalized solutions of the mathematical physics problems are constructed that demonstrate the regularization of the solving problems which traditionally had singular solutions. As applications, the singular problems for equations in Cartesian, polar and spherical coordinates are considered.
As an illustration the generalized regular solutions of the singular problems are received . In particular, we established that the problem of calculating the plate with a crack is reduced to the traditional problem of stress concentration.
We developed an experimental method for determining a parameter scale structural parameter of the media and received the corresponding experimental results.

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ON CORRECTNESS OF GRADIENT PLASTICITY THEORY

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In contrast to the classical elasticity, in which there is no scale parameters describing the internal structure of the material, in a nonlocal theory of elasticity the scale parameters appear in a natural way. The non-local models of continuous media are especially appealing for the modeling of the structured materials properties with submicron and nanoscale internal structures, in which the effective properties are largely determined by the scale effects (effects of the cohesion and adhesion).

There is no doubt that the non-local models are also promising in the study of phase transformations, elastic-plastic deformations. Generalized elasticity even for isotropic materials includes many additional physical constants, experimental determination of which is difficult. In this regard, the applied theories with a small number of additional physical parameters have considerable interest. However, the process of formulation of nonlocal theory, which have the goal to reduce the number of additional physical constants is quite non trivial and can lead to incorrect theories.

In the work the non-local theory of media with defects fields, gradient theory of elasticity and plasticity are discussed. We formulate a kinematic media models with field of the kept defects[1]. A brief classification and analysis of theories with field of defects are given.

The free and constrained deformations are determined, the main kinematic relations and compiled lists of arguments of variational models of deformation are established.

We formulate the Lagrangian in the case of static problems and we propose the applied version of the theory, which provides the reduction of the physical constants up to the maximum reduction when the physical properties are determined by the classical elastic moduli. We show that the kinematic model built on the basis of strict concepts for integrable and non-integrable generalized strains can be a criterion of correctness of theories of defective media and gradient theories of plasticity. It is proposed the revision of the variants of theories with defects fields where the integrable properties and generalized Cauchy relations are unreasonably attributed to the total strains.

We consider the models of the dynamic dissipative medias in which dissipative properties are associated with the strain rates [2]. It is given the formulation of the variation of the dissipative part of energy which provides the dissipativeness properties (properties of the lack of potential). We establish the conditions under which the introduction of energy of dissipation, can be justified formally by comparing the motion equations and boundary conditions with equations obtained correctly using the variation of energy of dissipation[3]. We give specific examples of refined equations of motion of elastic-plastic media with dissipation. Qualitative comparisons of the correct (in the case of the correct kinematic relations) and incorrect theories are given.

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FORMATION AND DEVELOPMENT OF METHANE FILTRATION WAVES IN STRESSED COAL SEAMS

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The analysis of gas pressure measurements in gas-bearing coal seams allows to make the following conclusions:

- intact coal beds are impenetrable everywhere below the gas weathering zone, despite the presence of fissures and pores of various scale levels;
- the pressure settling in a pressurized borehole that exposes a coal seam is always below the natural seam pressure and is defined by the dimensions of the permeability zone forming in the borehole environment.

Thus, the main factors influencing the formation of coal seams permeability in the conditions of their natural bedding with a change of the array stress-strain state associated with mining works have been considered. An analytical correlation describing the dependence of the permeability on the mean stress S and the quantity Q of the gas adsorbed by the coal has been proposed. The (S, Q) coordinates permeability surface that defines the parameters of the coal seam filtration zone and the laws of methane mass transfer has been constructed. A comparison of this correlation with the model widely used in the world that reflects the structure of coal has been carried out, as well as with the results of experimental studies. It has been demonstrated that the proposed model of the coal seam permeability is sufficiently adaptable, and with a suitable choice or an experimental determination of its parameters it enables the description of filtering and localization patterns of permeability zones in the coal seam.

Using the obtained dependency, the boundary value problem of the filtration in gas-bearing coal seams theory has been formulated with the consideration of gas-permeable zone formation and propagation processes. The main equations, along with the initial and boundary conditions of gas filtration and desorption have been written. The porousness and the permeability are viewed as functions of adsorbed gas concentration and stresses. It has been demonstrated that a pressure jump and an adsorbed gas concentration jump exist on the moving boundary of the permeable zone whose values are not constant but change during the filtration. They are linked between themselves and the propagation speed of the coal seam permeable zone by the flux continuousness and desorption kinetics conditions.

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NON-EQUILIBRIUM THERMAL EFFECTS IN FINITE ONE-DIMENSIONAL CRYSTALS

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The classical thermodynamics deals with equilibrium processes in ideal crystals. Non-equilibrium processes have a great importance for research, but description of these processes can be very complicated and an analytical solution is often unavailable. This work is based on earlier works [1-2] in which a simple analytical description of thermal processes were derived through a solution of the dynamic equations for statistical characteristics of the crystal. In this work, we consider an instantaneous thermal perturbation (e.g., an effect of ultrashort laser pulse) of one-dimensional crystal with Born-Karman boundary conditions. It has been found that root mean square velocities (the kinetic temperature) in the crystal can be represented as an infinite sum of shifted Bessel function. This solution describes the phenomenon of a periodic thermal echo, which can be observed in crystals subjected by instantaneous heat perturbation.

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THE FLAT SELF-SIMILAR PROBLEM ABOUT THE FALL OF PLANE SHOCK WAVE ON THE FLUID-SOLID INTERFACE

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The study of the propagation of reflected and refracted elastic perturbations on interface of fluid-solid is an important task, since the elastic wave can describe the processes causing them. Propagation of perturbations in fluids has been studied by experimental methods [1-4]. The problem of reflection and refraction of the compression wave from the liquid solid interface has been considered theoretically [5]. Propagation of perturbation in poroelastic ocean bed has been studied in [6]. In this paper we solve the problem of propagation of a plane shock wave moving in a perfect fluid and incident on the solid. Attention is focused on the distribution of energy after the passage of the reflected and refracted waves. Energy loss occurs due to friction or any inelastic link between particles which exists at the junction at the interface of fluid-solid. The numerical experiments are calculeted for a plane wave propagating downwards in the fluid-sandstone interface. Questions of numerical solution of such problems were discussed in detail in [7,8].

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DYNAMIC PROBLEM OF LONGITUDINAL SPHERICAL SHOCK WAVE IN ELASTIC-PLASTIC MEDIUM WITH SELF-SIMILAR RESTRICTIONS

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Most of the materials have residual stresses which are caused by the presence of reversible and irreversible deformations. This affects the behavior of the material in the further process of deformation.
Classical linear model of elastic-plastic medium does not describe similar effects. In order to consider the effect of irreversible accumulated deformations on further deformation processes (propagation of disturbances) the usage of non-linear model is needed. There are several non-linear models [1-6]. In the present study we used the model described in [7-9]. By using this model, we solved the problems in [10-15]. The problems of propagation of shock and simple waves in elastic-plastic medium are solved in [16-17]. Using this model, the self-similar solution, about the propagation of the longitudinal spherical shock wave in a medium with the accumulated irreversible deformations, was obtained.

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LINKING MOLECULAR AND CONTINUUM MECHANICS WITH APPLICATION TO BIOMIMETIC NANOMATERIALS AND BRITTLE FRACTURE

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The mechanical properties of hierarchically structured materials relies on the characterization and understanding of their nanostructure. A classical example is the dragline silk. Experimental studies have shown that the extraordinary mechanical properties of silk are conferred largely to the nanostructure. In the first part, we propose a three dimensional (3D) finite element model of a silk fiber, which is based on the secondary (nano-scale) structure of the Araneus diadematus silk fiber, taking into account the plasticity of the β-sheet crystals as well as the viscous behavior of the amorphous matrix. Our bottom-up approach to dragline silk fiber predicted mechanical properties agree with the experimental ones within the limits of the experimental accuracy.
In the second part, a novel combined method for highly brittle materials such as aragonite crystals is proposed, which provides an efficient and accurate in-sight understanding for multi-scale fracture modeling. In particular, physically-motivated molecular dynamics (MD) simulations are performed for crack modeling on the nano-scale, whereas a macroscopic modeling of fracture has proven successful using the diffusive phase-field modeling (PFM) approach. A link between the two modeling schemes is proposed by deriving PFM parameters from the MD atomistic simulations. Thus, in this combined approach, MD simulations provide a more realistic meaning and physical estimation of the PFM parameters.
The proposed computational approach, not requiring any empirical parameters, contributes towards an improved understanding of mechanics at all length-scale levels. Hence, it is an efficient model for the design of new materials as well as applicable to other semi-crystalline polymeric systems or composite materials.

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THERMAL EXPANSION OF QUASI ONE-DIMENSIONAL CHAIN WITH ANGULAR INTERACTIONS

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In paper [1], thermal expansion of quasi one-dimensional chain with Lennard-Jones-like interactions was investigated. It was shown that the dependence of thermal pressure on the thermal energy is strongly nonlinear at small deformations of the chain. At zero deformation, Gruneisen parameter is formally equal to minus infinity. In the present work, we consider the quasi one-dimensional chain with pair and three-particle interactions. The three-particle interactions are modeled by angular springs. We show numerically that in this system Gruneisen parameter at zero deformation is finite. However it linearly diverges with length of the chain. At non-zero tensile deformations, Gruneisen parameter also demonstrates length dependence. However, in this case it converges to finite value as chain length increases. It is expected that similar phenomenon can be observed in one-dimensional materials, such as, carbyne [2] and nanowires [3].

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NUMERICAL SIMULATION OF STRESS CONCENTRATION IN DEFORMED MATERIALS WITH A CURVILINEAR MODIFIED SURFACE LAYER - BASE MATERIAL INTERFACE

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The interfacial mechanisms of the stress concentration in materials with modified surface layers are investigated. A dynamic boundary-value problem in a plane-strain formulation is solved numerically by the finite-difference method [1 and 2]. The geometry of a curvilinear interface corresponds to the configuration found experimentally [3] and is explicitly accounted for in the calculations. Both the experimentally observed microstructure of a sample with a serrated coating-substrate interface and a model microstructure with an ideal sinusoidal shape of this boundary were considered. The constitutive model assumes that the modified surface layers are elastic, while the elasticity of the base material is followed by plastic flow which provides isotropic strain hardening. Serrated and wavy base material-surface layer interfaces observed experimentally are assigned explicitly in calculations. Two stages in the evolution of the stress concentration are found to occur due to irregular interfacial geometry. The stress concentration in near-interfacial regions turns out to depend on the parameters of sinusoidal wavy interface and coating thickness.

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FINITE-ELEMENT SIMULATION OF FRACTURE HEALING OF A HUMAN TIBIA USING MECHANO-REGULATION ALGORITHM

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It is known, that living tissues in the process of their growth and development significantly react to the external force field they are functioning in. Mechanical factor takes stimulating and regulating effect to the specific tissue cells, resulting in initiation and development of organ structural transformation processes in the macroscopic aspect [1]. Phenomenon of structural transformation from a soft primitive substance into a solid bone tissue is the result of bone cell differentiation. For example, it takes place during the process of bone continuity regeneration after fracture and skeletal implantation into a bone tissue solid substance that results in initiation of bone remodeling processes in the area of apposition with the surface of the foreign object or between pieces of the broken bone.

The general dynamic model of the changing poroelastic continuous medium and the mathematical algorithm conceptually describing the bone tissue regeneration process under impact of the external mechanical stimulus of periodic behavior is introduced in the paper. The model implies that forced interstitial fluid flows induced in the bone pore system due to osseous matrix deformation along with inherent elastic matrix strains are the key mechanical factor regulating bone tissue reparative regeneration. For numerical analysis of the developed mathematical model the computational algorithms to develop the software for computer simulation of the bone regeneration are suggested.

The mathematical model provides possibility of the investigation of the regeneration processes of the damaged bone elements of the human locomotion system upon the availability of a dynamic load and the theoretical argumentation of the choice of the optimal periodic impact to the damaged tissues for the fastest and stable healing. In particular, the created model allows studying the stimulating load frequency impact to the tissue transformation process, which is completely missing in the well-known references and the early loading influence to the callus elastic properties restoration as well.

The obtained numerical results are thought to be rather realistic and corresponding to the well-known medical investigations of the bone tissue regeneration processes in the fracture area.

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DYNAMICS OF OFFSHORE STRUCTURES IN ICE

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Ice actions on offshore structures are one of the main concerns for engineering activities in cold areas with ice-infested waters. This presentation focuses on the dynamics of structures in level ice – a topic that is of importance for design of fixed and floating wind turbines and drilling rigs. Main attention in the presentation is paid to the dynamic interaction of ice with vertically sided structures. This process is rather complex and includes ice crushing in the contact zone, bending and splitting failure at a larger distance from the structures and ice buckling. Understanding of the combination of ice crushing and buckling is especially important for the design of wind turbines in the subarctic areas, where ice is relatively thin but is capable of exerting dynamic loads that may accelerate fatigue of the support structures. The ice-structure interaction in the regime of combined crushing, splitting and buckling includes many interesting phenomena such as temporal and spatial synchronisation of the ice failure and the buckling under dynamically varying compressive load that does not always result in bending failure. These aspects will be addressed by means of an overview of available experimental results, recent observations and modelling with the help of a recently developed in TU Delft phenomenological model

[1,2]. The talk will also touch upon the bending failure of ice against a sloping at the ice level structure. Significance of the proper contact modelling and of the nonlinear hydrodynamic interaction between ice and water will be discussed. Finally, the added mass of water experienced by a vessel operating in the vicinity of an ice field will be addressed. The latter topic, although not directly related to the process of ice-structure interaction, is of importance for exploratory operations in ice-infested waters.

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FRACTIONAL LATTICE DYNAMICS: NONLOCAL CONSTITUTIVE BEHAVIOR GENERATED BY POWER LAW MATRIX FUNCTIONS AND THEIR FRACTIONAL CONTINUUM LIMIT KERNELS

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We introduce positive 'fractional' elastic potentials in the harmonic approximation leading by Hamilton's variational principle to fractional Laplacian matrices having the forms of power law matrix functions of the simple local Born von Karman Laplacian matrix defined on periodic lattices. The present approach generalizes the central symmetric second difference operator (Born von Karman Laplacian) to its fractional central symmetric counterpart (Fractional Laplacian matrix). The fractional Laplacian matrices obtained have all good properties of Laplacian matrices equivalent to elastic stability and translational invariance.

For non-integer powers of the Born von Karman Laplacian, the fractional Laplacian matrix is nondiagonal with nonzero matrix elements everywhere, corresponding to nonlocal constitutive behavior: For large lattices the matrix elements far from the diagonal expose power law asymptotics leading to continuum limit kernels of Riesz fractional derivative type. We present explicit results for the fractional Laplacian matrix in 1D for finite periodic and infinite linear chains (1D periodic lattices) and Riesz fractional derivative continuum limit kernels **[1,2].** This fractional Laplacian matrix recovers for integer power = 2 the well known classical Born von Karman linear chain with local next neighbor springs leading in the continuum limit to classic local standard elasticity, and for other integer powers to gradient elasticity. We demonstrate that our fractional lattice approach is a powerful tool to generate physically admissible nonlocal lattice material models and their continuum representations.

We also present the extension of the approach to n=1,2,3 dimensional finite periodic and infinite lattices of cubic symmetry. This extension is in accordance with a recently suggested fractional approach for general networks introduced by Riascos and Mateos in 2012 **[3,4]**.

Apart from nonlocal elasticity a further wide field of possible physical applications are fractional diffusion- and transport problems, involving the fractional Laplacian instead of standard Laplacian, describeing long range power law distributed jump distances (Levy flights).

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BEHAVIOR OF MIXTURES OF POLAR AND NONPOLAR LIQUIDS IN CARBON NANOTUBES

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Molecular dynamics (MD) simulations of an equililibrium structure and a flow of mixtures of polar water and nonpolar methane in carbon nanotubes have been performed. The results of these simulations allow to conclude that, for equilibrium behavior of mixtures, the polar water molecules play a dominant role, and this dominanant role is due to long – range Coulomb interactions between water ones. It has been also revealed that, for equilibrium flow of the mixture under external forces, trajectories of polar and nonpolar molecules are practically similar and their shapes coincide with those of molecules in a pure water. This fact also demonstrates the dominant role of the polar water molecules in the mixture. A dependence of a mean flow velocity on a concentration of nonpolar methane molecules has been determined, and a qualitative explanation of this dependence is presented.

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NUMERICAL MODELLING OF HYDRAULIC FRACTURES – ESSENTIALS OF ACCURATE AND STABLE COMPUTATIONS

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Hydraulic fractures (HFs) are present in many natural processes and technological operations. They can make up a desired phenomenon and then their effective stimulation is required (fracking technologies). However HFs may constitute a detrimental by-effect as well and then one needs to take adequate measures to counteract their creation (e.g. underground storage of contaminants). The characteristics of the underlying physical process can be different depending on the local conditions under which the fracture propagates. The typical dimensions of HFs may range from a few meters in length and few millilitres of width (e.g. fractures induced in the process of CO_2 sequestration) to the values of ten kilometres and few meters of maximal aperture (magmatic intrusions in the earth crust). The overall character of the HF evolution results from competition between multiple physical fields manifesting themselves with different intensities at different temporal and spatial scales.

Mathematical modelling of HFs constitutes an extremely challenging task. The multiphysical nature of the problem necessitates careful selection of the component physical mechanisms to be accounted for without excessive complication of the model. Furthermore, finding the numerical solution is always an extremely complex and computationally expensive process [1]. The first mathematical models of HFs were delivered in 1950s. An immense progress in the area has been made ever since [2], however there still exists a strong need for further improvements.

In the presentation we revisit the basic assumptions of mathematical modelling of HFs. The essential difficulties when constructing the respective models are itemized. We show the nature and sources of computational problems. Recent advances in the field of numerical simulation of HFs are elaborated. A unique approach to numerical modelling of HFs developed recently of the authors is presented [3,4]. The scheme combines proper accounting for the man problem features with effective handling of standard and dedicated numerical techniques. The advantages of presented algorithm are demonstrated on the basis of analytical benchmark solutions and data available in literature.

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SLEPYAN'S METHOD FOR SOLVING WAVE AND FRACTURE PROPAGATION PROBLEMS IN LATTICE STRUCTURES: ADVANTAGES AND LIMITATIONS

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In this talk we summarise the main ideas and capabilities of the Slepyan's method used to analyse and solve modern problems related to transition front propagation in complex heterogeneous lattice structures and metamaterials. Classic and more recent results in the area are shortly overviewed. Main challenges and open problems are indicated.

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STRUCTURAL-MECHANICAL AFM MAPPING OF OVERSTRESSED ZONES IN STRETCHED FILLED NATURAL RUBBER

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Surfaces of cracks in the stretched natural rubber filled with silica nanoparticles were studied. On the non-deformed material the notches were made and then the sample was stretched and fixed. As the result, the defects propagated deeper into the material and somehow stopped. The polymer matrix in the region of crack is in critical stress-strain state. If the elongation of the sample will be increased, the crack will grow further. The surface of such cracks was studied by atomic force microscope in nanomechanical mapping regime. The obtained tip-sample interaction force curves were approximated by Maugis elastic model [1, 2] and the modulus of the surface was obtained. It was found that the stiffness of the polymer in the crack is much higher than the stiffness of the material in the unloaded state. This is due to strain-induced crystallization and orientation of natural rubber. The formation of elastomeric strands oriented orthogonal to the axis of the crack was observed. It was shown that the stiffness and structure of the polymer and oriented strands depend both on the filler fraction and the distance from the crack tip.

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CONVECTIVE INSTABILITY DRIVEN BY A NEUTRALIZATION REACTION

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Studies of the processes of heat and mass transfer in the systems of reacting liquids are currently receiving attention of researchers from various fields of science [1]. It is connected with the huge industrial relevance of such systems and therefore the understanding the nature of the problem is one of the foundations of modern technologies of chemical production.

It is well known that bringing into contact two fixed layers of miscible reactive liquid leads to the formation of a narrow transition zone. Due to diffusion in this zone the mixing process and the reaction with the product formation are occurred. In the case, when the diffusion is a predominant mechanism of mass transfer, the typical time of the reaction lies between few hours to several days, depending on the size of the reactor. However, the mixing processes can proceed much faster due to convective motions caused by local heat and by product formation density of which is different from the density of the initial reagents. Therefore the main research focuses on the study of the structure of convective flows arising because of hydrodynamic instability in the reaction zone [2, 3].

In the paper the results of the experimental investigation of convective instabilities driven by an acid-base neutralization reaction are reported. Aqueous solutions of nitric acid and alkali metal hydroxides (Li, Na, K) were used as reactants. Depending on the initial reactants concentration, two reaction modes are observed. The first one is a diffusion mode, where the predominant mass transfer mechanism is diffusion, leading to slow rates of reaction and the second one is convective regime characterizing by the formation of the intense convective motion and rapid reaction. Physical model of the observed phenomenon and maps of regimes for various pairs "acid - base" have been proposed.

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SHAPE MEMORY EFFECT IN AN ORIENTED ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE

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In recent years great attention is given to the shape memory effect (SME) in polymers that is induced deformation. A variety of functional properties of the shape memory polymers (SMP) allows solving many engineering and technological challenges. In comparison with shape memory alloys and shape memory ceramics, polymers are deformed largely, they are cheaper, adaptable to streamlined production methods and lighter weight. Application of SMP opens possibilities for the creation of devices which are capable to rhythmic contractions controlled by an external stimulus – artificial muscles.

Recovery stress and reversible deformation are functional properties which used to characterize SME. The polymers have a very high ability to relative strain. In spite of it they have low recovery stress in comparison with shape memory alloys. Ultra-high molecular weight polyethylene (UHMWPE) demonstrates some of the highest recovery stress among SMPs – stress of highly oriented UHMWPE fibers is more than 20 MPa [1], whereas stress of another SMPs generally range from 1 MPa to 10 MPa [2].

In this work, a research of SMP was conducted in highly oriented UHMWPE fibers produced by a gel-spun method with various drawing ratings λ. This method involves sequential obtaining a gel spun fiber from the polymer's solution and its subsequent conversion into the xerogel. In the first step the solution of UHMWPE was obtained in p-xylene at 135 ° C and regular stirring. Gel fiber was formed by pressing the resulting solution through a ram extruder's spinning jet with 5 mm in diameter. Xerogel condition was achieved by drying the gel fiber. In the next step, the drawing of fibers was carried out by stepwise orientation thermal stretching at temperatures of 110 ÷ 140 ° C. Consequently, there were obtained fibers with drawing ratings λ=25, λ=50, λ=75 and λ=100.

Dynamic mechanical analysis was used to measure the recovery stress of highly oriented UHMWPE fiber arising upon heating, depending on the drawing rating λ. The results showed that the value of recovery stress increases with the increase of the drawing rating. For the fibers with λ = 100 drawing rating is 41.4 MPa, which is a record value for SMPs. Artificial muscles were produced by method of weaving [3] from highly oriented fiber with the drawing rating λ = 75 that are capable of reversible rhythmic reduction and straightening after heating and cooling. These muscles are reduced by 5% with stress of 8 MPa. Biological muscles in a static mode can elaborate a stress of 0.6 MPa.

Achieved values of reactive stress for highly oriented UHMWPE fibers are the maximum ones of those described in the literature. Obtained samples of artificial muscles have no analogues in the Russian market.

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MULTIWALL CARBON NANOTUBES REINFORCED NANOCOMPOSITES BASED ON ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE

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At the present time, one of the challenging problems is an obtaining of biocompatible polymer nanocomposites. Improved physical, mechanical and tribological characteristics allow polymer nanocomposites being perspectively used in various areas of production, especially in endoprosthesis replacement [1,2].

An amount of material, applied to obtain endoprosthesis is limited. In the present work, an ultra-high molecular weight polyethylene (UHMWPE) was used as a polymer matrix due to the fact that it is the only accepted one [3].

Multi-walled carbon nanotubes (MWCNT) were used as reinforced filler in the response of unique properties [4]. An orientation stretching was used to improve mechanical properties by additional dispersion of filler, its integration into polymer chain and by increasing of interaction between filler and the polymer matrix [4,5].
The addition of MWCNT into the matrix of UHMWPE was carried out in a planetary mill. As a result, composite powders of UHMWPE/ MWCNT were obtained with concentration from 0.1 wt. % to 2 wt. %. Bulk samples were carried out in two steps by an annealing process with an extra pressure. The first step deals with obtaining of a precursor from composite powders. The next step was the orientation of the precursors and its annealing. During the orientation process of precursors, MWCNT lined up along applied tensile stress, which allowed increasing an ability to redistribute stress from matrix to filler.
Mechanical tests showed a significant increase in breaking tenacity (up to 6 times) due to a presence of the MWCNT and orientation of UHMWPE structure. Combined effect of UHMWPE orientation structure and MWCNT presence is expressed in significant improvement of tribological characteristics of developing materials, friction coefficient decreased down to 0.135 (for an original UHMWPE this coefficient is 0.24) and durability increased by 56 %.
Collected results demonstrate that application of developed composite materials is very perspective in various fields of industry, which required for biocompatible materials with high mechanical and tribological properties.

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CALCULATIONS OF COLLOIDAL SOLUTION MICRODROP DRYING

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The microdrop of colloidal solution is considered as the modeling system in the presented work. The drop is placed on a glass substrate and dries for some time. The drop is a micro reactor where physicochemical process of crystallization or dissolved substance precipitation takes place. It results in a solid phase with certain morphology on a substrate.
The substrate is supposed to be smooth, flat and without any roughness of surface. For simplification the surface of the drop is considered to be spherical with a radius equal to R. Layer-by-layer evaporation of the drop with preservation of a surface form takes place. It is considered that a contact angle is constant. A pressure of saturated steam in air at distance δ is equal to zero, i.e. it is much less than at a surface.
The thermodynamic process happening in the analyzed system is supposed to be isothermal, i.e. drying of a drop happens without any changes of both external and internal temperature. Regarded under this simplified condition the process happening in the drop doesn't involve thermodynamic circulation, in other words, there is no convective motion of the molecules of liquid in the drop.
For quantification of a ratio between the variables which define the diffusion the first law of Adolf Fickis used. It says that the vector of density of a diffusive stream $\overrightarrow{J_p}$ is directly proportional to a concentration gradient with proportionality coefficient equal to coefficient of diffusion D.

$$\overrightarrow{J_p} = -D\nabla\rho_p \quad (1)$$

Here ρ_p - mass density of colloidal particles.
For receiving reliable results the following model is considered: according to the formula (3) which was received by the mathematical analysis of microdrop evaporation process, liquid dries linearly depending on time, in other words, on each temporary step the radius of a drop decreases in accordance to the above-mentioned formula (3), in the volume of system there is a process of redistribution of concentration of colloidal solution according to laws of diffusion.
From the first law of Fick:

$$J = -D_{st}\frac{\partial\rho_n}{\partial r} \quad (2)$$

Here D —the diffusion coefficient of vapor.
The initial conditions are the following: $r(t_0) = r_0$. Let $t_0 = 0$, then, after carrying out mathematical transformations dependence of the radius $R(t)$ of a drop life time is received:

$$R(t) = \frac{2J\sin\propto}{(1-\cos\propto)(3\sin\propto -1+\cos\propto)\rho}t + r_0 \quad (3)$$

Here $\propto$ - a contact angle.

It is shown that the radius of a drop decreases under the linear law.

The drying of colloidal solution drop model which illustrates solvent evaporation process and also enables to analyze procedure of precipitation of colloidal particles on a substrate is constructed.

Thus two phenomena were studied and analyzed. They are redistribution of density in drop as a result of substance diffusion and obtaining the graph of the dependence of surface density of colloidal particles on their location on the substrate-liquid interface.

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COMPARISON OF DIFFERENT METHODOLOGIES LEADING TO A GENERALIZED ELASTICITY THEORY FOR MODELING THE SIZE EFFECT

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Traditional elasticity theory of continuum mechanics fails to model structures on the micrometer length scale accurately. However, nowadays, for example in micro-electro-mechanical systems (MEMS), modeling and simulation of small scale designs are of paramount importance. Many experimental observations over the last decades – see for example [1], [2], and [3] – indicate a size effect showing up in micrometer length scale. By scaling down the dimensions of a structure, the deformation starts to deviate from the expected results calculated by traditional elasticity theory. This behavior is referred to as the size effect. As justified by many experimental observations we need a generalization of elasticity theory. There are, indeed, many propositions about possible generalizations in the literature. The different theories can be grouped under two methods.

Rational mechanics can be used to obtain a generalization of the elasticity theory. In addition to the balance of linear momentum, the balances of angular momentum and spin are utilized in order to capture the effects introduced by materials showing the size effect. In this work, we give a brief outline of the method based on rational mechanics, which is already implemented in [4], [5].

Classical mechanics delivers a straightforward way for generalizing elasticity theory. Starting from the principle of least action, we can incorporate the effects necessary for modeling the size effect. We also outline the method stemming from the classical mechanics, as done in [6].

The two different methodologies lead to weak forms that allow us to compute the size effect as observed in experiments. Both methods deliver the same deformation behavior as observed in experiments. However, the methods are inherently different. Hence, in this work, we want to compare the methods and find out their analogies as well as dissimilarities.

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ASSESSING DEFORMATION DUE TO SELF-GRAVITATION – TREACHEROUS PATHWAYS OF CONTINUUM MECHANICS

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Linear Hookean elasticity formulated in terms of linear

strain measures is the simplest way of modeling deformation in self-gravitating terrestrial bodies. In this case the solutions for the stresses, the strains, and the displacements can be presented in closed form, as was first shown by the great (linear) elastician A.E.H. Love around the beginning of last century [1]. We will, first, present the underlying theory in modern form. Second, solutions to the resulting equations will be obtained. Third, the equations will be evaluated by using physical data of various objects, such as terrestrial planets, moons, and asteroids. This will show that under certain circumstances the displacements may be enormous. Consequently, the limits of linear strain theory will become evident.
As a special feature we will then leave the canonical pathway of linear elasticity, where it is conventionally assumed that the body forces are applied to the undeformed configuration [2]. In contrast to conventional (engineering) literature, we will present an "extended model" and study the influence of linear terms of displacement gradients in the body force density. In fact, this approach may serve as a bridge between linear elasticity at small strains and elasticity at large deformations. Moreover, it has the advantage of still leading to closed-form solutions.
In an attempt to remedy the problem of large deformations once and for all we will then choose a nonlinear version of Hooke's law in the current configuration. More precisely, the Cauchy stress will be related to the nonlinear deformation measure of the current configuration, the Euler-Almansi fnite strain, which replaces the linear strain tensor of the ordinary Hooke's law [3]. However, even this approach has drawbacks: As we shall see, we will run into modeling and numerical problems again, if the mass of the self-gravitating object becomes too large. There will even be a limit mass beyond which stresses will go to infinity, similarly to the case of the Chandrasekhar limit for the mass of white dwarf stars. However, this phenomenon is an artifact of the constitutive law we chose for the stress-strain relation [4]: It can lead to a unique, two, three, or no solutions for the problem.
Finally we will turn to time-dependent modeling of deformation in terms of a deformation-wise linear viscoelastic model of the Kelvin-Voigt type [5]. Surprisingly it allows for a closed-form solution. As a new result it will turn out that in the early days of planet formation the so-called Love radius, which is the demarcation line between the completely compressive interior of a planet from a radial strain-wise tensile exterior, does not exist initially and requires time for its development.

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A DISCONTINUOUS GALERKIN APPROACH FOR HIGHER DIMENSIONAL FOKKER-PLANCK EQUATIONS IN NON-LINEAR STRUCTURAL DYNAMICS

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The random vibration of a structural dynamic system is described by stochastic partial differential equations (SPDE) which can be transformed into a Fokker-Planck Equation (FPE) [1], originally developed for Brownian motion of a Particle in viscous liquid. Analytical solutions can be provided for linear systems; however, a numerical treatment is necessary to solve FPE's for non-linear systems. A first challenge arises from the numerical solution of the advection-diffusion type equation; another is with regard to the dimension of the problem.
In this presentation a Time-Discontinuous Galerkin (TDG) approach will be introduced for the solution of advection-diffusion equation. To tackle the curse of dimensionality, a special discontinuous Galerkin method in higher dimensions is suggested [2]. I will be shown, that this enables for the solution of FPE's with moderate degrees of freedom.

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STOCHASTIC FINITE ELEMENT METHODS FOR NON-LINEAR SOLID MECHANICS

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Randomness of model parameters and loading conditions have to be considered for the analysis of structural safety, robustness and sensitivity. A classical approach on considering aleatory uncertainties for simplicity, probabilistic methods can be applied in a straight forward manner for systems with linear response, see e.g. [1,2,3]. In contrast, for systems with non-linear response behavior sophisticated techniques are needed. Focus in this presentation is led on

- An introduction to alternative stochastic finite element techniques in solid mechanics
- Specific challenges on the treatment of in-elastic material equations
- Evaluation of different computational techniques with regard to robustness and computational efficiency based on elasto-plastic and damage mechanics models

The presentation will conclude with a discussion on current demand in this research field, where special emphasis is focused on model reduction techniques for fast computations.

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METHANE EMISSION AND ADSORPTION-INDUCED DEFORMATION OF COAL BEDS: DIRECT AND INVERSE PROBLEMS

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Prior to mining, coal beds are subjected to obligatory pre-treatment and one of the most important stages of the pre-treatment is gas drainage, assisting to mitigate risk of disastrous events of coal and gas outbursts that are often accompanied by fire. For elaboration of an optimal operation scheme of gas drainage and to accelerate degasification, it is required to assess diffusion and storage capacities of coal bed as well as spatial distribution of gas content and natural stress field, the horizontal component of which is usually characterized by lateral earth pressure coefficient Q.

In situ coal is a hierarchically structured geo-material, and its permeability is conditioned by a system of pores and fractures of different scale. It is impossible to construct a detailed model of such medium as experimental data are very difficult to obtain; therefore it is common to synthesize various constitutive equations based on the concept of representative equivalent volume [1], one of the versions of which [2] is used in this study.

The authors have developed a geomechanical model of a horizontal gas-bearing coal bed with an access vertical well to describe desorption kinetics, evolution of gas content and stress–strain state and gas pressure field. It is proposed to implement the model using an original approach: distribution of pressure at each time moment is found by solving a nonlinear equation of filtration by the finite-difference method and, then, stresses and strains are calculated using quadratures.

One of the methods to obtain an express-estimate of initial coal bed content C is to evaluate volume of chippings W in access well drilling. The numerical experiments have allowed the functional connection between W, C and Q at different values of coal bed permeability K. It appears that W grows with a decrease in Q and with an increase in K.

An inverse problem has been formulated to find permeability and lateral earth pressure coefficient based on time variation of pressure P(t) in a shut-in well, and resolvability of the problem is tested. From the calculations, P(t) with time tends to a constant value S that is proportional to Q and independent of coal bed permeability and gas kinetics. This makes it possibe to asses lateral earth pressure coefficient based on S and, then, to estimate coal bed permability by minimizing objective function (mean-square deviation of measured P(t) and theoretical values of the pressure).

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EVOLUTION OF GEOMECHANICAL FIELDS AND TECHNOGENIC SEISMICITY OF NATURAL OBJECTS

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The authors present processes, algorithms and problem-solution reports on modeling of evolution of geomechanical fields of different-scale natural and technogenic objects.

The laboratory experiments “Brazilian test” with simultaneous registration of surface microdisplacements by

White Light Speckle Photography method [1] were carried out using the disk granite samples. Joint analysis of macrostresses (analytical solution of 2D elastic problem on diametral compression of circular domain) and microstrains revealed the cross correlation relationship between jointing and stress level in different parts of sample. It permits to estimate state and stability of whole object by monitoring data of object section only based on calibrated geomechanical model.

A rock mass and Earth's lithosphere have a block structure with elements interacting along contact surfaces, which deformation is described by non-linear state equations. The process is proposed for step-by-step solving of boundary-value problems based on hierarchy of 3D geomechanical models. Boundary conditions at the first global level are formulated based on indirect (seismotectonic, geodesic) information on stress fields in the lithosphere. At the second (regional) and third (local) levels the calculation data obtained at previous hierarchic levels were used for this purpose with refinement in terms of measured in-situ parameters of geomechanical fields. The approach was realized by applying the finite element method for the following objects: Central Asia [2], Altai-Sayan folded area, Tashtagol iron-ore deposit. The detailed 3D geomechanical model describing the history of the deposit exploitation and the stress field evolution was worked out for the last of the above objects.

Justification is given to the approach to establish correlation relations between parameters of space-time distribution of technogenic seismicity (number, power, and location of dynamic event spots as stochastic information) and stress-state of geotechnical entities (stress tensor invariants as deterministic information) in the course of mining operations. The proposed approach was verified using the database of dynamic events at Tashtagol mine (about 25000 events from 1 to 10 MJ in power within 1989-2014 period). This allowed forecasting of technogenic seismicity in geomechanical substantiation of perspective deposit mining plan for 2016-2020 period.

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VARIATIONAL FORMULATIONS AND ISOGEOMETRIC ANALYSIS OF GRADIENT-ELASTIC THIN-WALLED STRUCTURES

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Isogeometric methods [1] are used to analyse statics and dynamics of plate [2, 3], beam [4], membrane and bar models [5] based on Mindlin's strain gradient elasticity theory [6]. The current models include higher-order displacement gradients combined with length scale parameters enriching the strain and kinetic energies of the classical elasticity and hence resulting in higher-order partial differential equations with corresponding non-standard boundary conditions. The solvability of each problem is formulated in an appropriate Sobolev space setting, H^2 or higher, and the problem is then discretized by isogeometric NURBS basis functions with appropriate continuity properties, C^1 or higher. Benchmark problems examples illustrate the main features of both the models and the numerical approach.

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DYNAMICAL RESPONSE IN PASSIVELY ELASTIC SKELETALMUSCLES

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The theory of shear wave propagation in "soft solid" materials possessing anisotropy of elastic and dissipative properties is now developing for understanding the nature of low-frequency acoustic characteristics in skeletal muscles carrying important diagnostic information on the functional state of muscles and their pathologies, cardiorespiratory responses in space medicine, etc. The main experimental techniques are usually reduced to studying a response of the dynamic system to a monochromatic signal. The spectrum of this response to a sufficiently high-intensity signal can appear too complex to identify the structure of an object under investigation due to nonlinear processes. Therefore, one important theoretical problem is to describe the frequency ranges in which the dynamics of a system is the most predictable. A good theoretical sketch of skeletal muscles can be done as a stack of flat plates held together elastically with gelatin [1]. In the present paper, skeletal muscles are modeled in another way, namely, as a set of elastic filaments, oriented triangularly in parallel, and coupled together elastically along M-bridges. The lower-order resonances are fully classified in this model to lend us a structural scheme for nonlinear oscillatory wave processes in skeletal muscles. The first-order approximation analysis shows that the proposed scheme is able to provide an optimistic diagnostic information based on the instability of tensional waves with respect shear perturbations in the damped forced case.

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MOLECULAR DYNAMICS STUDY OF THE RELATIVE SLIDING MECHANISMS IN AMORPHOUS SILICA AND CARBON

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In the paper simulation of the treatment of two crystals with amorphous interlayer was carried out using the method of molecular dynamics. We studied three different configurations: α-silica (quartz) sample with amorphous interlayer, two α-Fe crystallites with amorphous carbon layer between them and two diamond crystallites with amorphous carbon interlayer. Interatomic interaction in case of iron and diamond crystallites with carbon interlayers was described by the modified embedded atom method [1]. To study the behavior of silica sample the tree-body interatomic interaction suggested by Tersoff was used [2]. The simulation result revealed several processes realized in the contact area as a result of shear loading. Depending on the temperature of the sample and material of the crystal and the amorphous layer we observed slip on the interface between the crystal and amorphous, deformation of an amorphous layer and formation of wear particles. It has been found that a necessary condition for the formation of wear particles is the presence of free volume in the interface. We compare the time dependencies of resistance forces for all samples. Both samples with carbon interlayer show stable mean values of resistance force. In case of sample with iron crystallites resistance is very low and no oscillations. Thus amorphous carbon interlayer can represent solid lubricant with very low friction characteristics. For the silica sample we can observe small stick-slip oscillations at the beginning of sliding connected with rolling of lamb of silica atoms. This result allows us to explain the low friction properties of silica tribofilm and also to say about silica amorphous layer as a solid lubricant.

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MOLECULAR DYNAMICS STUDY OF THE INFLUENCE OF THE PARAMETERS OF THE CRYSTALLIZATION PROCESS DURING SELECTIVE LASER SINTERING OF ALLOY TI-NB

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In the paper the study of the processes occurring at different stages of the process of laser sintering [1] is performed using the method of computer simulation on the atomic scale. The initial configuration of the system is two spherical crystallites with properties of titanium and niobium, with the interface. Interatomic interaction was described by the embedded atom method [2]. We analyzed the effect of cooling rate on the resulting crystal structure of the alloy Ti-Nb. We also investigated the dependence of the resistance forces to break of sintered particles on the heating time of the system and its rate of cooling. It is shown that the main parameter which determines the adhesive properties of sintered particles is the contact area obtained during sintering process. The simulation results can not only define the technological parameters of the process to provide the desired mechanical properties of the resulting products, but also are a necessary basis for calculations on large scale levels in order to study the behavior of implants in actual use.

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STATICS AND HARMONIC OSCILLATIONS OF SPRINGS AS RODS OF ARBITRARY SPATIAL SHAPE

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The springs applied in mechanical engineering have often forms of rods. The progress in mechanics of deformable solids resolves the previous problems [1]. The calculation is simplified due to advance of computer mathematics. From the recent studies into the spring dynamics, we note [2, 3].

For harmonic oscillations with the frequency ω, the equations of linear theory of rods [4] are:

$$\mathbf{Q}' + \mathbf{q} + \omega^2\rho(\mathbf{u} + \boldsymbol{\theta} \times \boldsymbol{\varepsilon}) = 0,\ \mathbf{M}' + \mathbf{r}' \times \mathbf{Q} + \mathbf{m} + \omega^2(\mathbf{I} \cdot \boldsymbol{\theta} + \rho\boldsymbol{\varepsilon} \times \mathbf{u}) = 0, \quad (1)$$
$$\boldsymbol{\theta}' = \mathbf{A} \cdot \mathbf{M} + \mathbf{C} \cdot \mathbf{Q},\ \mathbf{u}' = \boldsymbol{\theta} \times \mathbf{r}' + \mathbf{B} \cdot \mathbf{Q} + \mathbf{M} \cdot \mathbf{C}.$$

The rods are considered as material lines (of initial form $\mathbf{r}(s)$) whose particles are the elementary bodies with the vectors of displacement **u** and rotation **θ**. The loads are external distributed forces and moments **q,m** and internal ones **Q,M**. Prime indicates the derivative with respect to material coordinate s (not necessarily arc coordinate). The tensors **A,B,C** characterize the elastic compliances including the bending, twisting, tension and shear compliance. Three-dimensional model has to be used to calculate them; for example, the Saint-Venant problem. The inertial rod parameters are the density ρ, the eccentricity vector **ε** and the inertia tensor **I**.

In statics (ω = 0) the equations (1) are integrated in quadratures [5]:

$$\mathbf{Q} = -\int_0^s \mathbf{q}\,ds + \mathbf{Q}_0,\ \mathbf{M} = \int_0^s (\mathbf{Q} \times \mathbf{r}' - \mathbf{m})\,ds + \mathbf{M}_0,$$
$$\boldsymbol{\theta} = \int_0^s (\mathbf{A} \cdot \mathbf{M} + \mathbf{C} \cdot \mathbf{Q})\,ds + \boldsymbol{\theta}_0,\ \mathbf{u} = \int_0^s (\boldsymbol{\theta} \times \mathbf{r}' + \mathbf{B} \cdot \mathbf{Q} + \mathbf{M} \cdot \mathbf{C})\,ds + \mathbf{u}_0 \quad (2)$$

Here 4 vector constants arise determined by the boundary conditions. If the rod is fixed at $s = 0$ and is loaded at $s = L$, then we determine $\mathbf{Q}_0, \mathbf{M}_0$ from the first two equations of (2). $\boldsymbol{\theta}_0 = 0$, $\mathbf{u}_0 = 0$ are obvious from the last two equations of (2), and it is the statically determined problem. With the arbitrary initial form $\mathbf{r}(s)$, the integrals are calculated in components.

If the section has two axes of symmetry, then compliances **A,B,C** can be simplified [4]. In the statically indeterminate problem we construct and solve the linear system for the vector constants. However we can do it differently, numerically integrating the system of ordinary differential equations (ODE, of 12th order) [6].

As an example we consider the conical spring. Both approaches can be implemented straight forward.

The static case can be easily extended to the harmonic oscillations, if we use the computer mathematics. For the amplitudes we derive the system of ODE solved by the shooting method; for the free oscillations its order increases by one.

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LOCAL AND NONLOCAL CONSTITUTIVE LAWS GENERATED BY MATRIX FUNCTION FOR THE CASE OF 2D SQUARE LATTICES

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Two types (elastically “unstable” and “stable”) of two-dimensional discrete square lattices of N>>1 equidistant and identical mass particles with periodic boundary conditions are examined in this article.

The purpose is to describe nonlocal interparticle interactions in the harmonic approximation. For the sake of convenience we introduce elastic potentials, defined by Hamilton's variational principle: discrete "Laplacian operators" ("Laplacian matrices"), which are square lattice Laplacian’s operator (matrix) functions.

This model implies the non-locality of the constitutive law to be the natural consequence of the non-diagonality of mentioned Laplacian operator functions in the N×N - dimensional displacement fields’ vector space, where by means of the periodic boundary conditions (cyclic boundary conditions) the (Bloch-) eigenvectors of the lattices are maintained.

In the quasi-continuum limit (long-wave limit) the Laplacian matrices generate "Laplacian convolution kernels" (and the related elastic moduli kernels) of the non-local constitutive law.
The elastic stability is ensured by the positiveness of the elastic potentials.
This approach provides a general method to generate physically admissible (elastically stable) non-local constitutive laws using "simple" Laplacian matrix functions. The model can be extended to the third dimension, which is useful for further investigation.

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DETERMINATION OF THE GRUNEISEN FUNCTION FOR 2D CRYSTAL LATTICES

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Recent advance in nanotechnology has lead to the necessity of determining mechanical properties of solids with microstructure in a wide range of temperatures and mechanical loads [1]. In case of high pressures and temperatures, this problem is treated using Mie-Grüneisen equation of state, where Grüneisen coefficient [2] is material-dependent scalar parameter that relates pressure, volume and internal energy. It is clear that in general a scalar coefficient does not allow to account for tensor nature of thermal stresses in crystals. The latter becomes possible with the introduction of Grüneisen tensor function [3,4], and tensor temperature [5.6]. The equation of state of crystalline solids regarding the first factor was considered in [3], the second was taken into account in [7]. The aim of the present work is to obtain an asymptotically accurate (at low level of thermal motion) equation of state basing on both factors. A simple two-dimensional crystal lattice is modeled. It is shown that scalar Grüneisen coefficient is not sufficient to describe the state of the lattice in the presence of shear strain, i.e. tensor nature of Grüneisen function should be taken into account. At the same time, the ratio of the tensor temperature components affects the Grüneisen function at all deformations. The introduction of tensor temperature allows to increase the accuracy of stress calculation by 20% in comparison with [3,4]. The obtained equation of state can be integrated into software for modeling of thermomechanical processes in solids.

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MATHEMATICAL MODELING OF ION IMPLANTATION PROCESS WITH ACCOUNT THE DIFFUSION AND MECHANICAL WAVES INTERACTION

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Due to material processing with charged particle fluxes, the purposeful change of the surface layer material state is possible, thus improving its operating abilities. Achievement of important results requires a detailed study of the processes occurring during processing. Surface treatment is accompanied by different physical and chemical factors that affect each other and influence the formed macroscopic properties of work materials. The physical phenomena occurring in the substrate during beam of charged particles processing are studied by many authors [1-4]. The computer simulation has a big significance for this research, because the role of each separate factor can't be experimentally investigated. In [5-6] it was shown that the interrelation between mechanical and diffusion waves leads to a distortion of the deformation (and stress) wave profile, and the concentration distribution does not correspond to pure diffusion process
The paper is aimed at investigating the nature of interaction of two different scale processes - impurity diffusion and mechanical stress wave propagation under the action of a single pulse.

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RADIAL MODEL OF HYDRAULIC FRACTURE: BENCHMARK SOLUTIONS AND PARTICLE VELOCITY BASED SIMULATION

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The mathematical modelling of hydraulic fractures (HFs) propagating in a brittle medium is a complicated phenomenon. This results directly from the multiphysical character of the problem and a need to properly account for the interaction between respective component physical fields at different temporal and spatial scales. Consequently, even in the simplest HF models the following difficulties are observed: i.) Strong non-linearity of the system of governing equations ii.) singularites of the physical fields iii.) moving boundaries iv.) the multiscale nature of the problem v.) degeneration of the governing equations at the fracture tip, along with other problems.
The first mathematical models of HFs can be backdated 1950s. Later works resulted in a formulation of the so-called classic 1D models (PKN, KGD, radial). Although very simplified, these were used for decades to design the HF treatments. Despite the fact that the more advanced models finally superseded the classical ones in the practical applications, the latter can still be used to: i) investigate some inherent features of the underlying physical phenomenon and corresponding mathematical solutions (e.g. [1]), ii) construct and validate the computational algorithms [2]-[4]. A special role here plays the so-called radial (or penny-shaped) model. It mimics the tip behaviour of the planar 3D fracture. Additionally, the solution obtained for this model can be successfully applied as a benchmark when investigating the performance of 2D and 3D computational schemes. Surprisingly there is little data available in the literature that can be used [5-7].
In this talk we will address the problem of delivering a credible solution to the radial model of HF. The case of shear-thinning fluids is considered. The ways of constructing the analytical benchmark solutions is given. We discuss the methods of obtaining highly accurate numerical reference data by means of a universal algorithm developed by the authors [3]-[4]. Comparison with other results available in the literature is provided.

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SPHERICALLY-SYMMETRIC PROBLEM OF MECHANOCHEMISTRY WITH VISCO-ELASTIC REACTION PRODUCT

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We develop an approach to studying the influence of stresses and strains on the kinetics of a propagating chemical reaction front based on the notion of chemical affinity tensor [1,2]. In previous studies this approach was used for the problems on plane [3], cylindrical [4] and spherical [5] reaction fronts in which the solid constituents were linear elastic. In the present paper we focus on the effects of viscosity of the reaction product. We consider a linear elastic sphere subjected to a homogeneous external all-round tension/compression. We assume that the reaction starts at the outer surface of the sphere, the propagating reaction front is spherical and the reaction product is a visco-elastic material. We find stresses in a sphere with an elastic kernel and a visco-elastic core taking into account an additional kinetic equation that determines the reaction front velocity on the normal component of the chemical affinity tensor that in turn depends on stresses and strains at the reaction front, and stresses depend of the front radius. We study in detail how viscosity of the reaction product and stress relaxation behind the reaction front as well as external loading affect the velocity of the reaction front propagation.

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CONSTRUCTION OF SOLUTION FORCED QUASI 2D TURBULENCE WITH LARGE-SCALE DISSIPATION MECHANISMS ON INVERSE CASCADE

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In this study construction of numerical-analytical solutions of forced quasi 2D turbulence with chemical reactions is discussed. Recent theoretical and experimental results without chemical reactions are presented in review[1]. Kraichnan [2] discussed the inverse cascade in a finite box in the absence of a large-scale dissipation mechanism. In a physical space, condensation appears as the formation of two strong vortices of the opposite sign In papers [3], [4], [5]. the effect of chemical reactions which lead to new phenomena is added. The model of inverse cascade with the large-scale dissipation mechanism is used. Introduction of large-scale dissipation mechanism in our model results in steeping of low-k spectrum energy (from $k^{-5/3}$ to approximately k^{-3}, modification of turbulence in low-k spectrum energy). The additional study for a number of large-scale dissipation mechanisms is required. The influence chemical reactions and a number of large-scale dissipation mechanisms on inverse cascade are investigated.

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ABOUT REDUCING THE RESIDUAL STRESSES IN METALS AT TEMPERATURES THAT DO NOT LEAD TO PLASTIC FLOW

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In the manufacture and hardening of metal materials there takes place an accumulation of stresses, which are called residuals. Such stresses are present in the materials or structures in the absence of any external influences and, most of all, with further operation adversely affect the properties and structure of the product, causing hogging, occurrence of cracks, and ultimately destruction. To avoid such costly damage it is necessary to develop and apply different ways leading to the relief of unwanted stress. In technological practice, such a way is a heat treatment process, involving slow heating of the material to a certain temperature, exposure and subsequent slow cooling.

Note that the heat treatment (i.e., annealing) can be of different types depending on the heating temperature and the cooling rate of the metal. Typically, to minimize the residual stress high temperature annealing is applied. Such annealing is conducted at a temperature region not exceeding a certain maximum temperature above which the structural transformation may occur. Low-temperature annealing is used to the components for which it is more important to preserve the surface hardness than the maximum reduction of residual stresses.

Heating to the annealing temperature must be slow, so that the reduced yield strength at a given annealing temperature are possible simultaneously and uniformly achieved throughout the cross section of the product. Cooling mode is also an important stage in the process, since violation of the cooling mode prescribed by the technology not only reduces the effect of stress relief, but may even increase the stress in comparison with the initial state. Therefore, research in this area is relevant.

The process of removing the residual stresses [1] in metals under heating is simulated. There have been examined modes at the stages of slow heating to the temperature that do not lead to plastic flow, holding at this temperature, and slow cooling stage [2]. The holding stage is modeled with consideration of creeping properties of materials [3-4]. The boundary value problems are examined and the patterns responsible for the removal of residual stresses are described [2]. The analytical solutions are obtained under the conditions of Norton's creep [5].

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STRESS CORROSION CRACKING OF ROCKET DETENTION MATERIAL CAUSED BY SIMULATED ROCKET COMBUSTION GASES

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The cracking of detention housing material made from austenitic stainless steel was characterized and investigated in microscopic scale. In this study, SUS 310S austenitic stainless steel was selected for detention housing material. It contains Cr and Ni higher than others commercial austenitic stainless steels (304,316) enhancing corrosion resistance. The corrosive environment was carefully mixed hydrogen, chloride, carbon dioxide, and moisture which are the main constitutes of rocket combustion gas inside ceramic heating chamber at 900 degree celcius. The appling stress method is the deformation of specimen in U-Shape. The maximun stress on each specimen can be determined approximately at outside radius of curvature by sheet metal bending formula. Non destructive technique is implemented for primary observation on cracks and such specimens will be next characterized for detailed information. The classification of fracture (transgranular/intergranular/mixed mode) is obtained by Optical microscope and Scanning Electron Microscope and they can reveal certain evidences for root cause of cracks. The relationship among research parameters also concludes and provides some trends for crack prediction in the future. On the other hand, the corrosion products formed during corrosion test are characterized in advance for identification of types and quantity comparatively.

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CONTROL OF NONLINEAR WAVES IN MECHANICAL SYSTEMS

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Evolution of nonlinear waves in mechanical systems provides various interesting dynamic phenomena in material including deviations in its internal structure. Of special interest is an ability of a strain wave to localize in space and time and then to keep its shape and velocity on propagation. Localized wave of permanent shape transfers considerable energy, it may be used in nondestructive testing and medical acoustic devices.

Usually localization arises as a balance between various features of a mechanical system like nonlinear and dispersion properties of the material . Another important factor affecting localization, is the choice of suitable and consistent initial and boundary conditions for the wave generation.

Often it is difficult to achieve desired balances and conditions. As a result initially localized input may be splitted by parts yielding scattering of the wave energy, or generated strain wave amplifies giving rise to achievement of the yield point of the material or inelastic strain process.

One of the mechanism allowing stable localization of the wave may be application of the algorithms of control. The control algorithms are developed to achieve wave localization independent of the shape of the initial conditions. It is shown that non-distributed control gives rise to a desired shape but not the velocity of the localized wave.

The sine-Gordon (SG) equation arising for defects description in a chain as well as coupled nonlinear equations for di-atomic crystalline lattice are studied. Initial conditions with different topological charge are considered.

A new distributed speed-gradient feedback control algorithm for the SG equation creates the antikink traveling wave mode for a broader class initial conditions compared to the uncontrolled system. Even small variations in the initial velocity relative to that of the exact antikink solution of the SG equation give rise to the growing oscillations on the antikink profile. The control algorithm allows one both to suppress defects and to obtain stable propagation of an antikink in the form of the exact traveling wave solution of the SG equation. In contrast to the existing algorithms the proposed algorithm does not require additional dissipative term for the wave generation.

It is shown also how initially motionless Gaussian distribution may be modified to obtain propagation of localized waves in both directions. However, the resulting localized wave profile is described neither by an asymptotic envelope - wave solution to the sine-Gordon equation nor by its exact traveling breather solution. It is shown that localization of the waves in both directions is achieved by means of a feedforward (nonfeedback) control. The waves are similar to the envelope wave solution. The feedback distributed algorithm is shown to provide both localized waves according to analytical solutions and their unidirectional propagation.

Some preliminary results were obtained in Refs. [1,2].

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MATHEMATICAL SIMULATION OF IRON REDUCTION FROM INDUSTRIAL WASTE WITH ALUMINOTHERMIC METHOD

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The recycling of metallurgical and engineering industry waste, such as mill scale and aluminum chips, by conventional methods is ineffective. In conventional casting, expenditures of energy and fuel account for more than half of the total expenditures. Moreover, the major portion of metal losses during aluminum chips melting. Consequently, in addition to the increase of irrecoverable losses of metal the environment is damaged. The recycling of mentioned industry waste may be based on aluminothermic process, which is exothermic and therefore the effort of energy to charge mixture melting is not required. It means that this method of castings production is economically and ecologically perspective.

Essentially, the foregoing method is as follows [1]. Thermite charge is placed to fireproof crucible and then is ignited by spark discharge. Chemical reaction initiates on the surface of thermite mixture and sequentially propagates over the all volume. Moving reaction zone is the thin layer where chemical transformations occur. This layer divides initial matter from reaction products. Slag has the less density than steel melt and hence it comes to the surface.

It is suggested the mathematical model of exothermic chemical reaction in iron-aluminum thermite. It is considered the first stage of this process, namely, formation of melt. Process of slag separation has not been accounted. Gasification process was ignored.

This model takes into consideration thermal, mechanical and kinetic phenomena of process at hand as well as their mutual influence. It was developed finite difference formulation of the boundary problem within the bounds of introduced model [2]. The results of computing experiments make it possible to estimate distributions of physicochemical parameters of investigated technological process in space and time.

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NUMERICAL SIMULATION OF INTERACTION BETWEEN LONGITUDINAL SHOCK WAVE AND THE INTERFACE OF TWO ELASTIC BODIES

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It is known, that the processes of dynamic propagation of volume deformations and shear deformations in elastic media are inseparable if nonlinear properties of the media are taken into account. The interaction between these two types of deformations is the qualitative characteristic feature inherent in dynamics of solid which has to be considered even in the stage of problem statement. The information about types of waves caused by bounding actions is required for the establishment of boundary-value problem.

Zemplen's theorem states that only compression shock waves are possible in gas dynamics, while rarefaction

occurs without discontinuities, i.e. rarefaction waves are continuous in space. In dynamics of solid the thermodynamic restriction analogous to Zemplen's theorem doesn’t have a clear mechanical interpretation.
This leads to ambiguity of the determination of wave pattern even in simple self-similar problems of impact deformation of elastic media. It is possible to obtain different solutions of the same dynamic self-similar problem, which consist of different combinations of shock waves and Riemann waves, under the same boundary and initial conditions.
One way to overcome these difficulties is to solve boundary-value problems simultaneously for all wave patterns feasible from mathematical point of view. The unique realizable variant of deformations propagation is chosen on the basis of obtained solutions comparison in the course of numerical computations. The criteria of such choice are shock wave evolutionary condition and the second law of thermodynamics.
In the present work, numerical solution of self-similar problem of the interaction of a plane longitudinal shock wave with a plane interface between two elastic bodies is considered. Mechanical properties of elastic materials are determined by Murnaghan model. The analysis of the model equations system of adiabatic elastic media under the state of plane deformation shows [1] that wave pattern may consist of various combinations of plane shock fronts and simple Riemann waves. The parameters of the stress-strain state and motion at shock waves are connected by means of compatibility conditions [2].
Using the developed finite-difference algorithm of numerical simulation of plane self-similar boundary-value problems of dynamic elasticity theory [3,4], it has been computed the parameters of stress-strain state in elastic bodies depending on the intensity and incidence angle of the incident wave. For each set of parameters (elastic constants, characteristics of incident wave) it has been determined corresponding wave patterns.

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EFFECTS OF DISPERSION AND STRUCTURE MOLECULES ON TIME RELAXATION

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Here in the mechanics the influence of the angular momentum and the delay are investigated. . Non-symmetric stress tensor is obtained. The delay process is counted, which is important in describing of the discrete space and for the relaxation of the complicated molecules. The analysis of the recording the Lagrangian function for the collective interaction of the particles are made with changing distance of the inertia center. Another definition of temperature is obtained for molecules with vibration and rotation. This is making additional item for pressure. The analysis is complemented by new results of computational experiments. The simplest interaction of two homogeneous flows that moving in the same direction at different speeds is investigated.

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NONLINEAR EFFECTS IN ACOUSTIC STREAMING IN CYLINDRICAL CAVITY

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Acoustic streaming is a pattern of steady vortices or time-independent circulation, which is often found in addition to the “sound field” or periodic motion near vibrating surface [1]. Acoustic streaming can affect the heat exchange throw the cavity walls. Study of acoustic streaming is very important from a scientific and practical point of view.

In this article, the acoustic streaming in a cylindrical cavity subjected to the vibration with constant frequency ω and constant amplitude A is investigated. The cavity is filled with a perfect viscous gas (air). The side surface of the cylinder and its ends are maintained at a constant temperature equal to the initial one. The gas motion is described using the gas dynamics equations in cylindrical coordinates (axisymmetric case). The Clapeyron ideal gas law is used as the equation of state. The system of equations is solved numerically. The calculations are executed with use of the implicit numerical scheme of first order of accuracy in both space and time. The method used for numerical simulation is described for the one-dimensional statement in [2]. The axial and radial streaming velocity components are calculated by averaging for the period of cavity vibration.

The results were obtained for three frequencies and different amplitudes of vibration. When amplitude increases, the nonlinear effects become significant and the acoustic streaming is changing. The period average temperature in nonlinear case differs substantially from the initial temperature. Additional vortices can appear. Nonlinear effects also are described in [3] for the case of big amplitude of vibration and frequencies much less resonance.

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THE LEGACY OF ANTONIO CASTELLANOS' WORK IN GRANULAR MATERIALS

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For about the last twenty years of its scientific career, Prof. Antonio Castellanos was deeply interested in the connection between the macroscopic behaviour of powders and the details of the contact between their constituent particles. Although his firsts works in the subject were motivated by the need to improve the transfer of toner particles, he made the problem of connecting the continuum description of granular materials to the particle-particle interactions the subject of a long term research program in which he investigated, among other things, the sources of the adhesion between particles, their relationship with the macroscopic cohesion, the mutual influence between microstructure and stresses in granular media, the stability of the fluidized state of granular media and the effect of the discrete nature of granular media on sound propagation. Many of his findings were reported in previous APM Conferences, in which he always enjoyed being a participant. This talk makes a summary of his works as a tribute to his memory.

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ELECTRO-CHEMO-MECHANICS OF SOLIDS AND ITS APPLICATIONS IN FUEL CELLS AND BATTERIES

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Materials used in energy conversion and storage devices are often subjected to multi-field driving forces (electrical, chemical, radiological, thermal, mechanical, etc.). In predicting the deformation and failure of these materials, conventional mechanics of material theories are no longer adequate, because these multi-field driving forces are typically coupled and produce synergetic effects that are not predicted by the classical theories. To fully understand how the different driving forces interact requires theories and models that are capable of accounting for the coupling of multi-field interaction processes.

In this talk, a theory for the mechanics of solids will be presented that accounts for the coupled effects of mechanical, electrical and chemical driving forces. The presentation will begin with an introduction of the general framework of the electro-chemo-mechanics [1, 2], followed by examples of its applications to solid oxide fuel cells [3] and Li-ion batteries [4 - 6]. Finally, path-independent integrals in electro-chemo-mechanics will be discussed [7].

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MODIFIED STRAIN GRADIENT THEORY AND TIMOSHENKO BEAM ASSUMPTIONS – A DIRECT APPROACH

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Materials with intrinsic micro- or nano-structure may show size-dependent material behavior, which is reflected by a stiffer elastic response to external forces when the size of the material body is reduced. In order to account for the so-called size effect strain gradient theories are applied, which involve higher gradients of displacements [1,2]. The additional introduction of a micro-rotation measure, which incorporates second gradients of displacements, leads to a Cosserat pseudo-continuum description [3,4]. Such a modified strain gradient theory of elasticity for isotropic materials [5] is investigated in this paper, discussing a higher order model for static beam bending. Since the analytical solution for the Bernoulli-Euler beam model is already known in the context of the modified strain gradient theory [5], we apply the Timoshenko beam assumptions [6] in the present work. This is useful in context with an inverse analysis: The corresponding additional material coefficients (a.k.a. material length scale parameters), which are involved in strain gradient continua, can be identified by means of deflection experiments [7]. These were carried out according to the method of size-effect, as described in [8]. In contrast to the results of a Bernoulli-Euler beam model, the independent rotations of the cross-sections of the beam are taken into account. It is aimed for an analytical solution of the Timoshenko beam model incorporating the terms of the extended theory. A system of coupled differential equations for the functions of beam deflections and rotations is derived. Timoshenko's shear coefficient and the shear modulus are involved. Non-dimensionalization of the functions and coefficients is provided and first numerical results are discussed. The system of coupled differential equations is solved and deflections and rotations are calculated for a straight beam with a unified load distribution.

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MODELING OF FLUID CONFINED IN SYSTEM OF RESERVOIRS CONNECTED BY MEANS OF SINGLE-WALLED CARBON NANOTUBE AND MULTI-WALLED NANOTUBE CONNECTION

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The present research deals with the numerical solution to problems related to the features of system consised of combination of carbon nanotubes. Our analysis is based on the numerical simulations performed by means of molecular dynamics method. In this study we continue our previous research[1].

This work analyzes the fluid flow properties in system which consist of single-walled carbon nanotube and multi-walled nanotube connection. We have two reservoirs with fluid which are connected between each other with this system of nanotubes. We have compared properties of fluid flow pumping from one reservoir to another in one direction with pumping in opposite direction and have observed their differences.

We explored the propeties of the fluid flow in such system confined in channel filled with fluid. And measured how propeties depends on system environment. Also in this research we investigated the effect of the existing of defects of carbon nanotubes.

The performed investigations have demonstrated the features of behavior of fluid confined in system of reservoirs connected by means of single-walled carbon nanotube and three-walled nanotube connection.

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MODELING OF ELASTO-PLASTIC DEFORMATION OF ALUMINIUM ALLOY ON THE BASE OF VORONOI CELLS MESH

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This study is devoted to the numerical solution to the problem related to the modeling of elasto-plastic deformation of aluminium alloy.

We have developed a two-dimensional model for aluminium alloy modeling. As the base for mesh for this modeling we used Voronoi cells as the perfect example of shape of polycrystalline microstructures in metallic alloys. Each Voronoi cell represent the single grain of material. The present problem in plain strain formulation was solved numerically, by writing original program, using the finite-difference method [1,2]. The ability of the present model to take into account that failure process which take place on the boundary of the grain [3,4] provide possibility of more detail and realistic description of elasto-plastic deformation.

The performed investigations have demonstrated the features of failure process of aluminium alloy failure.

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UNIVERSAL COMPUTATIONAL MODULE ACCOUNTING FOR STRONG FIELD CONCENTRATION WITH APPLICATION TO HYDRAULIC FRACTURES

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The aim of the work is to increase the accuracy of finding fields in areas of their strong concentration caused by the edges of notches, intersections of structural elements, contours of cracks and fronts of hydraulic fractures (HF).

We suggest a universal computational module accounting for local singularities. The module provides the influence coefficients of a *trapezoid edge element with improved approximation of the geometry and density*. It is universal in three aspects.

Geometry. The trapezoid element is convenient for approximating an edge (singular line) of, say, a HF contour by one of its bases, while having the other base parallel to the edge. Commonly used triangular, rectangular and square elements are its particular cases.

Density approximation. A density is approximated by the monomial r^{α} , multiplied by an arbitrary polynomial. Herein, r is the distance from the trapezoid base, which coincides with a singular line. The exponent α is prescribed in accordance with the actual singular behavior of a field. It is either found by a highly efficient subroutine [3], or it is known in advance. In linear fracture mechanics, $\alpha = 1/2$; in HF problems, $\alpha = 2/3$ for the viscosity dominated regime of a Newtonian fluid, and $\alpha = 5/8$ for the leak-off dominated regime. For a non-Newtonian fluid and intermediate regimes, α is defined by the universal asymptotic umbrella [2].

Location of collocation points. The integration procedures employed are actually the same when a collocation point is located within the element (the evaluated integrals are hypersingular or singular) or outside it (the integrals are proper). In the both cases, computationally expensive repeated integration is avoided. Integration is performed either analytically, or, in exceptional cases, by reducing to one-dimensional integral over a standard interval. The efficiency of such "almost analytical" evaluation of the influence coefficients is demonstrated in [1] for $\alpha = 1/2$.

The results obtained imply that the universal element may serve for better simulation of HF propagation.

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EVALUATION OF SOUND VELOCITY AND DYNAMIC MODULUS OF ELASTICITY IN PLYWOOD PANAL BY LONGITUDINAL VIBRATION TEST

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In this study, the speed of sound and the dynamic modulus of elasticity in plywood plates with the dimensions of 108×50×2 cm (length, width, thickness) by the longitudinal vibration test has been studied. 4 clear samples of plywood plates were selected and longitudinal vibration tests was performed on them. Then extracted beams with dimensions of 50×5×2 cm (length, width, thickness)from each plywood plates and longitudinal vibration test was performed on them and results obtained from longitudinal test in plates and beams were compared together. Results showed strong correlation between speed of sound in plates and beams. The modulus of elasticity values which is an important factor in evaluation of mechanical properties of this product, has a very good correlation in plate and beam samples. As a result, we can assure it as a step forward in quality control and possibility of inspection on whole-plates with standard dimensions and at service time.

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MECHANICS OF SOFT MICROSTRUCTURED MATERIALS

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In this talk, I will specifically focus on the role of microstructures in the overall performance of deformable functional composites and soft biological tissues. We will explore the behavior of *fiber composites* which are extensively used in a large variety of engineering applications; these composites are also widely present in soft biological tissues. We will also examine the performance of *electroactive polymer composites* that gained the name “*artificial muscles*”. These materials can undergo large deformations when excited by an external electric field. The mathematical approach for modeling electroactive polymers can be extended to another class of active composites, namely, magnetorheological elastomers (MRE). MRE can deform and modify their stiffness in external magnetic field. They can be used in a large variety of application such as sensor, actuators and noise and vibration dampers. The microstructures play a crucial role in the performance of these active composite materials. Next, we will turn to *bio-inspired flexible armor* which draws its design principles from fish’s scale-tissue protective systems. As personal armor, these composites grant protection while preserving the flexibility so that the movement is not restricted. Finally, some aspects of elastic waves in finitely deformed composites will be discussed.
We will consider how large deformations and elastic instabilities can be used to trigger dramatic pattern transformations and control the large variety of functionalities. Analytical, numerical, and experimental results on 3D printed composites will illustrate the ideas.

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THE FORMATION OF LOW-ANGLE GRAIN BOUNDARIES DURING SHOCK LOADING OF METALS AND ALLOYS

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The study of microstructural changes in metals and alloys during plastic deformation is one of fundamental problems in the physics of strength and plasticity [1-4]. In recent years, an effective tool in theoretical modeling of the severe plastic deformation processes has become the approach of 2D discrete dislocation-disclination dynamics (the D^4-approach) which describes the collective behavior of straight dislocations interacting with partial disclinations [5-7]. Recently we have shown that this approach can also be used for modeling the grain fragmentation in polycrystalline metals and alloys under shock compression [8, 9]. In view of highly nonequilibrium conditions of shock wave propagation, we assumed that at the boundaries of the simulation box, which model the subgrain boundaries in a metallic grain under shock compression, there were some jumps of misorientation angles. For tilt boundaries, the jump points are effectively described in terms of partial wedge grain-boundary disclinations. These disclinations can capture the dislocations of opposite signs gliding nearby within the subgrain and make them to form new dislocation walls – fragment boundaries. This process, in fact, represents the physical mechanism of fragmentation within pre-existing subgrains in shear bands in metallic materials under shock loading. If in the process of modeling, the distance between two dislocations of opposite signs becomes less than a critical distance, it is considered that the dislocations are annihilated. To simulate the motion of dislocations, we used the 2D D^4-approach. In doing so, we took into account two new features as compared with our earlier works [8, 9]. First, we accounted for the temperature increase in the shear bands and used it for calculating the local drag coefficient β . Second, we considered the fact that on the subgrain boundaries, at the place of newly generated dislocations, new opposite-sign dislocations appear. Such dislocations create their own stress fields and strongly affect the dynamics of all dislocations in the simulation box. As a result, our new 2D D^4 computer model clearly demonstrated the subgrain fragmentation. In comparison to results of previous works [8, 9], the modification of the boundary conditions made a significant impact on the final microstructure in the case of both fine and coarse initial subgrains. We obtained stable dislocation structures similar to those observed in experiments [10, 11] and showed that the typical shock duration is enough to complete the fragmentation process within the initial subgrain, and the necessary stress magnitude (0.5 GPa) well agrees with experiments [10, 11].

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APPLICATION OF MECHANICAL METHODS FOR SOLVING THE PROBLEM OF HIGH-TEMPERATURE CREEP AND LONG-TERM STRENGTH OF METALS

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The problem of high-temperature creep and long-term strength of metals is demanded in such important fields of modern engineering, as thermal and nuclear power plants, aircraft and spacecraft, etc. In this regard the intensive research on this problem carried out; in particular, there are numerous experimental studies on changes of the porosity and density of various metals and alloys due to the formation and development of micropores and microcracks in the conditions of high-temperature creep [1]. The results of these studies allow us to consider the density as an integral measure of the accumulation of structural micro-defects, and the damage parameter is defined as the ratio of current density to initial. Taking into account this parameter and the mass conservation law interconnected kinetic equations for creep deformation and damage parameter are formulated. In the case of pure brittle fracture the analytical solutions of these equations are received and the criterion of long-term strength is formulated. It is shown that the Kachanov-Rabotnov criterion [2, 3] is a special case of the obtained criterion. According to the Kachanov-Rabotnov solution the damage in the process of creep is accumulating rapidly, which is typical in tests with a given load and the necking. In the case of experiments with a given stress there is a slow accumulation of damage and failure can occur without any noticeable necking. Proposed criterion is able to describe both fracture laws during creep process. The time to failure can be an order more compared with the time to fracture in the avalanche-like processes of creep and fracture. The ductile-brittle fracture is also considered. An analytical solution connecting the damage parameter to the value of deformation is obtained. In this case, the creep deformation is calculated approximately. The appropriate choice of the coefficients of the approximate solution allows describing the experimental creep curves.

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MATHEMATICAL MODEL OF STATIC DEFORMATION OF MICROPOLAR ELASTIC CIRCULAR THIN BAR

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The boundary value problem of statics of plane stress state of micropolar theory of elasticity is considered in a thin circular area. Rather adequate hypotheses of general nature are formulated [1-3] and on the basis of these hypotheses applied (one-dimensional) model of micropolar elastic circular thin bar is constructed. Mechanic balance equation is obtained. It is confirmed that all energy theorems and Ritz, Bubnov-Galerkin, FEM variation methods are applicable for the constructed applied model of micropolar elastic circular thin bar and for solutions of corresponding boundary value problems of the applied model. One-dimensional variation functional is constructed and it is proved that all basic equations and natural boundary conditions of applied model of micropolar elastic circular thin bar will be obtained from the corresponding variation equation (as Euler equations).

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ACOUSTIC STREAMING IN A RECTANGULAR CAVITY

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Acoustic streaming is a directed time average mass transfer by steady vortices or time-independent circulations, which is often found in addition to the periodic motion in a compressible fluid driven by vibrating surface [1]. In our time, acoustic streaming are widely investigated. Features of acoustic processes needs to be considered when developing various thermoacoustic devices.

In this article, the acoustic streaming in a rectangular cavity subjected to the vibration with constant frequency ω and constant amplitude A is investigated. The cavity is filled with a perfect viscous gas (air). Due to symmetry of the geometry, we consider the top half of the cavity as the computational domain.

The task is solved numerically. The calculations are executed with use of the implicit numerical scheme of first order of accuracy in both space and time. The method used for numerical simulation is described for the one-dimensional statement in [2]. Acoustic streaming pictures with small amplitude of vibration and wide frequency range of vibration are obtained. Comparison of the received results with results of calculation of a similar task in axisymmetric statement is executed [3].

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DEFORMATION AND FRACTURE OF GRAPHENE CONTAINING DEFECTS

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We presented a short overview of computer simulations (based on the AIREBO potential) addressing strength, plasticity and shape stability of graphene sheets with divacancies (5-8-5 defects, 555-777 defects, defects in graphene nanoribbons). These simulations have shown multistage character of deformation and fracture processes occurring in graphene sheets containing defects [1]-[2]. In particular, the final stage of plastic deformation of graphene sheets containing defects is realized through formation of carbon monatomic chains that join separate parts of the sheets under mechanical load. It was shown that temperature significantly influences fracture processes in graphene sheets under consideration [3]-[4].

When temperature rises, plastic deformation stage, occurring through simultaneous generation and growth of many separated nanovoids, becomes shorter. For example for comparatively high temperatures (400 K and more) the ensemble of 5-8-5 defects typically behaves as a single "large" defect triggering fast formation of a large elongated void (without the apparent preceding plastic deformation) [3].

By study of the deformation and failure processes in graphene sheets containing 555-777 defects (divacancies) it was found that the presence of divacancies of type 555-777 in graphene leads to a dramatic reduction of its strength as compared with the strength of a pristine graphene and graphene strength with divacancies type 5-8-5. It was revealed characteristics of the deformation and fracture processes of graphene with 555-777 defect by tension in arm-chair direction. Revealed in our study, the sequence of stages of deformation of graphene with bivacancies type 555-777 is significantly different from the normal sequence of steps deformation "deformation of elastic-plastic deformation-destruction" for ductile solids and "elastic deformation-destruction" for brittle solids.

There are examined deformation and fracture processes in graphene nanoribbons containing line disclination quadrupoles. A special attention is devoted to the effects of both graphene edges and disclination-produced curvature in graphene nanoribbons on their mechanical characteristics, namely stress-strain dependence, tensile strength and plastic strain. It is revealed that, due to the presence of line quadrupole of disclinations, the strength of the graphene nanoribbons significantly degrades (by factor of ≈ 2), as compared to that of pristine graphene. At the same time, the graphene nanoribbons under consideration exhibit both highly non-linear elasticity and enhanced plasticity characterized by plastic strain degree about 13.4 %.

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MECHANISM OF NONLINEARITY PHENOMENA IN LONGITUDINAL-AND-TRANSVERSAL OSCILLATIONS OF A GRAPHENE STRIP

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The system to simulate longitudinal-and-transversal dynamics of a graphene wire is studied. In the considering system the dominant part of the elastic energy is accumulated by means of deformations, orthogonal to the displacements of the inertia element of the system. So the expression for the potential energy of the system via the displacements of the inertia element becomes very uncomfortable to use in the theoretical analysis. The procedure to obtain the precise differential equations for longitudinal and transverse oscillations of such a system is offered. The procedure gives a system of ordinary differential equations. It is easy to interpret reliably the physical sense each of the corresponding movements for the system of two degrees of freedom. These equations may be used to explain the mechanism of nonlinearity, discovered in experiments with devices made of grapheme [1]. Thus, in the first approximation the equation of transversal oscillations is to be linear. The nonlinear terms appear in the equation of small longitudinal oscillations of the system to simulate the dynamics of the grapheme wire. These terms can not to be ignored even in the first approximation. The coupled system of two equations shows, that the nonlinear longitudinal oscillations are induced by the linear transversal displacements of the system. So it gives possibility to simulate the control of the properties for a device, based on the element made of graphene.

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FINITE-ELEMENT ALGORITHM FOR NUMERICAL IMPLEMENTATION OF THE PROBLEM OF NATURAL VIBRATIONS OF ELECTROVISCOELASTIC BODIES WITH EXTERNAL ELECTRICAL CIRCUITS

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Nowadays, the shunting of structural elements made of piezomaterials with external electrical circuits is a very popular method in technical applications, where compact size and weight are critical, or where there is practically no access to external energy sources.

During the modeling process the damping properties of structures are commonly estimated using the value of the amplitude in a resonance mode, or the rate of transient processes. In the first case, a problem of steady state forced vibrations is addressed, and in the second – a dynamic problem with initial conditions. Applications of these problems to finding optimal parameters for piezoelectric elements and external electrical circuits involve a number of features that make their use quite tedious.

According to works [1, 2], a natural vibration problem is particularly effective in identifying and optimizing the dynamic characteristics of the system, which is a structure made of elastic or viscoelastic material with attached piezoelements and external circuits. This is due to the fact that the dynamic characteristics of the system determined while solving this problem are integral and independent of the type and value of the external effect. Furthermore, no multiple repetitions of all the computational procedures associated with the change in a frequency range and different types of loading are required, as is the case when considering steady state forced vibrations or transient processes.
The mathematical formulation of the problem of natural vibrations of this type of structures has a number of specific features that do not allow direct use of the existing finite element packages for its solution, and this gives impetus to the development of a new algorithm. It is reasonable to use the capabilities of the available finite-element packages for constructing a geometric model and creating a finite element mesh.
This paper presents a new algorithm for estimating the natural frequencies of a viscoelastic structure with piezoelements and external electrical circuits based on the matrices created using the ANSYS FEM software. The algorithm enables the decomposition of the obtained rigidity matrices into components and can be used in future to compute the natural frequencies of the system described.
The main aspects of the mathematical formulation of this problem, as well as the peculiarities of numerical implementation of its solution, are considered. The problem of natural and forced vibrations of a shell structure is used as an example to demonstrate the efficiency of the algorithm.
The proposed algorithm can be viewed as a basis for developing effective optimization approaches to determine the parameters of systems with external circuits ensuring maximum damping of vibrations in such systems at a given frequency.

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EXPERIMENTAL RESEARCH AND COMPUTER MODELING OF THE MECHANICAL BEHAVIOR OF POLYMER/CLAY NANOCOMPOSITES UNDER LARGE DEFORMATIONS

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At present polymeric clay nanocomposites are the subject of intense basic and applied research [1]. This paper presents the results of experimental and theoretical studies of the mechanical properties of nanocomposites based polyethylene grade PE 107-02K filled with nanoparticles of modified clay (montmorillonite). These materials show well-defined elastic-plastic and visco-elastic properties.
The researches were based on a complex approach when derived from the experiment data were then used as input parameters for the theoretical modeling.
Experimental studies were carried out using a special technique, based on the cyclic deformation of the sample in the mode: stretching — stress relaxation — reducing the strain to some predetermined constant value of tensile strength — again relaxation — the next cycle of deformation. Each subsequent cycle is made with increasing amplitude in the deformations. This mode allows to clearly separate the visco-elastic and elastic-plastic behavior of the sample and to obtain all necessary input data for further theoretical studies.
The calculations were carried out using structural-phenomenological model describing viscous-elastic-plastic behavior of finite-deformable structural-heterogeneous medium [2]. The model is based on a differential approach to the construction of constitutive equations of material mechanical behavior with the help of symbolic schemes. The mathematical apparatus of mechanics of nonlinear finite deformations involving Runge–Kutta computing method and Nelder–Mead simplex method are used.
The symbolic model schema consists of two parallel branches containing two serially connected elements: a) the elastic and plastic, b) the elastic and viscous. Elastic-plastic branch simulates the behavior of agglomerates of more rigid crystallites, their displacement and destruction during the deformation. Visco-elastic branch describes the flow of the amorphous polymer between the lamellae inside the crystallites and in the space around the crystallites and particles. It is known from the literature that these processes occur almost independently, and that was the rationale for the choice of the scheme.
As a result, theoretical deformation and relaxation dependences of model parameters that characterize the change in the elastic, viscous and plastic properties of the composite during deformation were obtained. Calculations have shown that increasing the

concentration of the filler in the polymer naturally leads to an increase in its elastic stiffness and toughness, as well as promote the development of plastic flow. Comparison of calculated and experimental dependences showed that they are practically identical. This is indicative of the fact that the conclusions drawn from the analysis of the model parameters are close to reality.

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CASES OF INTEGRABILITY CORRESPONDING TO THE MOTION OF A PENDULUM IN THE THREE-DIMENSIONALSPACE

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In this activity, we systematize some results on the study of the equations of spatial motion of dynamically symmetric fixed rigid bodies-pendulums located in the nonconservative force fields [1]. The form of these equations is taken from the dynamics of real fixed rigid bodies placed in a homogeneous flow of a medium. In parallel, we study the problem of a spatial motion of a free rigid body also located in the similar force fields. Herewith, this free rigid body is influenced by a nonconservative tracing force; under action of this force, either the magnitude of the velocity of some characteristic point of the body remains constant, which means that the system possesses a nonintegrable servo-constraint, or the center of mass of the body moves rectilinearly and uniformly; this means that there exists a nonconservative couple of forces in the system. Earlier, the author already proved the complete integrability of the equations of a plane-parallel motion of a fixed rigid body-pendulum in a homogeneous flow of a medium under the jet flow conditions when the system of dynamical equations possesses a first integral, which is a transcendental (in the sense of the theory of functions of a complex variable, i.e., it has essential singularities) function of quasi-velocities. It was assumed that the interaction of the medium with the body is concentrated on a part of the surface of the body that has the form of a (one-dimensional) plate. In sequel, the planar problem was generalized to the spatial (three-dimensional) case, where the system of dynamical equations has a complete set of transcendental first integrals. It was assumed that the interaction of the homogeneous medium flow with the fixed body (the spherical pendulum) is concentrated on a part of the body surface that has the form of a planar (two-dimensional) disk. In this activity, the results relate to the case where all interaction of the homogeneous flow of a medium with the fixed body is concentrated on that part of the surface of the body, which has the form of a two-dimensional disk, and the action of the force is concentrated in a direction perpendicular to this disk. These results are systematized and are presented in invariant form [2].

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VIBRATORY CRUSHER FORCED OSCILLATIONS NEAR THE RESONANCE

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In recent years in many branches of a national economy, and especially in the field of development of mineral deposits, begin to introduce widely vibration and resonance machines and vibromethods of conducting various works. Introduction of vibration technics, including using of resonance effects [1, 2], increases the level of mechanization and automation of many labor-intensive operations, promotes radical improvement of technological processes, increases economic efficiency and significantly reduces power inputs [3].

Vibratory crushers, developed by the Research-and-Production Group «Mekhanobr-Tekhnika» for disintegration of different hard materials, are characterized by such advantages as a high reduction ratio and low content of small size fractions in crushed product (due to work in resonance frequency range). In this paper for ensuring effective operation of these machines scientific justification of the choice of their operating synchronous frequency is made, that has essential value for designing of modern vibratory crushers.

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NONLINEAR BEHAVIOR OF RUBBER-BASED COMPOSITES CLOSELY FILLED WITH ELLIPSOIDAL PARTICLES

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This work is focused on a numerical homogenization of rubber-based composites for a wide range of strains when nonlinear elasticity of the rubber greatly affects the deformational behavior of the composite material. Generation of the composite microstructure is an important step for numerical homogenization, predicting local fields, evaluating fracture of the adhesive layer etc., so one of the main objectives of the present work is developing of a new computationally-efficient algorithm to generate the microstructure of the composite.

We consider a matrix composite with ellipsoidal reinforcing particles. Space distribution and orientations of the particles are random. In the developed algorithm the existing “concurrent” method [1] based on the overlap elimination is extended to ellipsoidal shapes of the particles. The algorithm starts with randomly distributed and randomly oriented ellipsoidal particles which can overlap each other. During performance of the algorithm, intersections of the particles are allowed and, at each step, the volume of intersection is minimized by moving the particles. The movement (shifting and rotation) is defined for each particle basing on the volume of the intersection: if two particles are overlapped, then the reference point inside the intersection is chosen and then two particles are moved in such a way that the reference point becomes a tangent point for the particles. To define the relative position of two particles (separate, tangent or overlapping) and to choose reference point inside the intersection volume the technic [2] based on formulating the problem in four dimensions and then analyzing the roots of the characteristic equation are applied. The algorithm is able to generate packings of prolate and oblate ellipsoids with high aspect ratios. The generated packings are close to the densest produced experimentally and have uniform distribution of orientations.

It is shown that the shape of the particles significantly affects stress-strain curves of the composites, and higher aspects ratio give stiffer composites, moreover prolate particles make composite more stiffer than oblate or spherical particles. It is demonstrated that stress-strain diagrams indicate a good agreement with experimental data.

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INVESTIGATON OF THE SEDIMENTATION MAGNETIC NANOPARTICLES ON THE WALLS OF VESSELS

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Magnetic nanoparticles can be used as MRI contrast agents [1] and for blood vessel controlled occlusion [2]. The model for the study process was created, imitating section of the system circulation and allowing apply magnetic influence and also realize registration of the accumulation nanoparticles.

In the experimental setup the magnetic nanoparticles transported due to fluid flow along a cylindrical tube. These particles are deposited on the wall of the tube in the magnetic field of solenoid. The axis of solenoid is coincides with the tube axis. To describe this process we use a system of differential equations. The system describing the motion of the separate particle in the cylindrical coordinates has view:

$$m\frac{d^2 z}{dt^2} = F_z - \alpha\left(\frac{dz}{dt} - V(r)\right)$$

$$m\frac{d^2 r}{dt^2} = F_r - \alpha\frac{dz}{dt},$$

where z and r are the axial and radial coordinates of particle; t is the time, m is the mass of particle; $\alpha=6\pi\mu R$ is the coefficient of friction of nanoparticle on the liquid; R is radius of the particle, μ is the coefficient of dynamical viscosity, F_z and F_r are the axial and radial components of magnetic force; V(r) is the velocity of liquid in the tube.

This system of differential equations is integrated with initial conditions:

$$t = 0: \quad z = z_0, r = r_0, \frac{dz}{dt} = V(r_0), \frac{dr}{dt} = 0$$

For calculating components of magnetic induction we use the following expressions [3]:

$$Br = \frac{\mu 0 I}{4\pi}\frac{N}{L}\sqrt{\frac{Rs}{r}}\left[\left(\frac{k^2-2}{k}K(k^2)+\frac{2}{k}E(k^2)\right)\right]_{\zeta = z+\frac{L}{2}}^{\zeta = z-\frac{L}{2}}$$

$$Br = -\frac{\mu 0 I}{8\pi}\frac{N}{L}\frac{1}{\sqrt{rRs}}\left[\zeta k\left(K(k^2)+\frac{Rs-r}{Rs+r}\Pi(h^2;k^2)\right)\right]_{\zeta = z+\frac{L}{2}}^{\zeta = z-\frac{L}{2}}$$

where I is the currant in the solenoid, Rs , L and N are the radius, length and number of turns of the solenoid, $h^2 = \frac{4rR_s}{(r+R_s)^2}$, $k^2 = \frac{4rR_s}{(r+R_s)^2+\zeta^2}$, $K(x), E(x), \Pi(x,y)$ are the complete elliptic integrals.

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MORPHOLOGICAL STABILITY OF THIN FILM MATERIALS DURING ANNEALING

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Multilayer thin film materials are extensively used in engineering systems to accomplish a wide range of specific functions. The layered structure could be used for improving mechanical, optical, electrical, magnetic and thermal properties of microelectronic devices. However, multilayer thin film structures are inherently stressed owing to lattice mismatch between different layers [1]. Similar to other stressed solids, such materials can self-organize a surface shape with mass redistribution to minimize a total energy [2, 3]. But the morphological stability is very important in fabrication of defect-free microelectronic devices. In this paper, we present a model of surface pattern formation in multilayer thin film structure with an arbitrary number of layers by considering combined effect of volume and surface diffusion. Based on Gibbs thermodynamics and linear theory of elasticity, we design a procedure for constructing a governing equation that gives the amplitude change of surface perturbation. A parametric study of this equation leads to the definition of a critical undulation wavelength which stabilizes the surface. As an application of presented solution, we analyze the surface stability of two-layered film under different conditions.

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MULTILEVEL MODELING: KINEMATIC AND CONSTITUTIVE RELATIONS AT HIGH DISPLACEMENT GRADIENTS

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The formulation of geometrically nonlinear boundary value problems is required for modelling of materials thermomechanical processing, main issues in it are the description of the nonlinear kinematics and the formulation of constitutive relations. The corotational derivatives, traditionally used for constitutive equations formulation (Zaremba-Jaumann, Green-Naghdi, logarithmic spin derivative [1] and so on) spin tensors are not connected with elements of symmetry of material (in the general case - anisotropic) throughout the deformation process, so these spins can't describe the coordinate system rotation, where the anisotropic material properties tensor is determined. In authors' opinion, in determining the motion decomposition and responsible for quasi-solid motion rigid moving coordinate system this coordinate system must be related with elements characterizing the symmetry properties of the material. It should be noted that crystalline materials (including metals and alloys) at different scale levels always have anisotropic properties in a certain extent, in different directions properties can be differ significantly. In addition, under intense plastic deformation even initial isotropic (at the representative macrovolume level) polycrystalline materials are also becoming anisotropic due to the occurrence of texture.

In frameworks of multilevel approach at the crystallites level for metals symmetry elements (planes and axes of symmetry) can be determined, and the moving coordinate system, which defines the quasi-rigid motion, will be connected with them. The new way for motion decomposition to rigid and deformation parts is proposed – multiplicative representation of deformation gradient with explicit separation of the moving coordinate system motion. The spin at mesolevel is determined by the rotation velocity of the rigid moving coordinate system connected with the crystallographic direction and the crystallographic plane; elastoviscoplastic constitutive relations at mesolevel were formulated in terms of the stress free configuration with the proposed spin. The spin of representative macrovolume is determined by averaging of spins of crystallites contained in this volume, щith this spin constitutive equations at macrolevel in rate form are formulated.

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PLASTIC DEFORMATION MECHANISMS IN NANOTWINNED MATERIALS

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Ultrafine-grained metallic materials containing high-density ensembles of nanoscale twins within grains (nanotwinned metals) exhibit outstanding mechanical properties (first of all, simultaneously high strength and functional ductility at room temperature) and enhanced electrical conductivity due to their specific structural features [1-3]. Despite the recent progress in the research efforts focused on simultaneously high strength and functional ductility of nanotwinned metals, the fundamental nature of plastic deformation processes in these metals is not fully understood and represents the subject of intensive discussions [1-3]. Thus, we have suggested a theoretical model [4] that describes basic deformation modes – stress-driven migration of twin boundaries and lattice dislocation slip – in nanotwinned metals. Within our description, the micromechanism for stress-driven migration of twin boundaries in nanotwinned metals is glide of partial dislocations along twin boundaries. The energy and stress characteristics of this micromechanism are calculated. With the assumption that stress-driven migration of twin boundaries and lattice dislocation slip concurrently operate in nanotwinned metals, we calculated the dependence of the yield stress on the distance between twins in nanotwinned metals. Our theoretical results are well consistent with corresponding experimental data reported in the literature [1,2].

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SOME OF NANO- AND MICRO NONLINEAR ELECTROMECHANICAL TASKS

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This investigation is devoted to solution of some new nano-and micro electromechanical tasks (NEMS, MEMS) of a nonlinear dynamics of conductive and ferromagnetic elastic bodies placed into quasi-stationary electromagnetic fields. These solutions are carried out by methods of the theory of nonlinear oscillations, in particular, by the asymptotic method and the theory of branching. Additionally, some of electromechanical nonlinear equations were solved by using the numerical methods. These analytical and numerical solutions as far as possible were checked by real physical experiments. As well as ones experiments open the possibility of creating the new electromechanical mechanisms. These tasks are included the investigation of the equilibriums of the ferromagnetic membranes in constant magnetic fields and parametrical resonance of the three nanowires with alternating current. The alternation of a spectrum of mechanical oscillations at adhesion of nanoparticle is determined by changing of amplitude-frequency characteristic in a region of parametrical resonance. As it's known the width of zone of parametrical resonance is narrowed at decreasing the quality of this system. This fact can be useful for increasing of precision of determination of an eigen frequency of nano-resonator at low of its quality.

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TUNABLE INTERFACES IN SOFT VISCO-HYPERELASTIC COMPOSITES

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In general, mechanical instabilities are usually considered as failure mode, however it is possible to exploit them in order to design materials and structures with enhanced performance, for example to accumulate strain energy (Shan et al. 2015) or control elastic waves (Shan et al. 2014). Particularly, we interested in the mechanical behavior of soft layered composites, that exhibit the so-called buckling phenomenon when compressed to a critical level. At this point, the microstructure switches to the wavy patterns with the geometrical parameters that depend on the phase materials properties and initial internal geometry of the laminates (Li et al. 2013). This phenomenon can be used to actively control the material microstructures and achieve various functionalities, such as tunable band-gaps in elastic waves (Rudykh and Boyce 2014). Moreover, similar effects can be produced via non-mechanical external stimuli such as electric or magnetic field in active composites (Rudykh at el. 2014).

While the geometry of wavy interfaces in hyperelastic soft materials are mainly defined by initial geometry and contrast between elastic modules of layers and matrix, there is no much space for tuning, because no one can change these two parameters for designed and already manufactured composite. However, this difficulty can be overcome, if we take into account time-dependent behavior of layers and/or matrix material. Thus, the objective of this work was to exploit the time-dependent behavior of materials to control the post-bifurcation wavy interfaces. Here, we employed the finite element method to numerically predict the performance of the soft composites with visco-hyperelastic layers in the regular and post-bifurcation regime for various geometries. For an experimental validation of numerical predictions, composite samples with various materials for layers and matrix were manufactured by means of 3D printing. These samples were subjected to constrained compression at the different strain rates, and the critical buckling strain and post-bifurcation geometry were determined experimentally. Based on experimental study and numerical simulations, we showed that post-bifurcation geometry of soft composite with visco-hyperelastic layers could be significantly tuned by applying of different strain rates, and it may be useful for the various practical applications.

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MISFIT DISLOCATIONS IN THE PARALLELEPIPEDAL CORE OF A CORE-SHELL NANOWIRE

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Core-shell nanowires (NWs) are widely used in various electronic and optoelectronic devices [1]. Their physical properties significantly depend on the shape, size, chemical composition, and type of crystalline lattice of NW components as well as on the presence of various defects in their structure. Shape effects are tightly related with mechanisms of misfit stress relaxation in a nanostructure. Core-shell NWs with parallelepipedal cores represent the simplest case of cores with flat faces. For example, similar faces exist in truncated octahedral nanoparticles with Au cores and Pd shells, where they demonstrate new interesting defect structures [2]. In particular, recent experiments showed the presence of stacking faults at the core-shell interfaces in the nanoparticles [2]. It can be explained by the formation of Shockley partial dislocations accompanied by stacking faults. To consider a flat core-shell interface, we used a theoretical model of a NW with a Pd shell and an Au parallelepipedal core. Recently, we obtained a strict analytical solution for a boundary-value problem of a parallelepipedal misfitting inclusion in an elastic cylinder [3], which is a mathematical basis for the present work. The model is based on an energy approach and describes the possibility of generation of either Shockley partial misfit dislocations associated with stacking faults or perfect misfit dislocations by gliding along the core-shell interface in the Au core. The dislocation generation is energetically favorable if the total energy change, i.e. the difference in the total energy after and before the dislocation generation, is less than zero. Based on this criterion, we define the critical conditions for generation of partial and perfect misfit dislocations in the Au core of an Au-Pd core-shell NW and analyze the dependence of the total energy change on the core size a for each type of misfit dislocations. Our calculations show that there is an energy barrier for dislocation generation. For $a = 10$ nm, it decreases from 1.68 to 0.56 eV/nm for perfect misfit dislocations when the NW outer radius R increases from 7.5 to 8 nm, respectively, and it totally disappears for $R >$ 9 nm. In the case of partial misfit dislocations, for the same value of a, the energy barrier is 0.33 eV/nm for $R =$ 7.5 nm and totally disappears for $R > 8$ nm. Thus, the generation of partial misfit dislocations is more energetically favorable then that of perfect misfit dislocations.

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LOCALIZED HEAT IMPULSES IN 1D CRYSTALS. SOLUTIONS FOR NON-FOURIER HEAT EQUATION

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At present, interest in the study of nonlinwear thermomechanical processes in low-dimensional nanostructures attracts a lot of attention, particularly to describe the unique properties of advanced materials and devices based on them. Therefore, there appears high interest in simple models of lattice, in particular, one-dimensional harmonic crystals where the most noticeable abnormalities occur. These models allow to understand the nature of such important for practical applications effects such as the transition of mechanical energy into heat, the heat superconductivity and others. Properties of equation obtained in [1] describing heat conduction in 1D harmonic crystal were investigated. Exact analytical solutions for localized initial temperature distributions such as rectangular, triangle, saw functions obtained. It is obtained that wavefront approaches static shape which highly dependent on initial impulse shape. In general case it is shown that for localized initial impulse on coordinate intervals close to zero the decay law is proportional to $\boldsymbol{1/t}$ and near the wavefront proportional to $\boldsymbol{1/\sqrt{t}}$, when $\boldsymbol{t} \to \infty$, where $\boldsymbol{t}$ – time. This result coincides with the results obtained for exact solutions. It is shown that in general case of localized initial impulse the solution approaches to the same shape obtained for delta function initial impulse, on coordinate scales equal to $\boldsymbol{ct}$, when $\boldsymbol{t} \to \infty$, where $\boldsymbol{c}$ – speed of sound in given harmonic crystal.

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FEATURES OF SIMULATION OF THE TIRE IN THE CONDITIONS MOVEMENT OF THE CAR WITH ACCELERATION

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The paper reports on a study of the influence of the Mullins softening effect on changes in the stress fields of a rotating car wheel under acceleration and braking conditions. In our opinion, this effect has received little attention in tire industry until recently. Computer modeling of car tire softening is a complex mathematical problem. Therefore, we have developed an algorithm to evaluate changes in the stress-strain of the wheel of the acceleration car taking into account the Mullins effect and anisotropy.
With the algorithm proposed one can study the softening effect in different points of the tire during the first turn of a wheel under acceleration conditions. The results of numerical simulations demonstrate that the softening effect should be taken into account even when developing a simplified model of a car wheel, in which the tire material is considered as isotropic, and the model tire has a simpler geometry than the real tire. It has been found that the deformation of the lateral surface of the tire calculated with the Mullins effect is significantly higher than the deformation obtained in calculations where this effect has been ignored.

The hyperelastic forth-order Ogden model is applied to describe the mechanical properties of an elastomeric matrix of the tire. The degree of softening is evaluated in terms of the Ogden-Roxburgh model. Constants for the model proposed were determined during the cyclic tension test interrupted every 30 minutes after reaching a 5% deformation of the tire.

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NUMERICAL SIMULATION OF THE FOUR-POINT AND THREE-POINT BENDING TESTS IN THE THEORY OF ELASTIC MATERIALS WITH VOIDS

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The problem of numerical modeling of three-point and four-point bending of the porous beams is considered. Finite element method is used for numerical solution of the boundary value problems in the frame of the theory of linear elastic materials with voids (microdilatation theory) introduced by Cowin and Nunziato [1]. The influence of the scale parameters and additional physical modules of the microdilatation model on the effective stiffness and stress strain state of the porous beams are studied. Analytical solution for the pure bending problem [1] and the corresponding numerical solution are compared. The problem of fracture toughness determination of the porous beams in tests with notched samples is studied. The influence of the scale effects in the bending tests of porous materials are discussed. Additionally we investigate the possible influence of the surface porosity using model with surface effects. The strain energy of this model contains the surface part which depends on the porosity changes on the body surface [2]. It is shown the existence of special surface effects that provide the avoidance of scale effects and correctness of classical Saint-Venant's hypothesis [3] in the bending problem in the frame of microdilatation theory.

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THE EFFECT OF CYCLIC PRE-LOADING TO THE RESIDUAL STATIC STRENGTH OF COMPOSITE MATERIALS SAMPLES

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The complex of tests to estimating the residual static strength of composite samples after preliminary cyclic loading. The samples were made from of glass fiber prepreg strips. 23 samples, divided into five groups, were tested. Each group of samples of different value cyclic loading, which lies in the range of load cycles (N=0…$1.75*10^5$). Cyclic loading was performed on the test system Instron ElectroPuls E10000. The samples were tested at the same amplitude stress level with a maximum value $\sigma_{max}=0.5\sigma_b$ of the coefficient of asymmetry R=0.1 and a frequency of 50 Hz. The amplitude of the cyclic loading was $\sigma_{a=}0.225\ \sigma_b$. After cycling tests the quasi-static tensile test with the definition of the ultimate strength were carried out. This type of test was conducted using a testing system Instron 5882.
As a result were obtained depending on the strength limit of the composite material from the duration of previous cyclic loading. The point corresponding to the value σ=0 obtained as the mean fatigue life of the material samples. For determine this value three fatigue tests to failure were conducted. The cycle parameters of this fatigue tests is the same as in the previous cyclic loading.
Analyzing the results, we can conclude a reduction of tensile strength by increasing the value of the pre-cyclic loading. The schedule is not linear. In the first range (0 ... 10^5 cycles) reducing the tensile strength of the material sample is about 20%. The following range (10^5 ... $1.5*10^5$ cycles) reduce the tensile strength is not reduced. In the latter range ($1.5*10^5$... 2.1 * 10^5 cycles), a sharp decrease in the limit of the material strength.

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ON INCREASING EFFICIENCY OF HYDRAULIC FRACTURE SIMULATION BY USING DYNAMIC APPROACH OF MODIFIED THEORY

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The work aims to make a further step in using the computational advantages of the modified theory [1-4] for efficient simulation of hydraulic fracturing. For the KGD model, the advantages have been confirmed only when solving it in coordinates *normalized* by the fracture length [2-5]. This excluded singularity in the temporal derivative of the opening. However, such beneficial normalizing is unavailable in 3D problems. Thus, it is of value to solve the KGD problem in *global* coordinates. Furthermore, it is reasonable to employ *hypersingular* operator, which expresses the pressure via the opening, rather than its *weakly singular* inversion. The inversion is unavailable in an analytical form in general, and it restricts methods for integration in time to those compatible with ε-regularization.

The step is made by solving the KGD problem in frames of the *dynamic approach* with using the *hypersingular operator*. The accuracy is controlled by comparison with the bench-mark self-similar solution. The time is increased 100-fold from the unit initial value.

Firstly, we examine the approach in the normalized coordinates to see the influence of the hypersingular operator. It appears that the Runge-Kutta scheme provides the fracture length to the accuracy of 3.6% even for a quite hoarse mesh with merely 10 nodes. To reduce swiftly growing time expense for finer meshes, the Adams scheme is employed. Then for a mesh with 80 nodes, the time expense is reduced 4-fold.

Secondly, the approach is extended to the global coordinates. Now the temporal derivative is singular at the fracture front what is unfavorable for the accuracy. Calculations confirm that the accuracy decreases. The error of the fracture length grows to 6.8% for the mesh with 10 nodes. For 40 nodes it is 3.0%. Therefore, the accuracy is still acceptable. Again the Adams scheme is superior as concerns with the time expense.

At last, it is established that the results are true for Newtonian, as well as for thinning fluids. We conclude that the approach described may be successfully extended to 3D problems.

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APPLICATION OF HYBRID ALGORITHMS TO INVERSE EIGENVALUE PROBLEMS FOR HYDROMECHANICAL SYSTEMS

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The field of inverse eigenvalue problems is of great importance in numerous scientific and industrial applications. Reliable computer modeling in hydromechanical system dynamics represents an actual example. Problems of identification of anomalies in the phase constitution of the coolant circulating throw the reactor primary circuit are under consideration. Mathematical models of acoustic oscillations in the two-phase flow have been developed. Indirect diagnostic information is contained in flow oscillation spectra registered by established measuring equipment. The method uses an initial computer model and measured incomplete modal data to improve the model parameters. Problems of computational model validation are formulated as inverse eigenvalue problems. Incompleteness of registered data and possible presence of multiple frequencies result in the error function being multiextremal and not everywhere differentiable. As the function has numerous local minima, it is necessary to use global optimization methods. Two novel hybrid global optimization algorithms combining the stochastic Multi-Particle Collision Algorithm (for scanning the search space) and deterministic techniques (for local descent) are introduced. Hyperbolic smoothing approximations are inserted during the local search in the first algorithm. The second algorithm implements the local search procedure by use of numerical approximations to space-filling curves and geometric techniques working with a set of Hölder constants at each iteration. Results of successful computational experiments are presented to show the efficiency of the approach.

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DUAL-PURPOSE RESONANT SUPERCHARGER FOR INTERNAL COMBUSTION ENGINE

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Double purpose supercharger, performing both its main function, that is, boosting the internal combustion engine by means of air injection and the resonant formation of fuel mixture as well, is proposed.

Supercharging is used in the automotive industry to achieve highest power at smallest dimensions of the engine. Up to now no one of the existing turbochargers carries out the function of high-quality mixing of fuel and air. Meanwhile, the quality of the fuel-air mixture significantly affects the efficiency of its combustion and hence the effectiveness of the internal combustion engine at all.

Fuel-air mixture – is the dispersed system in which fine particles of fuel – dispersed phase, are distributed in the air – dispersed media. Smallest sizes of fuel droplets in the air and uniformity of their distribution just determine the quality of dispersing.

Imposition of resonant acoustic vibration on the dispersing process significantly improves its quality. Thus, fuel mixture for internal combustion engines, prepared by the resonant vibration, is proved to be saturated with oxygen just at the molecular level.

It is proposed to use acoustic resonant vibrations for preparing the fuel-air mixture in internal combustion engines, provided with the turbocharger of air. The resonant operating mode ensures optimal conditions for pumping energy into the gaseous mechanical oscillation system to carry out the work for preparation of high-dispersed systems.

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A NEURAL NETWORK MODEL TO INVESTIGATE THE EFFECT OF FREQUENCY AND TIME ON LOADING INDUCED OSTEOGENESIS

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In-vivo studies have been confirming that dynamic mechanical loading is beneficial in prevention or recovery of bone loss induced due to bone/muscle disuse in bedridden patient or in astronauts under micro-gravity conditions. It is believed that cyclic loading induces normal strain which inhibits bone resorption and promotes the osteogenesis (i.e., new bone formation) at the sites of elevated strain. Thus, computer models of bone adaptation have selected normal strain as a stimulus to predict site-specific osteogenesis [1]. These models have several limitations such as they only predict the location of new bone formation and do not provide any quantitative measurement of newly formed bone. This may be because these models overlook the effect of loading parameters such frequency, cycles and loading time on new bone formation, even when, the previous studies recommended that loading parameters significantly influence the amount of new bone formation [2-3]. This fact can only be incorporated in the computational model when a relationship between loading parameters and a new bone formation parameter is well established. Accordingly, this study presents a back-propagation neural network model where mechanical load/strain, frequency, loading cycle and time have been used as inputs and new bone formation parameter i.e., mineral apposition rate (MAR) is obtained as an output. The model establishes an empirical relationship to estimate mineral apposition rate as a function of loading parameters, which can be further used to define remodelling rate coefficients in computational models [4]. The modeling results fit several in-vivo experimental results. The effect of each loading parameter on MAR has been also studied which aligns with the literature as well. These findings may improve the computational models of bone adaptation and will ultimately aid in advancement of biomechanical interventions to treat or reverse the bone loss.

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CONTINUAL MODEL OF MULTILAYER NANO-PLATE BENDING AND FREE VIBRATIONS

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1. Model of a graphite plate. A continual model of a rectangular graphite plate, consisting of graphene layers is studied. Each of graphene layers is modeled as a thin isotropic plate with the extension stiffness K_0 and with the bending stiffness D_0 [1]. Between graphene layers there are comparatively small Van-der-Waals forces. The main our assumption is that we model the intermediate layers of thicknesses h_0 between graphene layers as isotropic elastic layers with the small stiffness. The problem is reduced to study a multilayer plate consisting of hard and soft layers.

2. Equivalent Timoshenko-Reissner model. Consider a multilayer plate, consisting of isotropic layers with Young moduli E_k, Poisson ratios ν_k, and thicknesses h_k. As it is established in [2,3] in the case of a great difference in stiffness between the Young moduli of hard and soft layers the equivalent TR model may be applied

$$D\,\Delta^2 w = F_3 - \frac{D}{\Gamma}\,\Delta F_3, \qquad \Delta(\cdot) = (\cdot)_{,xx} + (\cdot)_{,yy}, \tag{1}$$

where

$$D = \langle (z-a)^2 E_0(z) \rangle, \qquad a = \frac{\langle z E_0(z)\rangle}{\langle E_0(z)\rangle},$$

$$E_0 = \frac{E(z)}{1-\nu^2(z)}, \qquad \langle X \rangle = \int_0^h X(z)\,dz,$$

$$\frac{1}{\Gamma} = \frac{1}{D^2}\int_0^h \frac{(e(z))^2}{G_{13}(z)}dz, \quad e(z) = \int_0^h (z-a)E_0(z)\,dz,$$

$$G_{13} = \frac{E(z)}{2(1+\nu(z))}. \tag{2}$$

The most important here is the new expression for the equivalent transversal shear stiffness Γ. If there are the layers with small E_k, then Γ becomes small and the second term in the right side of (1) becomes large.

For simply supported edges and for the harmonic excitation $F_3(x,y)$ we get the explicit expression for deflection $w(x,y) = w^0 \sin r_x x \sin r_y y$, with the amplitude w^0:

$$w^0 = w_b + w_s, \quad w_b = \frac{F_3^0}{D\,r^4}, \quad w_s = \frac{F_3^0}{\Gamma r^2}, \quad r^2 = r_x^2 + r_y^2, \tag{3}$$

where w_h and w_s are the bending and the shear parts of deflection, respectively. We rewrite Eq. (3) as $w^0 = w_b(1 + g)$, where $g = \frac{r^2 D}{\Gamma}$ is the dimensionless shear parameter.

At the case of free vibrations with frequency ω we take $F_3 = \rho\omega^2 w$, and Eq. (3) gives the approximate expression for the first natural frequency

$$\omega^2 = \frac{D\,r^4}{\rho(1+g)}. \tag{4}$$

Eqs. (3) and (4) are acceptable at $g \sim 1$.

3. Model of the multilayer nano-plate bending. Let a graphite plate consist of $n + 1$ graphene layers. We calculate the equivalent stiffness D and Γ by Eqs. (2). At some simplifications we get

$$D = (n+1)D_0 + \alpha_n h_0^2 K_0, \quad \frac{1}{\Gamma} = \frac{\beta_n h_0^3 K_0^2}{D^2 G_{13}^0}, \quad \alpha_n = \frac{n(n+1)(n+2)}{12}, \quad \beta_n = \frac{\alpha_n(n^2+2n+2)}{10}. \tag{5}$$

Here G_{13}^0 is the transversal shear stiffness of the intermediate layers. In the stiffness D the first summand is much smaller than the second one and it is to be omitted. Now we may use Eqs. (3) and (4) to calculate the deflection and the frequency of free vibrations of a graphite nano-plate. Numerical examples are given.

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MODELING NONLINEAR DYNAMICS OF AXIALLY MOVING STRINGS IN EULERIAN AND LAGRANGIAN DESCRIPTIONS

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The practically relevant question of mathematical modeling of vibrations of axially moving strings is a challenging problem, which has attracted the attention of many researchers, see the review paper [1]. The inefficiency of the material (Lagrangian) modeling, at which we follow the motion of each material particle and the boundary conditions need to be set at moving points of the domain, has led to the use of the Eulerian description. Observing the process at a given axial position reduces the complexity of the problem and simplifies the boundary conditions, but requires a reliable transformation of the original equations of motion to the new variables. The transformation of variables becomes solution dependent in the case of axial deformations, when the relation between the original material coordinate and the new spatial one involves the unknown displacement, see the analysis in [2]. The geometrically nonlinear coupling between the transverse motion and the axial one makes the things even more complicated.

We consider vibrations of a string, whose velocity is prescribed at two points of the domain, and one of these points is moved in the transverse direction. This example problem allows for a numerical solution in the Lagrangian setting using a model with lumped masses and compliances, which serves as a benchmark for the computationally more efficient solutions in the Eulerian model. The latter is obtained by transforming the variational equation of the principle of virtual work to the new coordinates. The relation between variations at given material and spatial points needs to be accounted for. Further, we introduce an approximation of the unknown displacements over the fixed spatial domain and demonstrate, that the common Lagrangian equations of motion of the 2nd kind retain their form for the non-material volume in the present case of kinematic boundary conditions. Comparing against the above-mentioned results of material modeling as well as against simple analytical solutions for the case of small oscillations, we justify the obtained non-material finite element scheme.

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A QUALITATIVE ANALYSIS OF THE DYNAMICS OF A CYLINDER ON A HARMONICALLY OSCILLATING PLANE WITH FRICTION

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The dynamics of a rigid cylinder on a harmonically moving plane is investigated. The cylinder makes line contact with the surface and is subject to sliding and rolling friction. Sliding friction is governed by Coulomb law and rolling friction is governed by a multivalued law. For simplicity a two-dimensional model is considered. The angle between the plane and the horizon is a parameter of the problem. The problem is studied both in smoothed and switched frameworks. A qualitative analysis of the dynamics of the cylinder is given for different slopes of the plane. In the case of a horizontal plane, some periodic motions are obtained and their stability is investigated.

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COMPARISON EXPLICIT AND IMPLICIT SCHEME IN CASE OF THE HYPERBOLIC HEAT CONDUCTION

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Modern microelectronics require efficient cooling systems. But it is known that hyperbolic thermal conductivity predicts higher temperatures than the classical theory. Moreover, parabolic thermal conductivity equation has infinite propagation velocity.

In the second part of XX century began active investigation of hyperbolic thermoelasticity. The first model was proposed [1] by Lord and Shulman. It is based on generalized Fourier law with relaxation time constant. In this work the hyperbolic thermoelastic problem of Lord-Shulman type is considered. The numerical solution is founded for infinite layer with constant temperature and free boundaries using finite-difference method with explicit and implicit scheme. The layer is treated by laser impulse. Solution is compared with analytic and the error is founded.

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A TITH MODEL FOR CARTILAGE AND THE RELATED 3–D CONTACT PROBLEM TOWARDS EXPLANATION OF IN-VIVO EXPERIMENTS

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Articulation of the skeleton is a delicate task which must be acted without damaging the bones at the so- called diathrodial joints. It is indeed in these areas that the transmitted forces focus during the motion of the body. The function of eliminating the friction and lowering pressure peaks is mainly conducted by the articular cartilage coating via various mechanisms which require a complex interaction between the solid and fluid phase of such thin tissue.

Degenerative pathologies such as osteoarthritis seriously influence the effectiveness of lubrication and load bearing by reshaping the internal age-dependent structure. It suggests the necessity of studying the mechanics of the layer also accounting for the effect that inhomogeneity and anisotropy induce to the internal stresses and deformation.

Existing closed-form solutions of the deformation problem considered the biphasic layer isotropic or transversely isotropic, but homogeneous ([2,3]). Recently, a transversely isotropic, transversely homogeneous (TITH) asymptotic solution was developed ([7]).

Based on such solution, the 3–D contact problem involving two elliptic paraboloid bones covered by constant thickness cartilage has been studied under the assumption of monotonic increase of the contact area. The derivation follows the mathematical approach developed in [1, 3]. The solution is presented in terms of integral characteristics of the contact area and the closed-form is preserved. Its physical validity is related to the early phase of deformation, since it neglects the dependency of the material parameters on the strain.

In fact the compression of the solid proteoglycan matrix, producing shrinking of the internal pores, changes the permeability, then stiffens the structure via fluid self-pressurization. The phenomenon is simulated numerically to extend the applicability of the solution in time and allow comparison with existing in-vivo contact experiments (e.g. [4–6]).

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ASYMPTOTIC HOMOGENIZATION OF GRADIENT ELASTICITY EQUATIONS IN PERIODIC MEDIA

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In the paper, we develop mathematical tools [1] for effective solution of boundary value problems for gradient elasticity equations of the fourth order in the domains with inclusions of spherical or cylindrical form, periodically arranged in the uniform matrix. Considered gradient models allow to simulate [2] the scale effects in composite materials with nanoinclusions, which are resulted due to surface activity of ones. Mathematically, this means that in the considered gradient models along with the classical field near the interphase boundaries acts additional (cohesive) field, which decreases with distance from the boundary and which reproduces inclusions enhancing effect on the effective characteristics of composite materials. Particular case of gradient models are the classic models, which are corresponded to the zero cohesive field in the solution. Periodic media, composed of the homogeneous matrix and inclusions with different characteristics, correspond to the gradient equations of the fourth-order with periodic coefficients. Asymptotic homogenization procedure [3] reduces the problem of calculating the effective characteristics and the stress/strain fields in the material to the successive solution of a number of more simple problems in the representative periodic cell. And it also allows to construct the asymptotics, which approximate behavior of the solution in both scale levels (global and local). We develop special mathematical tool, a method of radial multipliers, for the high-precision approximation of fast variables functions in the asymptotic homogenization method for gradient elasticity equations. The exact analytical reproducing of the contact conditions on the interphase boundaries provided by the special construction of approximation functions [4], which allows to accurately reproduce the stress and strain fields in the cell with the inclusion and to simulate scale effects. The method is based on the representation of displacements through the auxiliary potentials, which are determined by the harmonic polynomials and special multiplier-functions on the radial coordinate. The radial multipliers ensure the accurate realization of contact conditions on the interphase boundaries, and degrees of freedom in the choice of harmonic polynomials provide the completeness of the approximating functions. On the basis of these functions the solution of the boundary value problems in heterogeneous materials is constructed using the block variant [5] of the least squares method. The constructed systems of functions are used for the exact solution of the problems on the periodic cell in the method of the asymptotic homogenization, as well as directly for immediate modeling of physical processes in the structurally inhomogeneous materials.

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PERIDYNAMIC GREEN'S FUNCTIONS FOR ELASTIC AND DIFFUSIVE PROBLEMS

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The peridynamic theory[1,2] replaces the conventional differential equation of motion of continuum mechanics with an integral formula, leading to a strongly nonlocal theory that accounts for long range interactions among material points. It also facilitates treatment of discontinuities, initiation and evolution of damage in continua. Noting that the one-dimensional and three-dimensional peridynamic Green's functions for point forces have been previously studied by other researchers[3,4], we will present the solutions of the Green's functions for point forces in one-, two- and three-dimensional domains, as well as the Green's functions for general diffusive problems within the formalism of peridynamics. We show that these peridynamic Green's functions can be uniformly expressed as classical solutions plus Dirac functions, and convergent nonlocal integrals. They also approach the classical theory when the nonlocal length tends to zero or the considered material point is far away from the loading point. The solution of general peridynamic diffusive problems can be constructed base on the solution of a point source; thus the Green's functions can be used to develop a method to solve diffusive problems in infinite, semi-infinite and finite domains.

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PERIDYNAMIC THERMOELASTICITY BASED ON NON-FOURIER HEAT CONDUCTION

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Nonlocality is very important in solving thermomechanical problems at small scales, and it may arise mathematically in modelling the overall mechanical properties of heterogeneous media[1,2] . Some nonlocal mechanical theories have been used to investigate the size-dependent mechanical behaviour in which the classical thermoelasticity is invalid, such as fully coupled peridynamic thermoelasticity[3]. However, heat conduction in the previously developed peridynamic thermoelasticity theory is based on the Fourier's law which may break down for materials in situations where the characteristic length is comparable to, or less than, the mean free path of the carriers. In order to alleviate this shortcoming, we propose the peridyanmic thermoselasticity based on non-Fourier heat conduction, which considers the nonlocal effect and non-Fourier heat conduction at the same time. Moreover, it retains the advantage of the peridynamic theory and can be easily applied to multidimensional media containing discontinuities.

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UNVEILING COMPLEXITIES OF DRILL-STRING AND BHA DYNAMICS

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We investigate complex drill-string dynamics in a downhole drilling where strong nonlinear interactions between various types of vibration take place. First we develop and study low dimensional models of the downhole drilling where a drill-bit cutting a rock formation has a strong coupling between torsional and axial oscillation [1,2]. Then we investigate a new experimental rig developed by the Centre for Applied Dynamics Research at the University of Aberdeen, capable of reproducing all major types of drill-string vibrations [3]. One of the most important features of this versatile experimental rig is the fact that commercial drill-bits, employed in the drilling industry, and real rock-samples are used. The rig allows for different configurations, which enables the experimental study of various phenomena, such as stick-slip oscillations, whirling and drill-bit bounce. Special attention is given to the estimation of the mechanical parameters of the flexible shaft and drag drill-bit, which play crucial role in generation of undesired vibrations.

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MESOMECHANICAL ANALYSIS OF THE COMPOSITE REINFORCED BY GRAINS

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The paper deals with the strain-state condition of a composite reinforced by grains under the action of compressive loads. Concrete is a special case of such composite material. The aim of the presented paper is analyze the influence of the internal contact interactions in the material on the strength of its structure under the action of applied loads. This work is the development of research presented in papers [1–3].

There was performed computer simulation of the cubic structural element deformation. This element is a matrix, reinforced by filler grains of different shapes. Grains are periodically located in the matrix. So one cell was accepted as a simulation model and it included parts of two grains with the fragment of surrounding matrix. The connection between the constituent elements of the material was modeled by contact pairs admitting the granules and matrix relative displacement.

Computations performed for different values of cohesion between the materials of composite showed that the stress distribution pattern is not changed substantially. However, for small cohesion values there is a relative displacement of the grain and matrix surfaces during the time from the load application and till system equilibrium . The presence of relative displacements indicates about the material stratification. This fact shows lack of material strength under the influence of compressive pressures. There were determined the minimal values of cohesion providing required material strength under compressive loads.

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NUMERICAL SIMULATION OF THE RELAXATION OF A TWO-DIMENSIONAL FOAM

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The foams have several application fields from the food industry to the drilling sector. The numerical simulation is an efficient tool to investigate the characteristic behaviour of the foams.

The present work introduces a simplified numerical model to simulate the mechanical relaxation of foam films. The model features deformable bubbles and captures their main geometrical characteristics [1].

As an illustration we present the results for the relaxation in time of a single soap film. The dynamic equation of the single film is written taking into account the surface tension, the pressure and the viscous force acting on the film [2].

The study is then extended to three films which meet at a single vertex, called the Steiner Fermat point. In terms of dynamics, we explore the evolution from an arbitrary initial geometry towards equilibrium, and the corresponding relaxation time is calculated.

Moving to the more complex system of many bubbles which constitute a foam, there are further dissipative time-scales based on microscopic information which we relate to the dynamics of local reorganization of the bubbles. The possible instantaneous configurations of these rearrangements, known as T1 events, are also implemented.

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INVARIANT CALCULATIONS IN BEAM PHYSICS: DYNAMICS ON SEMI-DIRECT PRODUCTS AND CWT

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We outline, according to Marsden approach, the semi-direct product structure that allows to consider, from general point of view, all kinematics groups such as Euclidean, Galilei, Poincare. Then we consider there the proper invariant Lie-Poisson equations and obtain the manifestation of semi-product structure the dynamical level. After that, we consider the Lagrangian theory related to semi-product structure and the explicit form of the variation principle and corresponding (semi-direct) Euler-Poincare equations. All that provides needful background for CWT and the corresponding analytical technique that allows to consider covariant wavelet analysis. The proper orbit technique allows to construct different types of invariant wavelet bases.

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SCATTERING OF FLEXURAL-GRAVITATIONAL WAVES BY A PERIODIC ARRAY OF OBSTACLES IN AN ELASTIC PLATE FLOATING ON A THIN FLUID LAYER

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Low-frequency time-harmonic flexural-gravitational waves in a floating elastic plate are considered. Straight-line obstacles in the plate are periodically spaced in the horizontal coordinate with an equal separation termed as the space period of the system. The obstacles under consideration are either rigid clamps, or movable clamps, or cracks, or their combinations. Propagation of flexural-gravitational waves through the plate is analytically studied under a thin fluid layer approximation. We are concerned with stopping and passing frequency bands, of which the boundaries are found.

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MODELLING OF THE MICROSTRUCTURE EVOLUTION DURING LASER ADDITIVE MANUFACTURING OF STEEL

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Laser additive manufacturing is finding increasingly widespread use in aerospace, automotive, defense, and biomedical industries to produce complex-shaped components. The mechanical properties are known to depend on the microstructural characteristics of the part. Thus, an accurate prediction of the microstructure evolution is very important to understand processing-microstructure-property relationships in a material obtained by additive manufacturing.
The present work is concerned with the modelling of the microstructure evolution during laser additive processing of metals. A two-dimensional numerical model of grain growth during laser beam melting, which is built in the framework of the Rappaz's and Gandin's approach to simulate a microstructure formation in solidification processes [1], is developed. To solve the artificial anisotropy problem, an original correction is proposed [2]. The numerical simulations of the temperature field as well as the melt pool geometry were realized with the use of the finite difference method. The Goldak's double ellipsoid model [3] is used to simulate a laser heat source moving in three-dimensional space.
The following process is simulated: a layer of powder is deposited on a substrate with equiaxed grains and then melted during a series of laser passes. Further, the next powder layer is deposited, and the process is repeated until a predetermined number of layers is reached.
Analysis of the results shows that the final microstructure mainly consists of coarse columnar grains. The grain growth in the direction of heat flow is observed, and grains tend to extend across several layers of powder. The simulated grain structures are shown to be in good agreement with the experimental ones obtained in Neue Materialien Bayreuth GmbH (Germany). The effects of the shape and arrangement of melt pools are examined. It is shown that as far as the material builds up, the grains, which are better oriented for growth with respect to the temperature gradient, overgrow others and become predominant. The rate of this process depends on the shape of the melt pool. When the centers of the melt pools within the current layer of powder are uniformly offset relative to those within the previous layer, the columnar grains are observed to tilt in the direction of displacement of the melt pool centers.

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INFLUENCE OF THE SUBSTRATE GRAIN SIZE ON THE MECHANICAL PROPERTIES OF THE COMPOSITION «CERAMIC POROUS COATING – STEEL SUBSTRATE»

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In this work, the influence of the substrate grain size on the mechanical properties of the «ceramic porous coating – steel substrate» composition is investigated. Specimens are compressed perpendicular to the «coating – substrate» interface. Dynamic boundary-value problem in the plane strain approximation is solved numerically with the use of the finite-difference scheme. Constitutive relations include models for the brittle fracture of the ceramic coating and for elastoplastic deformation of the steel substrate with isotropic strain hardening. The fracture criterion used in this work accounts for crack initiation in local regions experiencing tensile stresses. A regular curvilinear computational mesh is obtained using original approach based on the mechanical analogy method [1].

Microstructure of the steel substrate is taken into account in both implicit and explicit ways. In the first case, the mechanical properties of the substrate are considered to be uniform and depend on the average grain size according to the Hall–Petch relationship. In the second case, the developed model based on the Rappaz's and Gandin's cellular automata method [2] to simulate grain structure formation is used for microstructure modeling and the different grains in the substrate have different mechanical properties. The average grain size in the substrate is ranged from 5 to 30 microns. The «coating – pore» and «coating – substrate» interfaces are taken into account explicitly. We consider both plain and serrated types of the «coating – substrate» interface.

Fracture strain is shown to depend on the substrate grain size exponentially. In the case of plain «coating – substrate» interface, we observed two fracture modes: when initial crack is nucleated on the «coating – pore» interface (the grain size is less than 20 microns) and when the crack is nucleated on the «coating – substrate» interface (the grain size is more than 20 microns). The crack always nucleates near the serrated «coating – substrate» interface.

The support of the Russian Foundation for Basic Research and Russian Academy of Sciences is gratefully acknowledged.

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DILATOMETRY OF POLYETHYLENE NANOCOMPOSITE CONTAINING 5% OF MULTIWALL CARBON NANOTUBES

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In this work, the aim is studying the thermodynamic and structural behavior of nanocomposite based on high density of polyethylene containing 5% of multiwall carbon nanotubes.

Two samples were taken according to longitudinal and radial directions. Thermal expansion coefficients determined in both directions are different. We note that dilatometric curves of both samples: pure and nanocomposite measured according to longitudinal direction have the same form and practically identical. Each curve contained a peak at around of 55°C.

According to radial direction, the dilatometric behavior of tow samples changed. The thermal expansion coefficient measured in the radial direction of pure polyethylene has three intense dilatometric anomalies. The curve representing □(T) of nanocomposite (PE + 5%NTCM) contains only two peaks. In fact of, dimensional variations are changes from direction to another. The anisotropy is presented. dL/L according to radial direction of pure material (P) and its nanocomposite (N) PE + 5%NTCM have the same curve. When we move to longitudinal direction, we notice that the anisotropy becomes more intense. dL/L_N is lower than dL/L_P at all temperature range.

Furthermore, Dynamic Scanning Calorimeters (DSC) results shows that the curves of PE and its nanocomposites have the same form around 60°C, the nanomaterial DSC is lower than PE until that temperature is higher than 100°C. From 105°C, the two curves decrease suddenly. In the other side, the two curves of Thermogravimetry are not identical; For PE is trend to increase with temperature. On the other hand, the TG of PE 5%NTCM is constant in spite of rising of temperature. Probably, the multiwall carbon nanotubes is strengthen the structure.

Also, the two infrared spectrums of polyethylene pure and its nanocomposite based on polyethylene contains 5%NTCM are different. Which they are containing many anomalies around various frequencies. With changing of bands form for infrared spectrums in the case of polyethylene pure and leads to tend many peaks when we introduce 5%NTCM. This situation conducts an increasing of cristanility.

The two Raman spectrums of two materials are not the same. They are containing the same peaks' numbers and same frequencies range, for PE is more intense than PE 5%NTCM.

Finally, the observations from the scanning electron microscope show that the disturbance of multiwall carbon nanotubes is uniform. This dispersion can reflect the dilatometric behavior of nanocomposite. The carbon nanotubes quantity introduced have probably a great effect of significant reduction in the coefficient of thermal expansion and thus improving and also strengthening links.

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ASSESSMENT OF TOOTH ALVEOLUS DAMAGE DURING OCCLUSION FORCES ACTION: EFFECT OF IMPLANT MATERIALS

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Currently during orthopedic treatment and prosthetics a dentist basically makes decisions empirically, basing on his own experience and feeling of the patient.

Recent approaches for the modeling of biomechanics systems damage are developed in general for the long tubular bones, deferent bone structures and different types of cartilages [1, 2]. However the damage models for dental structures (tooth, periodontal ligament, alveolar bone) almost absent. There are only a few research papers in this direction [3]. In this connection it seems relevant and practically important to develop mathematical and finite element models for assessment of the alveolus bone damage and improving durability of dental implants and crowns.

Unlike natural teeth, dental implants transmit pressure loads directly into the surrounding bone. At high pressure load this may lead to bone loss and increased risk for implant failure. To mimic the natural conditions, one possible concept is to dampen the dynamics of mechanical stress peaks by suitable elastic elements, such as plastic abutments (e.g. PEEK). This approach could potentially lead to a protection of the bone against overloading and on the other hand improve the long-term durability of ceramic crowns.

The obtained results can be used by dentists for choosing optimal implant material/shape taking into account of individual features of the patient. The results can also be used to evaluate the damage arising in the periodontal ligament and bone in the case of tooth loading.

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MECHANICAL MODEL OF THE LUNG TISSUE CONSIDERED AS A SATURATED POROUS MEDIUM

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Flow simulating in a lung is challenging because of the large number of flow paths and the wide range of length scales. Airways have a tree structure, where the zeroth generation of the tree is the trachea, which has a typical diameter of about two centimeters. At each of approximately 23 bifurcations the diameter of the subsequent generation is reduced. Finally, the air passages are divided into even smaller tubes, connected with tiny air sacs called alveoli. In a human lung there are approximately 300 million alveolar sacs of about 0.3 mm in diameter each [3]. New aspects of therapy, diagnostic, analysis, and treatment require an exact knowledge of these media.

As a rule, flow modeling in a lung is carried out using computational fluid dynamics (CFD) methods on idealized airway trees. But at the moment it is difficult to resolve very small airways and alveoli with the use of conventional imaging and segmentation techniques. Thus, any physical description of the geometry at the fine scale can only be considered as a porous medium, while flow in larger airways can be simulated directly [4].

Modeling of the flow in the lung tissue as a porous structure is effective. It can provide the accurate results with the minimum computational and time costs. At the moment different kinds of models for porous media exist. Some of them are based on the Lagrangian description, and the others – on the Eulerian.

The current study (see [2]) proposes an approach, which combines material and spatial descriptions of the saturated porous continuum. This approach allows to avoid restraints of the Lagrangian and Eulerian descriptions used separately for a two-phase fluid-solid continuum. With the use of the hybrid material-spatial approach the balances of mass, momentum, and angular momentum have been formulated in the current configuration. In comparison with the other models the interaction peculiarities are considered attentively. Constitutive equations have been constructed for both elastic and inelastic components of stress tensor and interaction force. The constitutive equations for elastic components have been built on the basis of the energy balance equation; the constitutive equations for inelastic components have been proposed in accordance with the second law of thermodynamics. In the model air is regarded as an ideal gas. The soft tissue state is described by a thermoelastic model. We use the compressible Mooney-Rivlin model (see [1]) supplemented by thermoelastic terms to describe the lung tissue stress with the help of the elastic property parameters.

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MODELING MOUTION OF MELT PARTICLES UNDER THE GRAVITY

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In the Self-propagating high temperature synthesis reactions a special place are taken the prosses in which solid reactants are melted at the combustion wave. The initial components of mixture are often a metal oxide and metal restores. These reactions have the great technological interest for production of refractory materials, reduction of metals and a number of other products. As a result of these reactions appear a melt, which are separated at components by gravity. Accounting gravity in the melt in the combustion wave were considered in the papers [1, 2, 3]. In those papers were considered the process of the combustion wave moution in the medium with gravity under particles in the melt, wherein the system of equations has been recorded in quasi-stationary approximation.In the presented work, the process is modeled when a combustion wave were propagated and melt is separated under the influence of gravity. Thus, in this case it is necessary to use non quasi-stationary approximation.

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HEAT OSCILLATIONS IN NONLINEAR ONE-DIMENSION CRYSTAL

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There are a large number of models describing thermomechanical properties of ideal crystals [1, 2]. Not all of them allow to obtain the results which observed in experiments. It is known that propagation of heat does not obey the Fourier law in the simplest discrete systems [3-5]. The example of the discrete system is a model of a one-dimensional crystal. If at the initial instant the particles are ordered into the ideal crystal lattice and their velocities are specified randomly, then the dynamic transition of the kinetic energy into the potential energy of the bonds deformation is initiated in the crystal. An analytical solution for the linear one-dimensional crystal is derived in [4]. However, in the case of nonlinear interaction – analytical solution is not obtained.

A nonlinear one-dimensional (β-FPU [5-6]) crystal was considered. The dimensionless parameter α characterizing the relation between linear and nonlinear interactions was introduced. Two initials conditions were considered: random initial velocities and zero initial displacements, and a sinusoidal perturbation of a temperature field.

The dependence of kinetic energy from the nonlinearity parameter α was investigated for the first formulation of the problem. It is found that the decay rate of the kinetic energy oscillation increases with increasing the nonlinearity. The approximation function for the decay law of the kinetic energy is obtained for different values of the nonlinearity. It is established that the kinetic energy oscillation is compressed in time at small nonlinearity. An analytical expression for the temperature of β-FPU crystal was derived by using the Virial theorem. It is obtained that the temperature value from analytical expression and from the result of the numerical experiment are the same.

The dependence of the kinetic temperature from the nonlinearity parameter α was investigated for the second formulation of the problem. It is shown that the decay rate of the oscillations amplitude of the kinetic temperature also increases with increasing the nonlinearity. The previous used approximation was applied to finding the decay law of the oscillations amplitude. It also gives a good accordance for small nonlinearity of the interaction.

A solution of the equation of motion of β-FPU crystal was derived for the case of small nonlinearity. We suppose that the analytical solution for β-FPU crystal changes little with introducing a small nonlinearity in the equation of motion. Offered numerical and analytical solutions give good accordance at small nonlinearity. The proposed solution can be used for solving problems, previously described, for case of small nonlinearity.

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AUTHORS INDEX

Antonio Castellanos Mata

Antonio Castellanos Mata was born on March 7, 1947, near León, Spain. He was the third and youngest child of Manuel Castellanos Berjón (1910–1993), a school teacher, and Fidela Mata Sarmiento (1915–2013). A love for reading and admiration for science were always part of family life. In his childhood and adolescence Antonio studied in a seminary but was expelled from there. He decided to become a scientist and entered the University of Valladolid, where in 1972 he defended his PhD thesis. He worked at many universities: Universidad de Valladolid, Universidad del País Vasco, Universidad Autonoma de Madrid; since 1983, he was a full professor at the University of Seville. Antonio made long-term scientific visits to the USA, France, Nicaragua, and Russia, collaborated with researchers from the UK, Netherlands, China, Algeria. He worked in various fields of science: electrohydrodynamics, gas discharges at atmospheric pressure, cohesive granular materials.

Antonio founded a scientific school at the University of Seville. His research group of Electrohydrodynamics and Cohesive Granular Media included more than 20 researchers. Many of his former students are now full professors and continue the scientific tradition. He always treated his students as equals, with deep respect, discussed scientific problems with them, gave them freedom, and cared about their progress in science more than about anything else. He lectured physics at various universities during all his career. For the last 33 years, he taught electrodynamics and electromagnetism at the Faculty of Physics of the University of Seville, a task which he performed with enthusiasm and passion. Antonio directed research projects for more than 30 years, and this made it possible for him to organize two laboratories at the University. He always had bright ideas, scientific intuition, and creative mind. Dedicating a lot of efforts to pure science, Antonio was also interested in practical problems and collaborated with industry (Xerox Corporation, Novartis, Dow Corning, International Fine Particles Research Institute). Antonio signed only those papers to which he indeed contributed, but nevertheless authored more than 350 papers, with more than 7800 citations, though he never gave importance to the indices of scientific impact. He believed that only important contributions matter.

Antonio belonged to a generation that played an important role in the revival of physics in Spain. In 2013, he was awarded the Prize FAMA for the research career by the University of Seville.
Among his scientific results, we can mention the following:
- Galilean limits of electromagnetism.
- Temperature equation and entropy production in electrohydrodynamics.
- Seminal works on numerical simulation of electrohydrodynamic flows.
- Physical mechanism of electrothermohydrodynamic instabilities.
- Energy cascade in electrohydrodynamic turbulence.
- Stabilization of dielectric liquid bridges by ac electric fields.
- Absence of collisional regimes in fine powders for negligible intersticial gas interaction.
- Automated apparatus to characterize fine powders (Sevilla Powder Tester).
- Apparatus to characterise the cohesive properties of grains (Triana Powder Tester).
- Model of elastoplastic contact between two powder particles.
- Microstructure characterization of fluidized bed of fine particles: aggregation, solidlike-fluidlike transition, fluctuations, influence of electromagnetic fields.
- Experimental setup for measuring acoustic properties of fine (including magnetic) powders.

In his last years, Antonio worked on thermodynamics in relativity (but he did not have time to complete this work) and on triboelectricity in fine powders (not published due to contract restrictions). His work on wave propagation in powders at low pressure, as well as other research lines initiated by him, will be continued by his colleagues. As a researcher, Antonio combined a strong theoretical mind, experimental intuition, profound understanding of physics of phenomena, and passionate love for science.

In 1997 Antonio Castellanos visited St. Petersburg and IPME RAS for the first time. In 1998 he attended the conference “Advanced Problems in Mechanics” (at the time “Nonlinear Oscillations in Mechanical Systems”). Then he became a permanent member of scientific committee of APM and came to the conference many times. Actually, he was its first regular foreign participant. We had the pleasure to discuss with him scientific matters at a profound level and just enjoy his company, his nice sense of humour and open, sincere nature. Antonio helped to convert APM to a true international conference, he invited many foreign participants. Several times Antonio organized a minisymposium on powders and grains in the frame of APM, which attracted a lot of prominent scientists and young researchers. Antonio established long-lasting collaboration with scientists from Russia, many of them (P.A. Zhilin, N.A. Morozov, I.G. Goryacheva, A.M. Krivtsov, S.N. Gavrilov, E.F. Grekova) were invited to visit the University of Seville. They enjoyed his brilliant hospitality and the outstanding research atmosphere of his scientific school.

In 2014 Antonio was incidentally diagnosed with kidney cancer at an early stage, but of a rare and aggresive type. In 2015, it gave metastases, despite their very low probability, and after a year of fighting the disease, Antonio died on January 27, 2016. To his very last days, Antonio worked, gave classes, continued his research, and directed scientific projects. He kept his enchanting smile, his interest and love for science, generosity, care for people around him, fortitude and courage, for which he was admired and loved by his colleagues, friends, and family. We will deeply miss him.

Chairmen of APM 2016
Professor, Corresponding member of the Russian Academy of Sciences D.A. Indeitsev
Professor A.M. Krivtsov

Minisymposium in memoriam of Antonio Castellanos Mata will be held in the frame of the Advanced Problems in Mechanics 2017 Summer School-Conference
(June 25 - July 01, 2017, St. Petersburg, Russia).

http://www.pdmi.ras.ru/~elgreco/Antonio/ms/ms-Antonio-Castellanos.html

Contact person: Elena Grekova, elgreco@pdmi.ras.ru. If you are interested in the event please send her an e-mail.

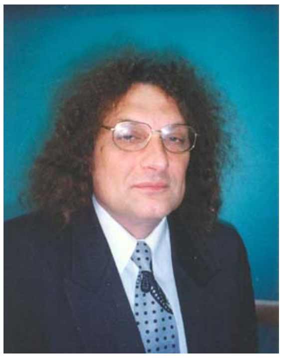
Topics: electrohydrodynamics (Antonio Ramos, ramos@us.es), gas discharges (Francisco Pontiga, pontiga@us.es), granular materials (Elena Grekova, elgreco@pdmi.ras.ru)

Granular session will be held at the beginning of the conference to avoid overlapping with Powders and Grains 2017.

We will be grateful if you distribute this information among your colleagues.

Co-Chairmen and Plenary Speakers

Dmitry A. Indeitsev, Professor, Corresponding member of the Russian Academy of Sciences, Institute of Problems of Mechanical Engineering of Russian Academy of Sciences, Russia (Co-Chairman)



Dmitry Indeitsev graduated Polytechnical Institute, Leningrad in 1972. In 1995 became Doctor of Science (Physics & Mathematics). Since 1996 he is the Head of State Attestation Committee at St.Petersburg State Technical University, since 2006 – Corresponding Member of RAS. Professor Indeitsev is head of the Mechanics and Control Processes department at Peter the Great St. Petersburg Polytechnical University; Professor of the Elasticity Theory Department at Mathematical Mechanical Faculty of St.Petersburg State University.

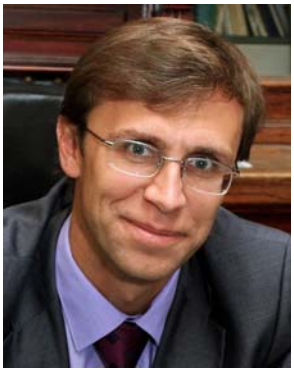
St. Petersburg Government awarded Professor Indeitsev for the Higher and Secondary Professional Education.

He is the member of GAMM, EUROMECH, member of the Russian National Council of Theoretical and Applied Mechanics.

Professor Indeitsev has a numerous number of publications, among them – publications in Springer, Journal of Wave motion, Russian Journal of Physical Chemistry, etc.

His current research interests are mechanics of solids, wave dynamics, hydroelasticity, theory of non-linear wave processes in elastic and elastic-acoustic media with inclusions.

Anton Krivtsov, Professor,
Peter the Great St.Petersburg Polytechnic University,
Institute of Problems of Mechanical Engineering of Russian Academy of Sciences, Russia (Co-Chairman)



Professor Anton Krivtsov is a Head of Dep. of Theoretical Mechanics in Peter the Great St.Petersburg Polytechnic University (SpbPU), Scientific supervisor of Center for scientific and technical creativity of the youth (CSTC) and Fab Lab Polytech, Head of laboratory "Applied fracture micromechanics", Head of laboratory "Discrete models in mechanics" of Institute of Problems of Mechanical Engineering, Russian Academy of Sciences. Received M. Eng., from Leningrad Polytechnical Institute (present SpbPU) in 1990, Ph. D. in Physics and Mathematics from St. Petersburg State Polytechnical University in 1995, Dr. Sci. in Physics and Mathematics from St. Petersburg State Polytechnical University in 2002.

He is a member of:

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- the Academic council of the Institute for Problems in Mechanical Engineering, Russian Academy of Sciences;
- committees for PhD and Doctoral degrees judgment;
- the Scientific Committee of International conference "Recent Advances in Numerical Simulation of Hydraulic Fracture" (HYDROFRAC2014);
- the Scientific Committee of International conference "Nonlinear Dynamics in Engineering: Modelling, Analysis and Applications" (UK, 2013);
- the Steering Committee of Sixth EUROMECH Nonlinear Dynamics Conference (ENOC 2008); editorial board of Journal of Mechanical Engineering Science.

Also Prof. Krivtsov is an external expert for Russian Foundation of Basic Research; scientific secretary of the Program for basic research of the Presidium of the Russian Academy of Sciences "Fundamental problems of mechanics of interactions in technical and natural systems, materials and mediums"; Co-Chairmen of annual international conference "Advanced problems in mechanics"; Chairmen of the Local Organizing Committee and member of the Scientific Committee of EUROMECH Colloquium 468 "Multi-scale Modelling in the Mechanics of Solids" (Russia, 2005)

His current research include particle and molecular dynamics, mechanics of mediums with microstructure, Nanomechanics, Geomechanics, computer methods in mechanics, continuum mechanics, multibody dynamics, nonlinear oscillations, dynamics of centrifuges, percussive drilling, astrophysics.

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Aristotle University, Greece

Currently directing the Michigan Technological University Research Center for the Mechanics of Materials and Instabilities. Also directing the Laboratory of Mechanics of Aristotle University of Thessaloniki and coordinating an EU-TMR Network on "Spatio-Temporal Instabilities in Deformation and Fracture" involving seven European laboratories through Aristotle University of Thessaloniki. He received Diploma/BS-MS from National Technical University of Athens, Mining and Metallurgy in1973, Ph.D from University of Minnesota, Chemical Engineering and Materials Science-Mechanics in 1975.

Prof. Aifantis is an awardee of Fellowship Award for 1 mo Visit to USSR/US Academy of Sciences, MTU Research Award, Michigan Tech Univ, Houghton/MI, Fellowship Award for 1 mo Visit to Japan/Japanese Government, ASME's Koiter Award, Selected for ASM's Author Award, KACST Award, Distinguished Foreign Scientist Fellowship Award, Fray International Sustainability Award, had been Selected for ASM's Author Award.

He has published more than 300 papers in the areas of mechanics and materials. Several of these publications helped to identify and establish research areas such as double porosity/diffusivity theory, dislocation patterning, strain gradient theory, material instabilities, and nanomechanics. He has edited five books, organized numerous international symposia and conferences, and been invited to present his research on more than 200 occasions. He is co-editor of the Journal of Mechanical Behavior of Materials, serves on the Advisory Board of the International Journal for Numerical and Analytical Methods in Geomechanics, and has served on the Advisory Board of the Journal of Mechanics of Cohesive-Frictional Materials and Acta Mechanica. His research and academic activities have been supported by NSF/ARMY/AFOSR/ of US, as well as by the Commission of European Communities of EU.

Presently he focuses on Porosity/Diffusivity theory, Dislocation patterning, Strain gradient theory, Material instabilities, Nanomechanics.

Vladimir Babeshko, Academician,
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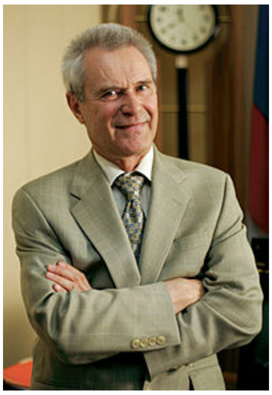

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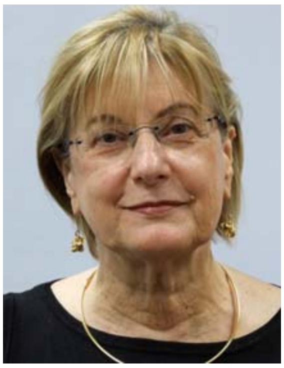
He is the Honoured Scientist of the Russian Federation, Kuban, and the Adygei Republic; the Honorary Senator of the Berlin University of Applied Sciences; a recipient of The State Prize in the field of science and technology (2001); The Sign of Honor order; The People's Friendship order; The Vavilov Medal; The medal of Kuban Hero of Labor; the Honorary Senator of the Berlin University of Applied Sciences.

Dr. Babeshko is a member of VAK, ASA.

His research focuses on Mechanics and applied mathematics, seismology, geophysics, environmental sciences.

Academician Babeshko is an initiator of several lines of research, the author of five monographs, and over 300 articles and inventions, including pioneering research publications.

Professor Leslie Banks-Sills, Professor Emerita, Tel Aviv University, Israel

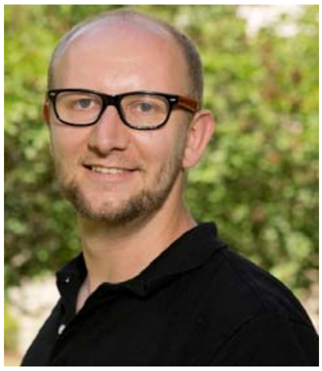


Leslie Banks-Sills is Professor Emerita in Tel Aviv University, Israel. She received Bachelor of Arts Degree in City University of New York, Queens College(1965), Master of Sciences in University of Michigan (1973), Doctor of Philosophy in Engineering (1977) in Harvard University Graduate School of Arts and Sciences. Professor Bernard Budiansky advised PhD thesis “Scattering of shear waves by surface irregularities”. Leslie Banks-Sills worked in many universities, among them Harvard University (Cambridge, Massachusetts), Tel Aviv University (Ramat Aviv, Israel), Research Center in Karlsruhe (Germany), Cornell University (Ithaca, New York), Lund University (Lund, Sweden), Brescia University (Brescia, Italy), and in Kyoto University (Kyoto, Japan) as a fellow of the Japan Society for the Promotion of Science. Leslie Banks-Sills is a member of the American Society of Mechanical Engineers, American Academy of Mechanics, American Society of Testing and Materials, the Society of Experimental Mechanics, the New York Academy of Sciences; she is a President of European Structural Integrity Society, and a Vice-President of European Society for Experimental Mechanics.

Professor Banks-Sills is an awardee of Teaching Excellence Award in Mechanical Engineering, Tel Aviv University (1995-1996), Teaching Excellence Award, Faculty of Engineering, Tel Aviv University (1998-1999), Hanin Prize in Aeronautical Engineering (2006), Teaching Commendation Award in Mechanical Engineering, Tel Aviv University (2010-2011). She is a Honorary Fellow of the International Congress of Fracture (2005), Honorary Membership to ESIS (European Society of Structural Integrity), Incumbent, Lise Meitner Chair at Lund University, Sweden (July, 2006 - December 2006), Incumbent, Diane and Arthur Belfer Chair of Mechanics and Biomechanics at Tel Aviv University (from November, 2006 – October, 2014), Fellow, American Academy of Mechanics (2008), Member of European Academy of Sciences and Arts (2012), Honorary Doctorate, Lund University (2014) and Honorary Member, Italian Group of Fracture (2015). She is author of more than 100 papers in respectable scientific journals.

Her current research topics are delamination of laminate composites, failure criteria for interface cracks and delaminations, accurate methods for obtaining stress intensity factors for interface cracks, effect of carbon nanotubes on the behavior of polymers.

Dr. Lars Beex, Research Fellow,
University of Luxembourg, Luxembourg



Dr. Lars Beex finished his BSc, MSc (2008) cum laude and PhD (2012, won Biezeno Award 2013, for the best PhD thesis in the field of Solid Mechanics in The Netherlands in 2012, awarded by the Royal Dutch Institute of Engineers KIVI NIRIA, included in the top 10 of best Engineering PhD theses in The Netherlands in 2012, according to Dutch Technology Foundation STW) studies at Eindhoven University of Technology, Netherlands, in Mechanics of Materials under supervision of Dr. Ron Peerlings and Prof. Marc Geers. Subsequently, he was a Lecturer in the Instute of Mechanics and Advanced Materials of Cardiff University (2012-2014), where he collaborated with Dr. Pierre Kerfriden and Prof. Stephane Bordas. Afterwards, he followed Prof. Bordas to the University of Luxembourg where Dr. Beex currently works as a Research Fellow.

Dr. Beex published twice with his MSc project, focusing on a continuous-discontinuous mechanical model for laminated paperboard creasing and folding, which was experimentally calibrated and validated (IJSS 46, 2009, p4192-4207 and Phil. Trans. R. Soc. A 370, 2012, p1912-1924).

His PhD studies focused on discrete models for fibrous materials and the quasicontinuum (QC) method as the multiscale approach to upscale the discrete models. As the QC method was previously only used for conservative atomistics, he formulated a new virtual-power-based variant that allows the method to be used for non-conservative discrete models (as required for discrete models for fibrous materials). The first virtual-power-based QC approach was published in JMPS 64, 2014, p154-169. Extensions of the framework aim at discrete models with fibre-to-fibre bond failure (CMAME 269, 2014, p108-122), elastoplastic lattices for electronic textile (Mech of Mat 80, 2015, p52-66) and higher-order QC approaches (CMAME 279, 2014, p348-378 and GAMM Mitt. 38, 2015, p344-368). Dr. Beex also contributed to reduced integration in the QC method for discrete models of fibrous materials (IJNME 87, 2011, p701-718) and for atomistics (JMPS 70, 2014, p242-261). Other contributions focused on discrete models for paper materials (IJSS 50, 2013, p1354-1363), textiles (Comp Part A 48, 2013, p82-92 and Comp Struct 116, 2014, p1-17) and metal foams (Mater Design 87, 2015, p36-41).

Dr. Beex's research continues to aim on discrete models. Fibrous materials are an important application area for these models, but metal foams and printed metal structures are currently also studied. QC methodologies remain Dr. Beex's most important multiscale approaches to computationally reduce the developed discrete models. He is for instance involved in a Czech research project of Dr. Ondrej Rokos and Dr. Jan Zeman to extend the virtual-power-based QC method one step further to variational QC frameworks. His two new research topics are stochastical approaches in the field of computational mechanics (including Bayes Inference) and other reduced order modeling techniques (e.g. those using proper-orthogonal-decomposition). Manuscripts in these two fields are currently being prepared for publications.

Tadeusz Burczynski, Professor and Director,
Institute of Fundamental Technological Research of Polish Academy of Sciences, Poland

Tadeusz Burczynski is a Professor and Director of IFTR PAS, Corresponding Member of PAS, President of Committee on Mechanics of PAS.

Prof. Burczynski received his Ph. D in 1980 from Silesian University of Technology, Dr hab. in 1990 from Silesian University of Technology, professor's degree in 1993, became a Corresponding Member of Polish Academy of Sciences in 2007.

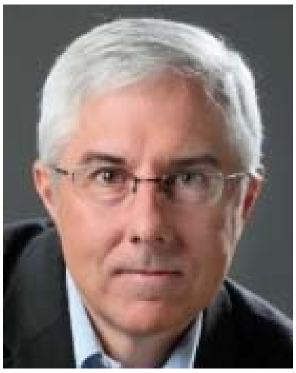
He isa member of General Council of International Association for Computational Mechanics (IACM), Member of Managing Board of European Community of Computer Methods in Applied Science (ECCOMAS).

T. Burczynski is a Co-Editor- in-Chief of Computer Assisted Methods in Engineering and Sciences, Member of Editorial Board of Computational Methods in Science and Technology, Computer Methods in Material Science, Advanced Modeling and Simulation in Engineering Sciences. Prof Burczynski is a fellow of IACM and a recipient of Award of O.C. Zienkiewicz Medal, Awards of Ministry of Science and Higher Education and Polish Academy of Sciences.

He has published over 550 scientific works, including 16 books, 12 chapters, editor of 11 special issues of scientific journals, many invited plenary and key-note lectures.

His research focuses on Computational Sciences (ComputationalMechanics, Computational Materials Science, Computational Intelligence), Multiscale Modelling and Nanomechanics, Soft and Granular Computing, Optimization and Inverse Problems.

William Curtin, Professor,
Ecole Polytechnique Federale de Lausanne, Switzerland



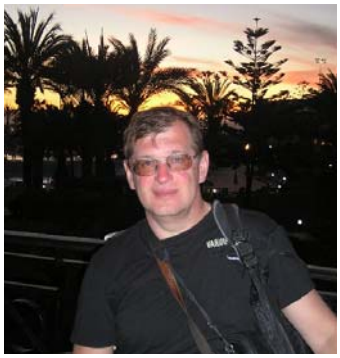
William Curtin is a professor in Ecole Polytechnique Federale de Lausanne, received a combined BS/MS in Physics from Brown University in 1981, a PhD in Theoretical Physics from Cornell University in the USA, in 1986.

He is an Editor-in-Chief of Modeling and Simulation in Materials Science and Engineering, an awardee of Guggenheim Fellowship, 2005, Elisha Benjamin Andrews Professorship (Brown University, 2005-2012).

Prof. Curtin has over 200 publications in major journals in the fields of Applied Mechanics, Materials Science, and Physics, encompassing work on statistical mechanics of freezing, hydrogen storage, fiber composite mechanics and failure, multiscale modeling methods, dislocation plasticity, and computational metallurgy, and other areas.

His current research include multiscale mechanics and applications for predictive computational metallurgy.

Victor Eremeev, Professor, Rzeszów University of Technology, Poland, South Federal University and South Sci Center of RASci, Russia

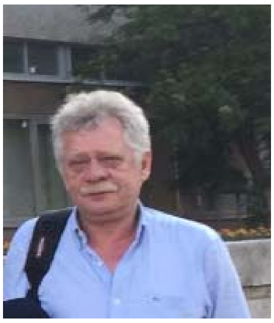


Victor Eremeev is a leading researcher in South Federal University and South Sci Center of RASci, Rostov on Don, Russia, and Professor in Rzeszów University of Technology, Rzeszów, Poland. He received in Diploma in Mechanics in 1985 in Department of Mechanics and Mathematics, Rostov State University, Russia, PhD at Rostov State University in 1990 (Thesis title: The stability of two-phase nonlinear thermo-elastic bodies), Diploma of Associate Professor (Docent) in 1990 in Department of Informatics and Computer Science, Rostov State University, Russia. He was awarded Dr. hab. in 2004 at Institute of Problems of Mechanical Engineering of RASci, Saint-Petersburg (Dissertation title: Mechanics of two-phase bodies with microstructure under finite deformations).

Professor Eremeev is a member of AMS, MEMOCS (Member of International Research Center on Mathematics and Mechanics of Complex Systems). He is a member of many editorial boards, among them: ZAMM, World Journal of Mechanics, Notices of South Sci Center of RASci. He is co-editor and member of Scientific Committee of Gabrio Piola Edition. The complete works of Gabrio Piola: Volume I. Commented English Translation. Co-editor (guest) of Continuum Mechanics and Thermodynamics, Springer 2014-2015; Mathematics and Mechanics of Solids (MMS), SAGE Journals 2014; International Journal of Engineering Science, Elsevier 2014; ZAMM, Wiley 2009, 2010, 2011, 2014; Technische Mechanik, 2009. Reviewer for: International Journal of Non-Linear Mechanics, Archive of Mechanics, Archive of Applied Mechanics, Journal of Engineering Mechanics, Soft Materials, Nonlinear Dynamics, Continuum Mechanics and Thermodynamics, Acta Mechanica, European Journal of Mechanics/A, Solids, International Journal of Engineering Science, International Journal of Solids and Structures, Mathematics and Mechanics of Solids, Research in Nondestructive Evaluation, Mechanical Systems and Signal Processing, Journal of Sound and Vibration, Physics of Fluids, Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM), Meccanica, Technische Mechanik, Mechanics of Solids, Journal of Applied Mathematics and Mechanics (PMM), etc. Professor Eremeev participated in grants of International Science Foundations (ISF), Russian Foundation of Basic Research (RFBR), CRDF, Jozef Mianowski fund, DFG, DAAD, Competition Center of Saint-Petersburg State University and Science program "Universities of Russia", 7th Framework Programme of European Union, Italian MIUR "PRIN 2012-2015 unit MeMoCS", Progetto ATENEO LA SAPIENZA 2013, Visiting Professorship award 2015 La Sapienza. Professor Eremeev has 8 books published in English, Russian and Spanish by Springer, World Scientific, Nauka (Moscow), Universidad Nacional de Colombia, South Scientific Center of RASci, and about 100 papers indexed by Scopus/Web of Science.

His current interests are general theory of elastic and inelastic shells and its applications. Theory of plates and shells made of functionally graded material, foams, etc; theory of generalized continuum media with microstructures such as micropolar fluids, Cosserat media, porous media, foams, nanostructures, strain gradient elasticity, nonlinear elasticity, nonlinear mechanics of elastic and inelastic media with phase transformations, nanomechanics and micromechanics, surface elasticity.

Victor Erokhin, Professor,
Institute of Materials for Electronics and Magnetism,
Italian National Council of Research, Italy



Victor Erokhin is a visiting professor in University of Parma, Senior Scientist in Institute of Materials for Electronics and Magnetism, Italian National Council of Research.

He received his Ph.D. in physical and mathematical sciences in 1990 from Moscow Institute of Crystallography of Academy of Sciences of USSR. V. Erokhin is a member of American Nano Society, Swiss NanoTera Program, ESRF Evaluation Panel and head of Open-Lab in Kazan Federal University.

He is Editor-in- Chief of BioNanoScience and editorial board member of Open Crystallography Journal. Prof. Erokhin is an author or editor of 162 journal articles, 1 book, 14 book chapters and 7 patents. Victor Erokhin's main application areas of research currently are:

- Neuromorphic systems,
- organic memristive devices,
- smart containers for targeted drug deliveri and triggered release;
- unconventional computing.

Alexander Freidin, Professor,
Institute of Problems of Mechanical Engineering of Russian Academy of Sciences, Russia

Professor Freidin graduated Mechanical Engineering Leningrad Polytechnic Institute (now Peter the Great St. Petersburg Polytechnic University), Department of Physics and Mechanics, Chair of Mechanics and Control - "Lurie's Chair" in 1976. His diploma thesis was "Crack Growth in a Model of Diffusive-Chemical Kinetics". In 1987 he received Ph.D. (Dissertation: Crazes and Shear Deformation of Glassy Polymers and ABS-composites) in Physics and Mathematics Moscow Physical and Technical Institute, Moscow.

In1997 became Doctor of Sciences (Dissertation: Phase Transition Zones and Phase Equilibrium in Elastic Solids under Deformation Processes) in Physics and Mathematics Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg.

Professor Freidin is Head of the Department of Mathematical Methods in Mechanics of Materials and Structures, Institute for Problems in Mechanical Engineering of Russian Academy of Sciences (IPME RAS), St. Petersburg, Russia; Head of the Departments of Continuum Mechanics (affiliated by IPME RAS), Professor of the Department of Mechanics and Control, Peter the Great St. Petersburg Polytechnic University; Professor of the Department of Mathematics and Mechanics, St. Petersburg State University.

Professor Freidin is Member of Russian National Committee on Theoretical and Applied Mechanics. He is a member of editorial boards of journals "Archive of Applied Mechanics", "Continuum Mechanics and Thermodynamics", "Physics and Mechanics of Materials". Professor Freidin is author of one monography and more than 100 papers.

His current research interests are stress-induced phase transformations, stress-assist chemical reactions, nonlinear elasticity, composite materials.

Andrey Gorodetskiy, Professor,
Institute of Problems of Mechanical Engineering of Russian Academy of Sciences, Russia

Professor Andrey Gorodetskiy is a head of laboratory of IPME RAS, doctor of Sciences (Engineering Sciences), honoured worker of science of the Russian Federation, academician of the Russian Academy of Natural Sciences.

Received candidate of Engineering Sciences degree from All-Russian Scientific Research Institute elmash in 1971, doctor of Engineering Sciences degree from the Saint Petersburg National Research University of Information Technologies, Mechanics and Optics in 1993

He is a review editor in the Section Biomedical Roboties of Frontiers in Robotics and AI (Switzerland).

Prof. Gorodetskiy has a number of publications on the following topics: Smart Electromechanical Systems (SEMS) are used in Cyber Physical Systems (CPS); methods of designing and modeling of SEMS based on the principles of adaptability, intelligence, biomorphism of parallel kinematics and parallelism in information processing and control computation.

Presently he focuses on: computer sciences; SEMS; the Central Nervous System of SEMS.

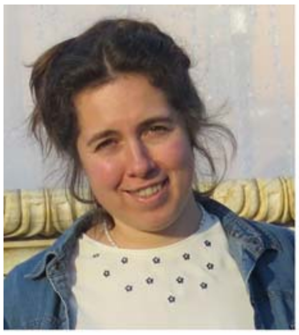
Irina Goryacheva, Academician,
Ishlinsky Institute for Problems in Mechanics RAS, Russia

Irina Goryacheva graduated Faculty of Mathematics and Mechanics of Lomonosov Moscow State University in 1970 with distinction, in 1974 defended her PhD ("The study of rolling resistance, taking into account slippage and viscoelasticity") on the same faculty. In 1988 г. she defended her doctoral thesis "Contact problems in tribology" (Ishlinsky Institute for Problems in Mechanics RAS, Moscow). Since 1996 Irina Goryacheva works in IPMe RAS as a head of Laboratory of Tribology. She is the leading researcher in the Institute of Mechanics in Lomonosov Moscow State University and a professor of department of plasticity at the same university, and also a professor of the department of control and applied mechanics in MIPT, Moscow. Since 1997 – member-correspondent of RAS, since 2003 – academician in Department of Energy, Engineering, Mechanics and Control Processes (Mechanics).

Academician Irina Goryacheva is author of more than 150 publications, including 3 monography works (1988, 1998, 2001), and a number of inventions. Irina Goryacheva was awarded the title of science and technology Lenin Komsomol Prize winner (1979) for a series of articles "Application of the theory of elasticity to the friction on wear and contact stiffness". For the development and implementation of large-scale engineering environmentally friendly components with high sliding friction tribological properties in the group of authors she was awarded the Prize of the Russian Federation in the field of science and technology (2006). She was awarded the National Prize of public recognition of the achievements of Russian women "Olympia" in the nomination "Scientific activity" for outstanding performance in the development of fundamental science (2005). I.G.Goryacheva is the Chairman of the Interdepartmental Scientific Council on Tribology Academy of Sciences, chairman of the section "Problems of vehicles," the Council of the Transport Academy of Sciences, member of the Presidium of the Russian national Committee, on Theoretical and Applied Mechanics, member of the Russian National Tribology Committee. She is Chairman of the Expert Council in the field of mechanics, engineering and management processes for awarding gold medals of the RAS to young scientists and students, a member of the youth Commission of the RAS, chairman of the expert RFBR Board, a member of the expert council of VAK, a member of the editorial board of the journal "Applied mathematics and mechanics" and the deputy of the international magazine chief editor of "Friction and wear ", published by the Russian Academy of Sciences and the National Academy of Sciences of Belarus. Member of the qualifying dissertation councils at IPMech Academy of Sciences and the Russian Institute of railway transport. Irina Goryacheva is also a member of EUROMECH, IUTAM, member of editorial boards "WEAR" and "Tribology Engineering".

Research interests of Irina Goryacheva concentrated mainly in the field of contact mechanics and tribology. Her most significant scientific results are the development of the theoretical foundations of the mechanics of discrete contact and contact methods of calculation of characteristics homogeneous and heterogeneous rough bodies. She has made a significant contribution to the development of the theory of interaction of elastic and viscoelastic bodies with adhesive forces of different nature; in the construction of analytical methods for the solution of a number of mixed problems of theory of elasticity and viscoelasticity in the development of a new direction in the theory of contact problems - contact problems in view of the forming surfaces when worn, the solution of which find application when the wear calculation of wheels and rails, pavements, rolling and sliding bearings and etc.

Elena Grekova, Dr., Senior Researcher, Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, Russia



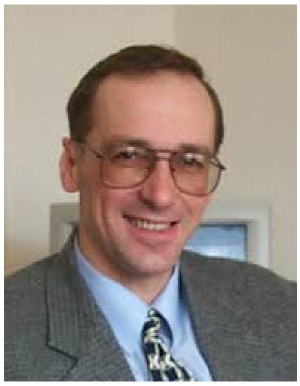
Dr. Elena Grekova graduated St. Petersburg Polytechnic University in 1996 and finished her PhD in physical and mathematical sciences at Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, in 1999. Science advisor of her master and PhD thesis ("Nonlinear dynamics of Cosserat medium and elastic ferromagnetic insulators") was P.A. Zhilin. (Degree recognized by the University of Seville in 2012). Since her graduation, she has been working in Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg. Also Dr. Grekova held some scientific visits to the Technical University of Delft (the Netherlands), Laboratoire de Modélisation en Mécanique, Université Pierre et Marie Curie (Paris, France), Dpto. Electronica y Electromagnetismo of Universidad de Sevilla (Spain).

Projects of Dr. Elena Grekova were supported by Spanish, Andalusian, St. Petersburg government; Shell E.&P., Russian Foundation for Basic Research, Russian Academy of Sciences.

Dr. Grekova is an awardee of a prize from Russian government "For active participation in realization of scientific programmes and creative approach in solution of scientific problems" in 1999 (among ten scientists of different specialization not older than 35 years in St. Petersburg). She is an author of more than 15 publications in scientific journals. Dr. Grekova is also member of the research group "Electrohydrodynamics and cohesive granular media" of the University of Seville; she was a co-organizer of the Day on Cosserat models in granular materials in Institute Henri Poincaré in 2005 and a member of Scientific and Organising Committees of Summer School - Conference "Advanced Problems in Mechanics" in different years, member of Technical Committee of "Modern Practice in Stress and Vibration Analysis" conference in Glasgow in 2003.

Her current research interests are rational mechanics, polar and multipolar continua, micromorphic media, magnetic materials, geophysics, powders and grains, nonlinear elasticity, constitutive theory, wave propagation, dynamics of rigid bodies. She is also interested in configurational mechanics, vibrational mechanics, synchronization.

Mikhail Guzev, Professor,
Institute for Applied Mathematics FEBRAS, Russia



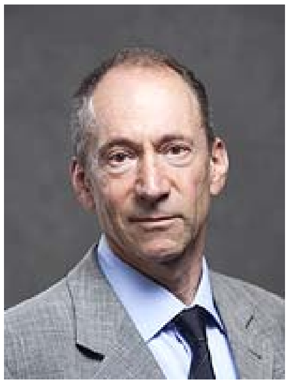
Mikhail Guzev is a Mathematician, Mechanician and a Director of Institute of Applied Mathematics of Far-Eastern Branch of RAS, Doctor of physical and mathematical sciences.

He received Ph. D from St. Petersburg State university in 1987.

In 2003 Guzev was elected a Corresponding member of the Russian Academy of Sciences.

Prof. Guzev has published a couple of books and papers in areas of Mathematical modelling of the elasto-plastic defect materials and Geomechanics.

Mark L. Kachanov, Professor,
Tufts University, USA



Mark Kachanov graduated with Ph.D. in Solid and Structural Mechanics in Brown University in 1981.

He is Professor of Mechanical Engineering in Tufts University, Visiting Professor in Ecole Normale Superieure (France); von Humboldt Research Professor in Darmstadt Polytechnic Institute and U. of Munchen (Germany); Visiting Scientist in SHELL Research & Development (Netherlands); Visiting Professor in Technion – Israel Institute of Technology; Visiting Scientist in Sandia National Laboratory (USA); Visiting Scientist in National Institute of Standards and Technology (USA); Visiting Professor (sponsored by MTS Corporation) in University of Minnesota.

Professor Kachcnov was awarded Distinguished Fulbright Chair, von Humboldt Research Award for Senior Scientists (Germany).

He is editor-in-Chief of International Journal of Engineering Science. Professor Kachanov is an author of more than 140 publications, among them 2 books.

His current research interests are Mechanics of heterogeneous materials; Multiple cracking and damage; Rough contacts: Mechanics and conductance; Geophysics and rock mechanics: Applications to oil exploration; Industrial Applications: Thermal barrier coatings, Porous ceramics (fracture under compression, thermal loading), Oil exploration (multiple fractures, anisotropy, rough surfaces, wavespeeds), Nano-indentation of piezoelectrics.

Takayuki Kitamura, Professor,
Kyoto University, Japan

Takayuki Kitamura is a Professor of Kyoto University, Japan, and a Member of Science Council, Japan. He received B. E. degree in mechanical engineering from Kyoto University in 1977, and M. E. degree in mechanical engineering from Kyoto University in 1979, and worked as a researcher for 5 years at the Central Research Institute of Electric Power Industry, Japan. After he received Ph.D. degree from Kyoto University in 1986, he was invited to the National Administration of Space and Aeronautics (NASA), USA, as a research fellow during 1987-1988.

He was promoted to a full-professor in Kyoto University on 1998 and is the member of Science Council, Japan, from 2008 till now. He was a vice president of Kyoto University in 2007 –2008 and an associate member of Science Council, Japan, in 2006- 2008.

He has authored or co-authored more than 250 original research papers, and recently published a book, "Fracture Nanomechanics". He received the Society Award 5 time from the Japan Society of Mechanical Engineers (JSME) and 4 times from the Society of Materials Science Japan (JSMS). He has presented more than 30 invited talks in international conferences since 2004.

He was an executive board director in the JSME in 2007, 2008, 2011 and 2012, and in the JSMS in 1994, 1995, 1999, 2000, 2009, 2010 and 2013. He was elected to be a fellow of the JSME in 2003.

His research interest includes Experimental investigation on fracture mechanics of nano-materials, Multi-physics properties of low-dimensional nano-materials on the basis of ab initio simulations, In situ TEM/SEM observation on mechanism of fatigue and fracture of nano-components, Analysis on intrinsic localized mode in atomic components, and High temperature strength of heat-resisting materials.

Vladimir Levin, Academician,
Lomonosov Moscow State University, Russia

Vladimir Levin is head of department of Computational Mechanics at the Faculty of Mechanics and Mathematics in Lomonosov Moscow State University, Russia. Head of research laboratory in The Institute of Mechanics, Lomonosov Moscow State University, Russia, Head of research laboratory of Institute of Automation and Control Processes Far Eastern Branch of RAS. He received Ph.D from Lomonosov Moscow State University in 1965, Doctor of Physical and Mathematical Science degree from Moscow University Institute of Mechanics of Lomonosov Moscow State University in 1976.

Dr. Levin is the member of the bureau of the department of power and mechanic engineering, fundamental mechanics, control processes of RAS; Presidium of Far Eastern Branch of RAS; bureau of Explosion and Combustion Research Council RAS; Russian National Committee on Theoretical and Applied Mechanics; European Hypersonic Association; Chairman of the Academic Council.

He is a recipient of The medal of the order "For Merits before the Fatherland" of the II degree (1999); The State Prize in the field of science and technology (2002); The Honor order (2011); The Chaplygin Prize (1976); The Zhukovsky Prize with silver medal (1984); The Lomonosov Prize, I degree (1991); The Keldysh Medal (2009); The Nyuma Manson Medal by the Institute for the Dynamics of Explosions and Reactive Systems (2013); The Cherny Prize (2014). Vladimir Levin is the honoured Professor of Lomonosov Moscow State University since 2015 .

V. Levin's list of publications counts over 300 scientific papers and 16 inventions and patents.

His current research include: Gas dynamics of explosion and reacting systems, initiation and propagation of blast and detonation waves in combustible gas mixtures, supersonic aerodynamics, plasma aerodynamics and problems of wave drag reduction, mechanics of natural processes.

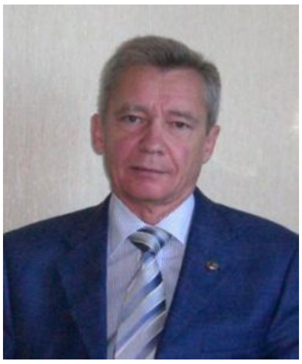
Aleksandr Linkov, Professor,
Institute for Problems of Mechanical Engineering, Russia

Aleksandr Linkov, Chief Scientist (Institute for Problems of Mechanical Engineering, Russian Academy of Sciences), has over 50 years of experience in rock, fracture and computational mechanics. Linkov was educated at the Leningrad State Mechanical University and got the first and second Doctor Degrees from the Leningrad State University in 1969 and 1977. He suggested and implemented new integral equations for blocky systems with cracks, inclusions and cavities; developed the theories of protective seams, rock and outbursts in mines, instability in the form of a dynamic event; fracture acceleration and amplification under softening; complex variable hypersingular integrals and integral equations; asymptotics of fields near singular points of harmonic and elasticity problems. He is a member of St. Petersburg Scientific Society, Int. Assoc. for Boundary Element Method, The American Geophysical Union, Society of Petroleum Engineers, Active Member of the New York Academy of Sciences.

Aleksandr Linkov was awarded the International Schlumberger Award for outstanding input into rock mechanics (1994), Salamon's Award for studying wave amplification (2002) and the title of Honored Scientist of Russian Federation (2008). For his authorship out over 300 papers and10 books.

Presently he focuses on: Theory and numerical modeling of hydraulic fractures; Development of efficient methods and computer codes for 2D and 3D problems involving strongly inhomogeneous media with multiple points of field concentration (crack tips, corner and multi-wedge points).; Simulation of seismicity with applications to mining and hydraulic fracturing.

Evgeniy Lomakin, Academician,
Lomonosov Moscow State University, Russia



Evgeniy Lomakin graduated Faculty of Mathematics and Mechanics of Lomonosov Moscow State University in 1968. In 1989 he defended his doctoral thesis.

Since 1993 Evgeniy Lomakin is the professor of the department of plasticity of Lomonosov Moscow State University. Since 2008 he is a member-correspondent of Russian Academy of Science, Department of Energy, Engineering, Mechanics and Control Processes (Mechanics).

Professor Lomakin is an author of more than 60 scientific works, including monograph "Fundamentals of Experimental Fracture Mechanics". He is a member of editorial boards of journals «News of RAS. Solid Mechanics», «Intern. J. Archive of Applied Mechanics», a member of the Scientific Council of RAS on Solid Mechanics, a member of the Expert Council of VAK of Russian Ministry of Education in Mathematics and Mechanics, member of the Expert Council of the Russian Foundation for Basic Research, a member of dissertation councils at Lomonosov Moscow State University and Institute of Mechanical Engineering, RAS.

During his scientific work Professor Lomakin investigated the basic properties and characteristics of deformation and fracture of graphite, carbon-carbon composites, thermal materials, some alloys, on which a new direction was formulated - mechanical environments depending on the type of the stress state properties. He developed the theory of elastic and plastic deformation microinhomogeneous and damaged media, which allowed describing the volumetric expansion of the materials under the action of compressive stress, relationship processes, shear deformation and volume dependence of their properties on the type of external influences.

Sergey Lurie, Professor,
Head of Laboratory "Non classical models of composite materials of Institute Applied Mechanics of Russian Academy of Sciences, Chief Researcher,
Institute of Applied Mechanics of RAS
(and Institute for problems of Mechanics), Russia

Sergei Lurie defeated his Engineer-Mechanic Diploma in 1972 in Moscow Aviation Institute, Moscow, USSR, Diploma Defense (Aircraft Strength), Mathematics Diploma in 1975 in Moscow State University, Moscow, USSR, Ph.D. was received in 1975 in Moscow Aviation Institute (Aircraft Strength), and in 1986 in Moscow, USSR, Defense of Dissertation, of Doctor (Russian Classification) of Sc. Degree (Solid Mechanics), habil, in Moscow Aviation Institute.

Sergey Lurie is a member of many scientific associations: Member of Consul Group on Composite Materials Mechanics of Russian Academy of Sciences, Member of Russian National Committee on Theoretical and Applied Mechanic, Member of GAMM (International Association of Applied Mathematics and Mechanics), Member of ESIS (european structural integrity society), Member of EUROMECH, Member in the Engineering Mechanics Institute (EMI) of ASCE.

Professor Lurie member of the editorial board of five journals: Mechanics of Solids, "Izv of RAS" (translated in Springer), "Mechanics of Composite Materials and Structures" – Journal of Russian Academy of Sciences, "Composites and Nanostructures" – Journal of Academy of Sciences, "Deformation and Fracture of materials" (translated -Shpringer-SCOPUS), Herald PNIPU. Mechanics (Scopus). He is a honorary research fellow of The Centre for Micro- and Nanomechanics Aberdeen University (CEMINACS).

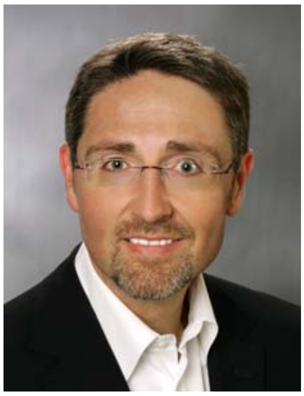
Professor Lurie research work has appeared in more than 190 publications including 6 books (three books were translated in English) and over 115 journal papers. Last book was published in 2015- Elsevier Store,: Structural Integrity and Durability of Advanced Composites, 872p. 1st Edition from Peter Beaumont, Constantinos Soutis, Alma Hodzic. Lurie is author of Chapter ·"Modeling of damage evaluation and failure of laminated composite materials across length scales".

Prof. Lurie has over 25 years of experience in working with composite structures, multi-scale modelling of damage in orthotropic laminates under multi-axial in-plane loading, fracture of composites.

Current research interests and activities are connected with developing of nonlocal theories of elasticity, fracture mechanics and modelling of mechanical physical properties composites and heterogeneous structures across the length scale. Refined and corrected nonlocal theory of elasticity, nano-mechanical modelling in framework of continuum mechanics and extended thermodynamics determine his scientific interests for the last few years.

Some of the applied gradient models for composites, ceramics, metal- matrix composites and fracture models he developed have been implemented in commercial computer design packages, used successfully by industry and academia.

Bernd Markert, Professor,
Institute of General Mechanics, RWTH Aachen University, Germany



Bernd Markert is a Scientific Director of the International Master Programme in Computer Aided Mechanical, Full Professor and Director of the Institute of General Mechanics (IAM) at RWTH Science Engineering (CAME) at RWTH International Academy gGmbH, Germany Aachen University, Germany, Faculty of Mechanical Engineering, received diploma degree (Dipl.-Ing.) in Civil Engineering from University of Stuttgart, Germany in 1998, doctoral degree (Dr.-Ing.) with distinction from University of Stuttgart in 2005.

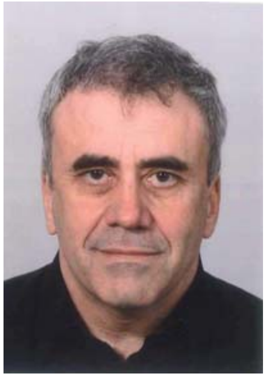
He is a member of: the GAMM Phase-Field Modelling Activity Group; the International Society for Porous Media (InterPore); the German Society of Biomechanics (DgfB) in 2010-2013; Associate Member of the International Research Training Group NUPUS in 2003-2014; the GAMM Biomechanics Activity Group; International Association of Applied Mathematics and Mechanics (GAMM) in 1998-2004; Junior member of the Association of German Engineers (VDI).

Prof. Markert is a Editorial Board Member of the Journal of Coupled Systems and Multiscale Dynamics and the Journal of Coupled Systems Mechanics. He is a recipient of the Royal Token from Her Royal Highness Princess Maha Chakri Sirindhorn for personal commitment to the Thai-German Graduate School (TGGS) of Engineering, King Monkut's University of Technology North Bangkok; invited Participant of the 1st Indo-German Frontiers of Engineering (INDOGFOE) Symposium of the Alexander von Humboldt Foundation, IIT Madras; finalist of the award to the Europe-wide best PhD thesis 2005 of the European Community on Computational Methods in Applied Sciences (ECCOMAS).

Brend Markert has over 70 publications on the following topics: Continuum Mechanics; Applied Mechanics; Porous Media; Computational Biomechanics; Coupled Problems.

His present research focuses on the theory and numerics of general coupled problems of continuum physics, computational and experimental biomechanics and structural mechanics, as well as extended continuum methods, such as phase-field modeling.

Andrei Metrikine, Antoni van Leeuwenhoek Professor, Faculty of Civil Engineering and Geosciences, TU Delft, The Netherlands



Andrei Metrikine is currently Antoni van Leeuwenhoek Professor and is head of the Wave Mechanics Research Group, based in the Faculty of Civil Engineering and Geosciences at the Delft University of Technology, the Netherlands. He graduated in radio-physics from the State University of Nizhniy Novgorod, Russia in 1989, received his PhD in 1992 in Theoretical Mechanics from the State technical University of St. Petersburg, Russia, received his DSc in 1999 in Mechanics of Solids from the Institute for Problems in Mechanical Engineering RAS, ST. Petersburg, Russia. In 1994-1998 he held a number of post-doctoral positions, including one at the Institute for Mechanics of the Hannover University, Germany awarded by the Alexander von Humboldt foundation. Since 1999 Andrei is employed by TU Delft. Currently he also holds positions of Deputy Editor-in-Chief of the Journal of Sound and Vibration and Adjunct Professor in Arctic Marine Civil Engineering at the Norwegian University of Science and Technology, Trondheim, Norway.

Prof. Metrikine has published over 120 papers in areas of vibrations of and waves in structures that are in contact with solids and fluids and on the dynamics, including failure, of complex materials.

Andrei Metrikine's main application areas of my research currently are: Dynamics of offshore pipelines focusing on the flow-induced instabilities such as divergence and flutter induced by axial flows and vortex induced vibration in currents; Dynamics of structures in ice centering on ice-induced vibrations of bottom-founded structures and interaction of level ice with floating structures; Dynamics of high-speed trains and railway lines with the emphasis on the effect of soil on the global dynamics of the train-railway-subgrade system; Dynamics of offshore wind turbines focusing on the installation, including noise generation during piling, and on the dynamic interaction of offshore turbine foundations with soil.

Thomas Michelitsch, Dr., Senior staff scientist (Directeur de recherche at CNRS), CNRS, France

Dr. Thomas Michelitsch obtained diploma in physics by Stuttgart University (Germany) in 1990 and PhD degree also by Stuttgart University in 1994. He is a winner of a doctoral Grant of Land Baden-Wurttemberg 1993 in Theorectical Physics, University of Stuttgart, Germany.

Dr. Thomas Michelitsch is a member of Editorial Board in Journal of Modern Transportation (www.springer.com/40534), associate in AFM, Euromech. His key publications include solutions of analytical static and dynamic problems (such as the static electroelastic Green's function (1997) in hexagonal (transversely isotropic) materials and Eshelby inclusion problem in transversely isotropic solids (jnumerous oint works with Prof. Valery M. Levin , Petrozavodsk State Univ. during 1997-2007); expertise in solid state physics, analytical mechanics, applied mathematics. Recently were published fractional calculus models of nonlocal material behavior including models on fractal material behavior. Recent works include the development of fractional dynamics approach in both continua and lattices (T. Michelitsch et al. J. Phys. A: Math. Theor. 48 (2015)).

His current research include fractional Lattice Dynamics: development of a fractional generalization of lattice dynamics; analytical models of 'anomalous phenomena' and nonlocal material. Starting point of the approach is the fractional lattice calculus introduced recently and presented in the talk.

Gennady Mishuris, Professor,
Aberystwyth University, Wales, UK

Professor Gennady Mishuris graduated from Faculty of Mathematics and Mechanics of the Leningrad State University in 1982 with distinction and defended his PhD at the same faculty in 1985.

Prof. Mishuris is a member of LMS, AMS, EUROMECH, GAMM. He is honoured as Belvedere Professor; Prof. Mishuris is the fellow of the Learned Society of Wales.

Gennady Mishuris is author/co-author of more than 130 publications in international scientific journals, 3 monographs and 3 textbooks.

His current research interests are matrix factorisation, Wiener-Hopf technique, integral equations, biomechanics, failure waves in lattice and discrete structures, hydraulic fracture.

Wolfgang H. Müller, Professor,
TU Berlin, Germany

Professor Müller graduated with a Diploma in Physics in 1982 and with a PhD (summa cum laude) in Physical Engineering Science in 1986, both from the Technische Universität in Berlin. In 1997 he finished his habilitation work at the Universität Paderborn and was awarded the Venia Legendi in Technical Mechanics.

Professor Müller is an advising Professor to Fraunhofer IZM Berlin, Member of the board of Continuum Mechanics and Thermodynamics, Mechanics of Advanced Materials and Modern Processes.

He was awarded with Best Paper Award, EPTC 2009, Singapore; Distinguished Visiting Fellowship of the Royal Academy of Engineering, London, August 2008 – February 2009; Honorary Professor of Mechanical Engineering at Heriot-Watt University / Edinburgh, December 2001.

Professor Müller is an author of more than 10 books on mechanics, thermodynamics and continuum theory, more than 250 peer-reviewed publications and conference proceedings papers.

His current research interests are continuum theory and modeling of the performance and behavior of advanced materials and technical structures; fracture and damage mechanics, in particular "fracture electronics"; numerical mathematics and computer simulations; mechanics and thermodynamics of advanced materials (composites, ceramics, glasses, solders, steels, and alloys); experimental determination of micro-mechanics parameters; thermodynamics and materials theory.

Udo Nackenhorst, Professor,
Leibniz Universität Hannover, Germany

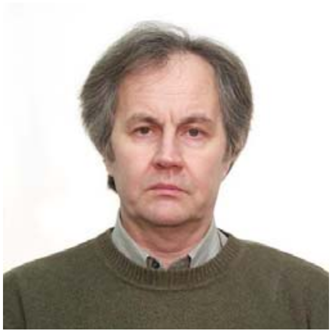
Udo Nackenhorst is a Prof. and Head, Institut for Mechanics and Computational Mechanics, Leibniz Universität Hannover, Germany.

He received Diploma Mechanical Engineering in 1987 from Ruhr-Universität Bochum, Doctor Engineer degree in 1992 from University of the Federal Armed Forces Hamburg, Professor's for Mechanics and Modeling of

Materials degree in 2000 from University of Hannover. He is a member of: GAMM, GACM, ECCOMAS.

Prof. Nackenhorst has published about 80 publications in international journals. His research focuses on biomechanics, contact mechanics, finite element methods, uncertainties.

Alexey Porubov, Professor,
Institute of Problems of Mechanical Engineering of Russian Academy of Sciences, Russia



Alexey Porubov is head of Department of Micromechanics of Materials in Institute of Problems of Mechanical Engineering of Russian Academy of Sciences. He is a member of Euromech and Russian Acoustic Society.

Received M.S.in Mechanics of fluid and gas from Leningrad Polytechnical Institute in 1987, Ph.D. in Mechanics of fluid, gas and plasma from St.Petersburg Technical University in 1996, Doctor of Sciences degree in Mechanics of deformable solids from St.Petersburg Institute for Problems in Mechanical Engineering of the Russian academy of Sciences in 2007.

Dr. Porubov has published two monographs, 7 chapters in collective monographs, 59 papers in refereed journals, 26 papers in Conference Proceedings in areas of Nonlinear waves, Nonlinear Elasticity.

His current research include: Control of nonlinear wave processes; nonlinear waves in solids, fluids and discrete structures; nonlinear mechanics of lattices; solutions to nonlinear partial differential equations; mechanics of media with microstructure; computer methods in mechanics.

Jianmin Qu, Professor,
Tufts University, USA

Jianmin Qu is Karol Family Professor and Dean of Tufts University School of Engineering, where he holds an appointment in the department of Mechanical Engineering. Dr. Qu received his Ph.D. from Northwestern University in Evanston, USA in 1987 in theoretical and applied mechanics and is a fellow of ASME, IEEE, ASEE.

He is a member of editorial boards of Acta Mechanica Sinica since 2015, Acta Mechanica since 2014, International Journal of Computational Methods since 2013, International Journal of Modern Mechanics since 2014; Water Arbitration Prize, Institute of Mechanical Engineers, UK, 2001; Ralph R. Teetor Education Award, SAE, 1996; Sigma Xi Young Faculty Award, 1994; Dow Outstanding Young Faculty Award, ASEE, 1993; Amoco Junior Faculty Teaching. Excellence Award, Amoco Foundation, 1992.

Jianmin Qu is a recipient of Outstanding Sustained Technical Contribution Award, Institute of Electrical and Electronics Engineers (IEEE), Components, Packaging, & Manufacturing Technology Society (CPMT), 2008; ASME Electronic and Photonic Packaging Division Outstanding Contribution Award (Engineering Mechanics), 2006; Outstanding Young Researcher Award, Natural Science Foundation of China, 2002.

Professor Qu has authored/co-authored two books, 12 book chapters and over 190 referred journal papers in these areas with an h-index of 43. His research has been sponsored by the National Science Foundation, the Office of Naval Research, the U.S. Air Force, U.S. Army, DARPA, the Department of Energy, and many industries including Motorola, Ford Motor Co., IBM, AT&T, General Electric, Intel, AMD, and Northrop Grumman.

His research focuses on several areas of theoretical and applied mechanics including micromechanics of composites, interfacial fracture and adhesion, fatigue and creep damage in solder alloys, thermomechanical reliability of microelectronic packaging, defects and transport in solids with applications to solid oxide fuel cells and batteries, and ultrasonic nondestructive evaluation of advanced engineering materials.

Stepan Rudykh, Assistant Professor, Technion – Israel Institute of Technology, Israel

Stepan Rudykh is assistant professor and head of the Laboratory on Mechanics of Soft Materials in Israel Institute of Technology. Received master degree from Peter the Great St.Petersburg Polytechnic University in 2004, PhD is from Ben-Gurion University in 2012. He is a member of European Mechanics Society (EuroMech); American Society of Mechanical Engineering (ASME); Society of Engineering Science (SES); European Society of Biomechanics (EBS); Gesellschaft fur Angewandte Mathematik und Mechanik (GAMM); Israel Society of Theoretical and Applied Mechanics (ISTAM).

Stepan Rudykh is: recipient of Rahamimoff Award for young scientists by Binational US-Israel Science Foundation (BSF); Horev Fellow, Leaders in Science in Technology.

His works are published in peer-reviewed journals including Phys. Rev. Lett., Applied Physics Letters, Soft Matter, Journal of the Mechanics and Physics of Solids; Proc. Royal Society London and others.

Rudykh's group research focuses on the mechanics and physics of soft microstructured materials including electro- and magneto-active materials, acoustic metamaterials, biological tissues and bioinspired materials, nonlinear composites, and 3D printing.

Boris Semenov, Associate Professor,
Saint Petersburg State University, Russia

Boris Semenov is an associate Professor at Department of Elasticity, Mathematics & Mechanics Faculty of St. Petersburg State University, received his Ph. D. in 1979 from Leningrad State University.

He is a member of GAMM, ESIS. B.Semenov is the author and co-author of several works on the themes: F. Formation and Mechanical Properties of Alumina Ceramics Based on Al2O3 Micro- and Nanoparticles; mechanical characteristics of graphene sheets containing high-density ensembles of 5-8- 5 defects; tensile strength of graphene containing 5-8- 5 defects; finite-element analysis of deformation of titanium cylinder with a ceramic coating under axial compression; Deformation and Fracture Processes in Graphene Nanoribbons with Linear Quadrupoles of Disclinations. His research focuses on mechanics of solids, fracture mechanics, nanomechanics.

Jianxiang Wang, Professor,
Peking University, China

Prof. Jianxiang Wang received BEng (Bachelor of Engineering) from Nanjing University of Aeronautics and Astronautics (NUAA) in 1983, MSc (Master of Science), from South China University of Technology in 1986, PhD (Doctor of Philosophy) at The University of Sydney in 1995. He is an associate editor of: Acta Mechanica Solida Sinica; Advanced Modeling and Simulation in Engineering Sciences. Jianxiang Wang is Changjiang Chair Professor.

He has over 80 papers in journals including PNAS, Proc R Soc A, J Mech Phys Solids, Phys Rev B, Acta Materialia, Int J Solids Struct, Mech Mater, Appl Phys Lett, Sci Rep.

His current research include mechanics of composites, murface effect in solids, theory of peridynamics.

Marian Wiercigroch, Professor,
University of Aberdeen, UK

Marian Wiercigroch obtained his MEng in 1985 and ScD in 1990 in Silesian University of Technology, DSc in 2007 in University of Aberdeen, Doctor Honoris Causa in 2013 in Lodz University of Technology.

He is Professor and Director in University of Aberdeen, member of Institution of Mechanical Engineers, Institute of Mathematics and its Applications, European Mechanics Society, International Union of Theoretical and Applied Mechanics.

Professor Wiercigroch is Editor-in- Chief of the International Journal of Mechanical Sciences, Editor of Acta Mechanica Sinica, Member of a dozen editorial boards including Nonlinear Dynamics and International Journal of Nonlinear Mechanics.

Marian Wiercigroch was awarded as Senior Fulbright Scholar, Fellow of the Royal Society of Edinburgh, Doctor honoris causa of the Lodz University of Technology. He is the author of over 300 journal and conference papers (169 journal papers), 10 patents, 2 monographs and 16 edited volumes.

Professor’s Wiercigroch current research interests are Nonlinear dynamics and stability; chaotic and stochastic dynamics; mathematical modelling; application of numerical methods in engineering; mechanical vibrations; vibro-impact systems; vortex induced vibration; dynamics and control of smart structures; dynamics of machine tools and cutting processes; fracture; friction and tribology; design; fatigue; machining, manufacturing, underwater acoustics; renewable energy; oil & gas drilling.