XLII Summer School – Conference
“Advanced Problems in Mechanics”

June 30 - July 5, 2014,
St. Petersburg (Repino), Russia

APM 2014

BOOK OF ABSTRACTS

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General Information

The International Summer School – Conference "Advanced Problems in Mechanics – 2014" is the forty second 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), Saint Petersburg State Polytechnical 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 cross-fertilisation 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 12/31/1983) 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” (find the information further).

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
- nanomechanics
- molecular and particle dynamics
- phase transitions
- computational mechanics
- wave motion
- nonlinear dynamics, chaos and vibration
- dynamics of rigid bodies and multibody dynamics
- solids and structures
- fluid and gas
- mechanical and civil engineering applications
- aerospace mechanics

Accompanying Events

[MS1] Minisymposium "Computational Contact Mechanics"
Prof. Udo Nackenhorst (Germany)
[MS2] Minisymposium " Shells and membranes in biomechanics/medicine".
Prof. Svetlana Bauer (Russia) and Prof. Anders Eriksson (Sweden)
[MS3] Minisymposium "Mathematical and numerical modelling in Hydraulic Fracturing".
A. Linkov (Russia, Poland), A. M. Krivtsov, V. A.Kuzkin (Russia), G. Mishuris (UK)
[MS4] International workshop "Multiscale modelling in ceramics"
D. Bigoni (Italy), M. Gei (Italy), G. Mishuris (UK), A. Movchan (UK)

Four different forms of presentations are offered, namely, plenary lectures (45 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), St. Petersburg Scientific Center of RAS. This support has helped substantially to organize the conference and to increase the participation of young researchers.

Day 1 – Monday, June 30

ROOM A

08.30–09.45	REGISTRATION
09.45–10.00	OPENING
10.00–11.30	PLENARY LECTURES – I
11.30–11.50	COFFEE BREAK
11.50–12.35	PLENARY LECTURES – II
12.35–13.30	MWM OPENING
	LUNCH BREAK
15.30–16.50	MATHEMATICAL AND NUMERICAL MODELLING IN HYDRAULIC FRACTURING – I
16.50–17.10	COFFEE BREAK
17.10–19.00	MATHEMATICAL AND NUMERICAL MODELLING IN HYDRAULIC FRACTURING – II
	20.00 WELCOME PARTY

ROOM B

15.30–16.50	MWM PRESENTATIONS
16.50–17.10	COFFEE BREAK
17.10–18.50	NANOMECHANICS

ROOM C

15.30–16.50	SOLIDS AND STRUCTURES – I
16.50–17.10	COFFEE BREAK
17.10–19.10	SOLIDS AND STRUCTURES – II

Day 2 – Tuesday, July 1

ROOM A

09.15–11.30	PLENARY LECTURES – III
11.30–11.50	COFFEE BREAK
11.50–13.20	COMPUTATIONAL CONTACT MECHANICS
	LUNCH BREAK
15.30–16.50	SHELLS AND MEMBRANES IN BIOMECHANICS/MEDICINE – I
16.50–17.10	COFFEE BREAK
17.10–18.30	SHELLS AND MEMBRANES IN BIOMECHANICS/MEDICINE – II

ROOM B

11.50–14.00	NONLINEAR DYNAMICS, CHAOS AND VIBRATION I
	LUNCH BREAK
15.20–16.50	MWM POSTERS
16.50–17.10	COFFEE BREAK
17.10–19.10	MWM ACTIVITIES

ROOM C

11.50–13.20	WAVE MOTION – I
	LUNCH BREAK
15.30–19.10	POSTER SESSION Possibility of the EU funding. Overview of FP7 and Horizon 2020 EU program

Day 3 – Wednesday, July 2

ROOM A

10.00–11.30	PLENARY LECTURES – IV
11.30–11.50	COFFEE BREAK
11.50–13.40	COMPUTATIONAL MECHANICS – I
	LUNCH BREAK
15.30–16.50	COMPUTATIONAL MECHANICS – II
16.50–17.10	COFFEE BREAK
17.10–19.10	COMPUTATIONAL MECHANICS – III
	NIGHT EXCURSION (optional)

ROOM B

11.50–13.50	MULTISCALE MODELLING IN CERAMICS – I
	LUNCH BREAK
15.30–16.50	MULTISCALE MODELLING IN CERAMICS – II
16.50–17.10	COFFEE BREAK
17.10–19.10	MULTISCALE MODELLING IN CERAMICS – III

ROOM C

11.50–13.30	MECHANICS OF MEDIA WITH MICROSTRUCTURE – I
	LUNCH BREAK
15.20–16.50	DYNAMICS OF RIGID BODIES AND MULTIBODY DYNAMICS – I
16.50–17.10	COFFEE BREAK
17.10–18.50	DYNAMICS OF RIGID BODIES AND MULTIBODY DYNAMICS – II

Day 4 – Thursday, July 3

EXCURSION

21.00 BANQUET

Day 5 – Friday, July 4

ROOM B

10.00–11.30	PLENARY LECTURES – V
11.30–11.50	COFFEE BREAK
11.50–13.50	MOLECULAR AND PARTICLE DYNAMICS
	LUNCH BREAK
15.30–16.50	WAVE MOTION – II
16.50–17.10	COFFEE BREAK
17.10–17.50	NONLINEAR DYNAMICS, CHAOS AND VIBRATION II
17.50 – 19.10	AEROSPACE MECHANICS

ROOM C

11.50–13.50	MECHANICAL AND CIVIL ENGINEERING APPLICATIONS
	LUNCH BREAK
15.30–16.50	FLUID AND GAS – I
16.50–17.10	COFFEE BREAK
17.10–18.50	FLUID AND GAS – II

Day 6 – Saturday, July 5

ROOM A

10.00–11.30	PLENARY LECTURES – VI
11.30–11.50	COFFEE BREAK
11.50–13.50	MECHANICS OF MEDIA WITH MICROSTRUCTURE – II
	LUNCH BREAK
15.30–16.50	MECHANICS OF MEDIA WITH MICROSTRUCTURE – III
16.50–17.10	COFFEE BREAK
19.10–19.30	CLOSING CEREMONY

ROOM B

17.10–19.10	POSTER SESSION

Day 1 – Monday, June 30

ROOM A

08.30–09.45 **REGISTRATION**
09.45–10.00 **OPENING CEREMONY**
10.00–11.30 **PLENARY LECTURES – I**
Chair: ***D.A. Indeitsev***
10.00–10.45 ***M.L. Kachanov***. Micromechanics of heterogeneous materials and cross-property connections
10.45–11.30 ***Z.-P.Huang***. A new constitutive formulation in rubber elasticity
11.30–11.50 **COFFEE BREAK**
11.50–13.30 **PLENARY LECTURES – II**
11.50–12.35 ***N.N. Smirnov****, A.B. Kiselev, V.F. Nikitin, A.I. Bogdanova, A.S. Manenkova.* Continua traffic flow models.
12.35–12.45 **MWM OPENING**
Chair: ***I.E. Berinskii***
12.45–13.30 ***D. Bigoni****, F. Bosi, F. Dal Corso, D. Misseroni, A. Piccolroaz.* Structures releasing energy.

LUNCH BREAK

15.20–16.50 **MATHEMATICAL AND NUMERICAL MODELLING IN HYDRAULIC FRACTURING – I**
Chair: ***A.M. Linkov, G. Mishuris***
15.20–15.50 ***A.M. Linkov.*** Speed equation, asymptotic umbrella and explicit level set method in hydraulic fracture modeling.
15.50–16.20 *M. Wrobel,* ***G. Mishuris****.* Universal algorithm for hydraulic fractures simulation based on the particle velocity.
16.20–16.50 *V. Mykhailov, O. Karpenko,* ***I. Karpenko****.* Geological features of Ukrainian shale formations promising for the presence of industrial unconventional hydrocarbons accumulations in connection with hydraulic fracturing.
16.50–17.10 **COFFEE BREAK**
17.10–19.00 **MATHEMATICAL AND NUMERICAL MODELLING IN HYDRAULIC FRACTURING – II**
Chair: ***A.M. Linkov, G. Mishuris***
17.10–17.40 ***D. Jaworski****, A.M. Linkov, E. Rejwer, L. Rybarska-Rusinek.* Numerical simulation of local field concentration near the contour of a fracture.
17.40–18.10 ***M. Perkowska****, G. Mishuris, M. Wrobel.* Numerical simulation of PKN model of hydrofracturing for shear-thinning fluids.
18.10–18.40 ***P. Kusmierczyk****, G. Mishuris.* PKN based multifracturing model featuring fracture interactions. New approach and implementation.
18.40–19.00 ***Discussion***

20.00 Welcome Party

Day 1 – Monday, June 30

ROOM B

15.30–16.50 **MWM PRESENTATIONS**
Chair: ***I.E. Berinskii***
16.50–17.10 **COFFEE BREAK**
17.10–18.50 **NANOMECHANICS**
Chair: ***M.Yu. Gutkin***
17.10–17.30 *A.K. Abramyan, N.M. Bessonov,* ***L.V. Mirantsev****, N. Reynberg*. Transport of polar and nonpolar fluids through nanotubes placed into liquid medium.
17.30–17.50 ***M.Yu. Gutkin****, A.L. Kolesnikova, S.A. Krasnitckii, A.E. Romanov.* Circular prismatic loops of misfit dislocations in bulk and hollow core-shell nanoparticles.
17.50–18.10 ***G.I. Mikhasev.*** Prediction of localized natural modes of single-walled carbon nanotubes embedded in nonhomogeneous elastic medium.
18.10–18.30 ***K.P. Zolnikov****, D.S. Kryzhevich, A.V. Korchuganov.* Influence of loading schemeon the deformation behaviour of titanium crystals.
18.30–18.50 *S.N. Romashin, L.Yu. Frolenkova,* ***V.S. Shorkin****.* Contact elastic bodies with taking into account their adhesion.

ROOM C

15.30–16.50 **SOLIDS AND STRUCTURES – I**
Chair: ***A.B. Freidin, E.N. Vilchevskaya***
15.30–15.50 ***E.N. Barkanov****, M.I. Chebakov.* Inverse technique for characterisation of elastic and dissipative properties of materials used in a composite repair of pipelines.
15.50–16.10 ***N.N. Myagkov****, M.V. Silant'ev.* Critical behavior in high–velocity impact fragmentation.
16.10–16.30 ***N.V. Banichuk****, S.Yu. Ivanova, E.V. Makeev.* Strength analysis of axisymmetric shells moving in deformed media at high speed.
16.30–16.50 ***P.Y. Akishin****, E.N. Barkanov, M. Wesolowski, E.M. Kolosova.* Static and dynamic techniques for nondestructive elastic material properties characterisation.
16.50–17.10 **COFFEE BREAK**
17.10–19.10 **SOLIDS AND STRUCTURES – II**
Chair: ***A.B. Freidin, E.N. Vilchevskaya***
17.10–17.30 ***I.A. Brigadnov****, K. Naumenko.* Non-homogeneous radial deformations in the problem of torsion of hyperelastic circular cylinder.
17.30–17.50 ***R.A. Arutuynyan****.* Fracture problem of brittle and quasibrittle materials.
17.50–18.10 ***A.B. Freidin****, E.N. Vilchevskaya.* Coupled problems of mechanochemistry: statements and solutions
18.10–18.30 ***E.N. Vilchevskya****, A.B. Freidin***.** On kinetics of chemical reaction front in axially-symmetric problems.
18.30–18.50 ***I.K. Korolev****, S.P. Aleshchenko, A.B. Freidin, E.N. Vilchevskaya*. FEM simulation of a chemical reaction front propagation near the stress concentrator
18.50–19.10 ***Discussion***

20.00 Welcome Party

Day 2 – Tuesday, July 1

ROOM A

09.15–11.30 **PLENARY LECTURES – III**
Chair: ***S.M. Bauer***
09.15–10.00 ***U. Nackenhorst.*** Computational techniques for tires in rolling contact.
10.00–10.45 ***G.I. Mikhasev***. Thin composite sandwich beams, plates and shells containing magnetorheological elastomer: vibrations, waves and their suppression
10.45–11.30 ***A. Eriksson***.Stability aspects of pressurized membranes.
11.30–11.50 **COFFEE BREAK**
11.50–13.20 **COMPUTATIONAL CONTACT MECHANICS**
Chair: ***U. Nackenhorst***
11.50–12.20 ***R. Beyer***, *U. Nackenhorst.* Towards a thermo-visco-elastic constitutive contactModel for tire-road interaction.
12.20–12.50 ***A.I. Dmitriev***, *W.Oesterle.* About the role of tribofilms formed during automotive braking. Results of nano-scale modeling.
12.50–13.20 ***R.S. Telyatnik***. Critical conditions for buckling with delamination and other misfit defects in Aln(0001)/SiC/Si(111) thin film heterostructure.

LUNCH BREAK

15.20–16.50 **SHELLS AND MEMBRANES IN BIOMECHANICS/MEDICINE – I**
Chair: ***S.M. Bauer, A. Eriksson***
15.20–15.50 ***S.M. Bosiakov***, *A.F. Mselati.*The analytical model of a periodontal membrane in the form of an elliptical hyperboloid.
15.50–16.20 ***A.A. Stein***, *I.N. Moiseeva, G.A. Lyubimov.* Two-component model of the eyeball and its application to determining the mechanical characteristics of the eye in clinics.
16.20–16.50 ***S.M. Bauer***, *A.L. Smirnov.*Deformation of the orthotropic spherical layer under normal pressure.
16.50–17.10 **COFFEE BREAK**
17.10–18.30 **SHELLS AND MEMBRANES IN BIOMECHANICS/MEDICINE – II**
Chair: ***S.M. Bauer, A. Eriksson***
17.10–17.40 *S.M. Bauer,* **E.B. Voronkova**, *K. Kotliar.* Shell theory based models for pressure volume relationship in the human eye.
17.40–18.10 ***I.L. Slavashevich***, *G.I. Mikhasev, K.S. Urkevich.* Analyse of natural frequencies of reconstructed middle ear after tympanoplasty and stapedotomy.
18.10–18.30 ***Discussion***

Day 2 – Tuesday, July 1

ROOM B

11.50–14.00 **NONLINEAR DYNAMICS, CHAOS AND VIBRATION – I**
Chair: ***I.E. Berinskii***

11.50–12.20 Key-note lecture. ***D.Yu. Skubov****, I.E. Berinskii, D.A. Indeitsev, O.V. Privalova, L.V. Shtukin.* Nonlinear dynamics of mechanical systems placed in quasi-stationary magnetic and electric field.

12.20–12.40 *I.A. Pasynkova,* ***P.P. Stepanova****.* Nonlinear dynamics of the “rotor - massive-compliant supports” system.

12.40–13.00 ***M.V. Shamolin.*** New cases of integrability in multidimensional dynamics in a nonconservative field.

13.00–13.20 ***V.A. Il'in****, A.N. Mordvinov.* Investigation of electroconvection models of ideal dielectric in the alternating electric field of the horizontal capacitor.

13.20–13.40 ***V.S. Sorokin****.* The suppression of vibration in prescribed areas of a string subjected to action of a distributed load by continuous spatial modulation of its cross-section.

13.40–14.00 ***R. Darula****, S.V.Sorokin.* On non-linear dynamics of coupled 1+1DOF versus 1+1/2DOF electro-mechanical system

LUNCH BREAK

15.20–16.50 **MWM POSTERS**

16.50–17.10 **COFFEE BREAK**

17.10–19.10 **MWM ACTIVITIES**

Day 2 – Tuesday, July 1

ROOM C

11.50–13.20 **WAVE MOTION – I**
Chair: ***S.N. Gavrilov, E.V. Shishkina***

11.50–12.20 Key-note lecture. ***S.N. Gavrilov****, E.V. Shishkina*. New phase nucleation due to collision of two non-stationary waves

12.20–12.40 ***P.S. Uglich***. On the problem of forced plane vibrations of transversally inhomogeneous elastic layer.

12.40–13.00 ***G.V. Filippenko***. The vibrations of the system of coaxial cylinders partially submerged into the water.

13.00–13.20 *R.V. Ardazishvili,* ***M.V. Wilde.*** Antisymmetric higher order edge waves in plates with fixed faces.

LUNCH BREAK

15.30–19.10 **POSTER SESSION**:
Possibility of the EU funding. Overview of FP7 and Horizon2020 EU program

- ***I. Jatro,*** *A. Piccolroaz.* CERMAT2 – New ceramic technologies and novel multifunctional ceramic devices and structures
- *F. Dal Corso,* ***I. Jatro***. HOTBRICKS – Mechanics of refractory materials at high-temperature for advanced industrial technologies
- *D. Bigoni,* ***I. Jatro***. INSTABILITIES – Instabilities and nonlocal multiscale modelling of materials
- *M. Gei,* ***I. Jatro***. INTERCER2 – Modelling and optimal design of ceramic structures with defects and imperfect interfaces
- *F. Bosi, E. Mazzocchi,* ***I. Jatro****, F. Dal Corso, A. Piccolroaz, L. Deseri, D. Bigoni, A. Cocquio, M. Cova, S. Odorizzi.* A collaborative project between industry and academia to enhance engineering education at graduate and phd level in ceramic technology.
- ***G. Mishuris.*** HYDROFRAC - Enhancing hydraulic fracturing on the basis of numerical simulation of coupled geomechanical, hydrodynamic and microseismic processes
- ***G. Mishuris*****.** PARM-2 Vibro-impact machines based on parametric resonance: Concepts, mathematical modelling, experimental verification and implementation
- ***G. Mishuris.*** TAMER - Trans-Atlantic Micromechanics Evolving Research "Materials containing
  inhomogeneities of diverse physical properties, shapes and orientations"
- *D. Bigoni,* ***I. Jatro****, A. Piccolroaz.* MeMic: Fracture mechanics of microstructured composites incorporating intrinsic length-scales
- ***G. Mishuris****, A. Piccolroaz.* INTERCRACKS: Unsolved problems in fracture mechanics of heterogeneous materials
- ***G. Mishuris****, I. Argatov.* OA AM: Asymptotic modelling of biomechanical contact phenomena under dynamic and impact loading.

Day 3 – Wednesday, July 2

ROOM A

10.00–11.30 **PLENARY LECTURES – IV**
Chair: ***E. Grekova***

10.00–10.45 ***V.A. Levin***, *I.S. Manuylovich, V.V. Markov.* Initiation and propagation of detonation waves, taking into account three-dimensional effects

10.45–11.30 ***A.T. Perez***, *P. Garcia-Sanchez.* Permanent magnetic leviation of levitrons using periodic magnetic forcing.

11.30–11.50 **COFFEE BREAK**

11.50–13.40 **COMPUTATIONAL MECHANICS – I**
Chair: ***I.K. Korolev***

11.50–12.20 Key-note lecture.***S.V. Petinov***, *T.I. Letova, R.V. Guchinsky.* Modeling of fatigue process by combining the crack initiation and growth.

12.20–12.40 ***R.V. Guchinsky***, *S.V. Petinov.* Finite-element modeling of semi-elliptical fatigue crack growth using damage accumulation approach.

12.40–13.00 *A.V. Dimaki,* **A.I. Dmitriev**, *G.J. Polevshchikov.* Simulation of sorption of carbon dioxide in the porous coal by means of hybrid cellular automaton method.

13.00–13.20 ***P.V. Makarov***, *M.O. Eremin.* Loaded solids and media as the nonlinear dynamic systems.The numerical simulation of stress-strain state and fracture evolution.

13.20–13.40 ***K.S. Yurkevich***, *G.I. Mikhasev, A.D. Dosta, I.K. Korolev.* On new technique for bone fracture fixation

LUNCH BREAK

15.30–16.50 **COMPUTATIONAL MECHANICS – II**
Chair: ***K.S. Yurkevich***

15.30–15.50 ***I.K. Marchevsky***, *G.A. Shcheglov.* Numerical simulation of hydroelastic Beam dynamics in the flow using vortex element method.

15.50–16.10 *B.P. Kazakov, A.V. Shalimov,* ***A.V. Zaitsev***, *Yu.A. Klyukin, M.A. Semin.* Mine thermodynamic parameters control by means of suballocated conditioned air distribution system.

16.10–16.30 ***A.V. Dimaki***, *S.V. Astafurov, E.V. Shilko, S.G. Psakhie.* Computer-aided simulation of the mechanical response of water-saturated sandstone on the basis of the hybrid cellular automaton method.

16.30–16.50 ***I. Neygebauer.*** Continuum models with constitutive laws for body forces and moments.

16.50–17.10 **COFFEE BREAK**

17.10–19.10 **COMPUTATIONAL MECHANICS – III**
Chair: ***I.K. Marchevsky***

17.10–17.40 ***M. Srinivasan***, *P. Mättig, K.W. Glitza, B. Sanny, A. Schumacher.*Multiscale calculation for increasing the thermal conductivity of carbon fiber composite with diamond powder.

17.40–18.10 ***Ig.S. Konovalenko***, *Ch.O. Toktohoev, Iv.S. Konovalenko, Vl.V. Promakhov, S.G. Psakhie.* Investigation of deformation and fracture of the ceramic composites based on nanocrystalline metaloxides. Computer simulation on the basis of movable cellular automaton method.

18.10–18.30 ***V.D. Sulimov***, *P.M. Shkapov*. Derivative-free local search in hybrid algorithms for hydromechanical system model updating.

18.30–18.50 ***S.N. Shubin***, *A.B. Freidin.* Sealing application of elastomer composites based on fillers with negative thermal expansion coefficient

18.50–19.10 ***Discussion***

21.00-02.30 NIGHT EXCURSION (optional)

Day 3 – Wednesday, July 2

ROOM B

11.50–13.50 **MULTISCALE MODELLING IN CERAMICS – I**
*Chair:**A. Piccolroaz***

11.50–12.10 ***S. Sprio**, A. Ruffini, S. Panseri, A. Tampieri.* From wood to bone: a new generation of biomorphic scaffolds for regeneration of long segmental bones.

12.10–12.30 *A. Nobili, **E. Radi**, L. Lanzoni.* Full field solution for a rectilinear crack in an infinite Kirchhoff plate supported by a Pasternak elastic foundation.

12.30–12.50 ***S. Rudykh.*** Magneto- and electroactive deformable composites

12.50–13.10 ***D. Bigoni**, F. Bosi, F. Dal Corso, D. Misseroni, A. Piccolroaz.* Forming of ceramic powders.

13.10–13.30 ***F. Dal Corso**, M. Bacca.* Multiscale modelling of ceramic composites.

13.30–13.50 ***L.P. Argani**, D. Bigoni, G. Mishuris.* Dislocations and inclusions in prestressed solids.

LUNCH BREAK

15.30–16.50 **MULTISCALE MODELLING IN CERAMICS – II**
*Chair: **D.Bigoni***

15.30–15.50 ***A. Piccolroaz**, L. Morini, P. Gourgiotis.* Incorporating intrinsic length-scales in fracture toughness of microstructured ceramics.

15.50–16.10 ***E. Bortot**, R. Springhetti, M. Gei.* Enhancing the performance of soft dielectric generators using ceramic fillers.

16.10–16.30 ***L. Morini**, A. Piccolroaz.* Modelling of interface cracks between dissimilar ceramic materials of interest for solid oxide fuell cells fabrication.

16.30–16.50 ***A. Zagnetko**.* To the modelling of crack in the bimaterial anisotropic structures.

16.50–17.10 **COFFEE BREAK**

17.10–19.10 **MULTISCALE MODELLING IN CERAMICS – III**
*Chair: **G. Mishuris***

17.10–17.30 ***F. Bosi**, A. Piccolroaz, M. Gei, Corso F. Dal, A. Cocquio.* Mechanical characterization of the elasto-platicbehaviour of aluminum silicate spray dried powder during cold compaction.

17.30–18.50 Poster presentations announcement:

- ***E. Bortot**, R. Springhetti, F. DalCorso, M. Gei.* Numerical analysis of cracks and rigid line inclusions in elastic plates.
- ***F. Bosi**, A. Cocquio, M. Cova.* Testing protocol and experimental investigation on green body.
- ***F. Dal Corso,** S. Shahzad, D. Misseroni, G. Noselli.* Validation of rigid inclusion model for the analysis of reinforced composite materials.
- *M. Jones, S. Fearn, **G. Mishuris**, R. Winter, A. Lennie, J. Parker, S. Thompson, C. Tang*. Dynamic strain in granular ceramics probed by real-time x-ray diffraction.
- ***F. Bosi**, **D. Misseroni***. Elastic characteristics of green bodies detected by ultrasonic tests
- ***D. Misseroni, D.Bigoni, G. Noselli.*** S-shape constraints for elastic rods: tensile buckling in tension and multiple bifurcations.
- *L. Pryce, **L. Morini**, G. Mishuris.* Mathematical modelling of interfacial cracks in anisotropic and piezoelectric ceramic materials
- ***L. Morini**, A. Piccolroaz, G. Mishuris.* Cracks propagation in ceramic materials: a singular integral formulation

- *M. Penasa,* **A. Piccolroaz***, L. Argani, D. Bigoni.* Integration algorithms of elastoplasticity for ceramic powder compaction
- ***I.Yu. Smolin****, M.O. Eremin, P.V. Makarov, S.P. Buyakova.* Simulation of pore space structure and mechanical behavior of porous ceramics
- ***S. Sprio****, M. Dapporto, A. Tampieri*. Highly osteointegrative, self-hardening biomimetic bone cements for vertebral regeneration.
- *L. Pryce, A. Vellender,* **A. Zagnetko***, G. Mishuris.* Mathematical modelling of anisotropic bimaterials with imperfect interfaces

18.50–19.10 ***Discussion***

21.00-02.30 NIGHT EXCURSION (optional)

Day 3 – Wednesday, July 2

ROOM C

11.50–13.30 **MECHANICS OF MEDIA WITH MICROSTRUCTURE – I**
Chair: ***A.T. Perez***

11.50–12.10 ***M.I. Karyakin,*** *O.A. Mayorova, O.G. Pustovalova.* Bending and torsion of nonlinearly elastic body with microstructure.

12.10–12.30 ***E. Grekova****, F. Ruiz-Botello, A. Castellanos, V. Tournat.* Reduced Cosserat medium with local anisotropy: a model for powders at low consolidation*?*

12.30–12.50 *F. Ruiz-Botello,* **A. Castellanos***, V. Tournat, E. Grekova.* Sound wave propagation in cohesive powders at low consolidations

12.50–13.10 ***L.A. Nazarov****, L.A. Nazarova, G.N. Khan.* Determination of underground void geometrics by the subsidence trough configuration on the basis of inverse problem solution.

13.10–13.30 ***L.A. Nazarova****, L.A Nazarov, A.L Karchevsky, A.V Panov.* Inverse problems for the productive stratum geomechanics.

LUNCH BREAK

15.20–16.50 **DYNAMICS OF RIGID BODIES AND MULTIBODY DYNAMICS – I**
Chair: ***W.H. Mueller, P.E. Tovstik***

15.20–15.50 Key-note lecture.***W.H. Mueller****.* The spin, the nutation and the precession of the Earth axis revisited: a (numerical) mechanics perspective.

15.50–16.10 ***A.S. Kuleshov****, V.V.Rybin.* Controllability of the Ishlinsky system.

16.10–16.30 ***G.B. Filimonikhin****, I.I. Filimonikhina.* On investigation of process of changing angle of nutation of rotating carrying body in an isolated system.

16.30–16.50 ***V.V. Goncharov****, G.B. Filimonikhin.* To analytical study of transient processes in rotor systems with passive auto-balancers.

16.50–17.10 **COFFEE BREAK**

17.10–18.50 **DYNAMICS OF RIGID BODIES AND MULTIBODY DYNAMICS – II**
Chair: ***W.H. Mueller, P.E. Tovstik***

17.10–17.30 ***P.E. Tovstik****.* Kinematic and dynamics of the Stewart platform.

17.30–17.50 ***L.Ya. Banakh****.* Oscillations of branched self-similar systems.

17.50–18.10 ***O.A. Volokhovskaia****.* Model of a rotor oscillations having an initial deflection and mounted on anisotropic supports.

18.10–18.30 *V.G. Kozlov,* ***V.D. Schipitsyn****.* Behavior of neutral buoyancy solid in cavity with liquid under rotational vibration.

18.30–18.50 ***Discussion***

21.00-02.30 NIGHT EXCURSION (optional)

Day 4 –Thursday, July 3

EXCURSION

21.00 BANQUET

Day 5 – Friday, July 4

ROOM B

10.00–11.30 **PLENARY LECTURES – V**
Chair: ***O.S. Loboda***

10.00–10.45 *G. Martin, A. Mikhailova,* **B. Pavlov**. Beating of modes in dissipative systems, with applications to seismo-gravitatoponal oscillation of tectonic plates

10.45–11.30 ***V.A. Babeshko****, O.V. Evdokimova, O.M. Babeshko, D.V. Grishenko.* Localization in mechanics and nature.

11.30–11.50 **COFFEE BREAK**

11.50–13.50 **MOLECULAR AND PARTICLE DYNAMICS**
Chair: ***V.A. Kuzkin***

11.50–12.10 ***V.A. Kuzkin****, A.M. Krivtsov*. Nonlinear positive/negative thermal expansion of a chain with longitudinal and transverse vibrations.

12.10–12.30 ***A.Yu. Panchenko,*** *O.S. Loboda, A.M. Krivtsov.* Analytical and numerical investigation of stationary correlations in ideal crystal lattices

12.30–12.50 ***V.V.Pisarev***, *S.V.Starikov.* Two-temperature atomistic model for ion tracks in UO_2

12.50–13.10 ***A.D. Pshenov****, V.A. Kuzkin*. Dynamic buckling of discrete elastic rods: influence of loading rate.

13.10–13.30 *A.N. Fedorova,* ***M.G. Zeitlin****.* Beam-beam interaction: from localization to non-gaussian spectrum

13.30–13.50 ***A.N. Fedorova****, M.G. Zeitlin*. RMS envelope moment beam dynamics via nonlinear/non-gaussian effects.

LUNCH BREAK

15.30–16.50 **WAVE MOTION – II**
Chair: ***A.P. Kiselev***

15.30–15.50 ***A.R. Dehadrai****, I. Sharma, S.S. Gupta.* Stability of an inclined traveling heavy cable

15.50–16.10 ***T.Kuklin****, Y. Mochalova, D.A. Indeitsev.* Localized buckling of elastic beams on weakened Winkler foundation.

16.10–16.30 *A.M. Tagirdzhanov,* ***A.P. Kiselev.*** Generalized spherical waves. A short review

16.30–16.50 *D.P. Kouzov,* ***M.G. Zhuchkova****.* Low-frequency vibrations of a semi-infinite floating elastic plate interfaced with a rigid vertical wall.

16.50–17.10 **COFFEE BREAK**

17.10–17.50 **NONLINEAR DYNAMICS, CHAOS AND VIBRATION – II**
Chair: ***M.G. Zhuchkova***

17.10–17.30 ***I.I. Blekhman****, L.I. Blekhman, L.A. Vaisberg, V.B. Vasilkov, K.S. Yakimova.* Vibrational segregation - simulation, experiment, and application to create new classifying machines.

17.30–17.50 *A.A Gubaidullin,* ***A.V. Yakovenko****.* Numerical investigation of the gas dynamics in the vibrating cylindrical cavity.

17.50–18.10 ***A.D. Polishchuk****.* The different types transverse oscillations of thin helical beam.

18.10–19.10 **AEROSPACE MECHANICS**
Chair: ***A.Yu. Panchenko***

18.10–18.30 ***P.Yu. Georgievsky.*** Application of thermal spike for control of supersonic flow past blunt and pointed bodies

18.30–18.50 ***M.N. Smirnova****, A.V. Zvyaguin.* Comparison of analytical and numerical solutions for a problem of thin body motion in gas near rigid surface

18.50–19.10 ***A.S. Murachev****, A.M. Krivtsov*. Equilibrium of a dust and gas cloud

Day 5 – Friday, July 4

ROOM C

11.50–13.50 **MECHANICAL AND CIVIL ENGINEERING APPLICATIONS**
Chair: ***B.N. Semenov***

11.50–12.10 ***B.N. Semenov,*** *Yu.V. Sudenkov, A.V. Voronin.* Impact of plasma jet on tungsten barrier.Experiment and simulation.

12.10–12.30 ***V.I. Monine****, J.T. Assis, L.D. Rodrigues, J.L.F. Freire, V.E.L. Paiva.* Influence of surface roughness on stress measurements by x-ray diffraction technique.

12.30–12.50 ***I.Yu. Smolin****, V.P. Kuznetsov, A.I. Dmitriev.* Numerical analysis of the stress-strain state of the steel superficial layer under nanostructuring burnishing.

12.50–13.10 ***S.E. Al-Lubani****.* The effect of copper content, annealing temperature, and aging time on the hardness of aluminum alloys using artificial neural networks.

13.10–13.30 ***A.V. Morozov****.* Estimation of the coefficient of friction epilam - coated materials.

13.30–13.50 *V. Kolykhalin,* ***A. Novoselova****.* About the compensating technique of low frequency components of magnetic electric motor noise.

LUNCH BREAK

15.30–16.50 **FLUID AND GAS – I**
Chair: ***N.N. Smirnov***

15.30–15.50 *R. Hechter, K. Rozovsky,* ***A. Yakhot****.* Turbulent pulsatile flow in an axisymmetric stenotic tube.

15.50–16.10 ***Ya.N*****.** ***Parshakova****, T.P. Lyubimova.* Numerical investigation directional solidification of binary alloys under the action of rotational vibrations.

16.10–16.30 ***N.N*****.** ***Kizilova.*** Mathematical modelling of coupled newtonian and non-newtonian flows for blood flows in the cardiovascular system.

16.30–16.50 ***S.A. Chivilikhin.*** The stokes equations in the special non-inertial system of reference.

16.50–17.10 **COFFEE BREAK**

17.10–18.50 **FLUID AND GAS – II**
Chair: ***N.N. Smirnov***

17.10–17.30 ***V.S*****.** ***Teslenko****, A.P. Drozhzhin, R.N. Medvedev.* Dynamics of cavitational clusters and vortex rings in water.

17.30–17.50 ***A.P*****.** ***Drozhzhin****, V.S. Teslenko.* Generation of pulse-cyclicflows in a liquid.

17.50–18.10 ***R.N. Medvedev,*** *V.S. Teslenko.* Calculation of the period of toroidal bubble pulsations during electrical discharge in an electrolyte in adiabatic approximation.

18.10–18.30 ***A.A. Alabuzhev.*** Cylindrical drop in oscillating electric field

18.30–18.50 ***Discussion***

Day 6 – Saturday, July 5

ROOM A

10.00–11.30 **PLENARY LECTURES – VI**
Chair: ***N.F. Morozov***
10.00–10.45 ***A.M. Krivtsov.*** Thermomechanical processes in discrete mechanics.
10.45–11.30 *I.A. Ovid'ko,* ***A.G. Sheinerman****.* Models of strength and toughness of nanostructured materials and graphene.
11.30–11.50 **COFFEE BREAK**
11.50–13.50 **MECHANICS OF MEDIA WITH MICROSTRUCTURE – II**
Chair: ***S.A. Lurie***
11.50–12.10 ***A.V. Porubov****, I.E. Berinskii.* Longitudinal plane waves in media with hexagonal structure.
12.10–12.30 ***J.A.W. Van Dommelen****, A. Sedighiamiri, L.E. Govaert.* Micromechanics of the deformation and failure kinetics of semicrystalline polymers.
12.30–12.50 *E.L Aero,* ***A.N. Bulygin****, Yu.V Pavlov, N.A. Reinberg.* Nonlinear theory of Deformation of crystal media with complex structure of lattice: plane deformation.
12.50–13.10 *E.L. Aero,* ***A.L. Korzhenevskii****.* Microscopic approach to reconstructive and martensitic phase transformations.
13.10–13.30 ***A.A. Vakulenko****, A.V. Zakharov* Microflows and periodic distortions in nematic liquid crystal cells imposed by a strong orthogonal electric field.
13.30–13.50 ***A.T. Akhmetov****, A.A. Rakhimov, A.A .Valiev.* Hydrodynamic effects emulsions and biological dispersions in microchannels with different configurations.

LUNCH BREAK

15.30–16.50 **MECHANICS OF MEDIA WITH MICROSTRUCTURE – III**
Chair: ***A.V. Porubov***
15.30–15.50 ***S.A. Lurie****.* Refined theory of microstructure-dependent beams and plates.
15.50–16.10 ***M. Poluektov****, J.A.W van Dommelen., L.E Govaert., M.G.D Geers.* Micromechanical modelling of the thermo-mechanical behaviour of oriented semicrystalline polymer foils.
16.10–16.30 ***T.M. Michelitsch,*** *B.A. Collet.* Nonlocal constitutive laws: lattice model approaches and their continuum limits.
16.30–16.50 ***S.H. Sargsyan****, K.A. Zhamakochyan.* Finite element method for solving boundary value problems of bending of micropolar elastic thin bars.
16.50–17.10 **COFFEE BREAK**

19.10–19.30 **CLOSING CEREMONY**

ROOM B

17.10–19.10 **POSTER SESSION**

Poster Session

1. **Argunova T.S., Gutkin M.Yu., Mokhov E.N., Nagalyuk S.S., Je J.H.** Micro-structural evidence of crack prevention in ALN crystals grown on gradually decomposing sic substrates.
2. **Arutuynyan A.R.** Consumption of fracture energy in speed and frequency experiments.
3. **Astafurov S.V., Shilko E.V., Dimaki A.V., Psakhie S.G.** Theoretical investigation of influence of multimodal internal structure on mechanical characteristics of intermetallic alloys.
4. **Astafurov S.V., Shilko E.V., Dimaki A.V., Psakhie S.G.** Investigation of influence of interphase boundaries characteristics on peculiarities of mechanical response of metal-ceramic composites.
5. **Azarov E.B., Rumyantsev S.A., Azarov E.B., Shihov A.M.** Mathematical model of the electromechanical system vibro-transporting machine with non-linear equations in the electric part.
6. **Balokhonov R.R., Romanova V.A., Martynov S.A.** Mesomechanical analysis of deformation and fracture in steel with a bilayer iron-boride coating.
7. **Balokhonov R.R., Schwab E.A., Romanova V.A.** Computational analysis of deformation and fracture localization in aluminum with laser deposited composite al-tic coating.
8. **Bortot E., Springhetti R., Dal Corso F., Gei M.** Numerical analysis of cracks and rigid line inclusions in elastic plates.
9. **Bosi F., Cocquio A., Cova M.** Testing protocol and experimental investigation on green body.
10. **Castellanos A., Durán-Olivencia F.J., Pontiga F.** Multi-species simulation of negative corona pulses in oxygen.
11. **Dal Corso F., Shahzad S., Misseroni D., Noselli G.** Validation of rigid inclusion model for the analysis of reinforced composite materials.
12. **Dal Corso F., Piccolroaz A., Poltronieri F., Romero-Baivier S.** Constitutive modelling of rock-like materials for industrial applications.
13. **Dmitriev A.I., Kolubaev E.A., Nikonov A.Yu., Rubtsov V.E., Psakhie S.G.** Study patterns of microstructure formation during friction stir welding.
14. **Dmitriev A.I., Kuznetsov V.P., Tarasov S.Yu.** Determination of boundary conditions of critical state of shear instability of the material surface under friction.
15. **Evlampieva S.E., Svistkov A.L., Parkaeva E.A.** The influence of structural features of composite material on its macroscopic properties.
16. **Fedorovsky G.** About endochronic approach, "horizontal" and "vertical" scaling at deformation and destruction modelling of rheology complex media.
17. **Garishin O.K., Lebedev S.N.** Computer modeling of the interaction between afm probe and nano-strands arising in the polymer at its destruction.
18. **Golotina L.F., Glot I.O.** Numerical simulation of the shape memory effects in semi-crystalline polymers in the non-uniform stress-strain state.
19. **Hakem A., Bilek A., Bouafia Y.** Study of the behavior and the tensile and impact failure of polycrystalline 43000 alloy subjected to variations in homogenization temperatures.
20. **Hamamda S., Revo S., Dorbani T., Zahaf A., Boubertakh A.** Calorimetric study of fluoroplastic containing nanotubes of carbon.
21. **Il'in V.A., Mordvinov A.N.** Investigation of electroconvection of poorly conducting liquid in the modulated electric field under unipolar charge injection with the cathode.
22. **Ivanova Yu.E., Ragozina V.E.** The evolution equations for intensive deformation problems of the elastic inhomogeneous medium.
23. **Kartavykh N.N., Il'in V.A.** Investigation of electroconvection of poorly conducting liquid in the alternating electric field of the horizontal capacitor.
24. **Klyueva N.V., Soldatov I.N.** Non-axisymmetric evanescent waves in a swirling viscous jet.

25. **Komar L.A., Shadrin V.V., Morozov I.A., Belyaev A.Yu., Mokhireva K.A.** Comprehensive analysis of the structure and mechanical properties of filled vulcanizates.
26. **Konovalenko Iv.S., Smolin A.Yu., Promakhov V.V., Konovalenko Ig.S., Psakhie S.G.** Computer study of the dependence of mechanical properties of ceramics based on metal nanocrystal oxides under compression loading on partial concentrations of pores with different size in its structure.
27. **Konovalov D., Smirnov S., Parchin S., Vyskrebentsev S.** Application of fem for estimation of residual stress in framework metalware.
28. **Krasnitckii S.A., Gutkin M.Yu., Kolesnikova A.L., Romanov A.E.** Generation of circular prismatic dislocation loops near spherical voids under anaxial compression.
29. **Kryzhevich D.S., Korchuganov A.V., Zolnikov K.P., Psakhie S.G.** Generation and evolution of local structural changes peculiarities in copper crystallites.
30. **Kucher D.A., Chivilikhin S.A.** Hydrodynamic model of hydrothermal synthesis of inorganic nanotubes.
31. **Mishuris G., Jones M.E., Fearn S., Winter R., Lennie A., Parker J., Thompson S., Tang Ch.** Dynamic strain in granular ceramics probed by real-time x-ray diffraction.
32. **Misseroni D.** Elastic characteristics of green bodies detected by ultrasonic tests.
33. **Morini L., Piccolroaz A., Mishuris G.** Cracks propagation in ceramic materials: a singular integral formulation.
34. **Morini L., Pryce L., Mishuris G.** Mathematical modelling of interfacial cracks in anisotropic and piezoelectric ceramic materials.
35. **Mugin O.O., Korendyasev G.K.** Innovative reduction approaches vibrations and noise transmitted to the machine environment.
36. **Pankratova E.V., Belykh V.N**. Synchronous chaos in a system of identical self-sustained electromechanical oscillators mounted on a movable platform.
37. **Petrov V.E.** Mathematical modeling of forced quasi 2d turbulence with global reaction.
38. **Piccolroaz A., Penasa M., Argani L., Bigoni D.** Integration algorithms of elastoplasticity for ceramic powder compaction.
39. **Piccolroaz A., Movchan A.** Dispersion and localization in structured rayleigh beams.
40. **Potianikhin D.A., Komarov O.N.** Mathematical modelling of the aluminothermic iron reduction process.
41. **Prozorova E.V.** Influence of the discrete on mathematical models for continuous mechanics and rarefied gas for great gradients.
42. **Sayah T.** Roughness and wear of sintered nanomaterials produced by hot isostatic pressing (HIP).
43. **Shadrin V.V., Garishin O.K., Korlyakov A.S.** Investigation of thermoplastic materials elastic-viscous-plastic behavior. experiment and simulation.
44. **Shilko E.V., Psakhie S.G.** Key features of shear (mode ii) crack propagation in sub-raleigh and intersonic regime.
45. **Smirnov A.M., Gutkin M.Yu.** Generation of rectangular prismatic dislocation loops in composite nanostructures.
46. **Smirnov A.S., Konovalov A.V.** Interrelation between the rheological behaviour of the Al-Mg-Sc-Zr alloy and the formation of microstructure under high-temperature deformation.
47. **Smirnov A.S., Konovalov A.V.** Identification of strain resistance model subject to volume fraction of dynamic recrystallization.
48. **Smirnova E.O., Smirnov S.V.** A technique for determining the stress-strain diagram by nano-scratch test results.
49. **Smirnova E.O., Zybkova T.A., Yakovleva I.L., Karkina L.E.** Characterization of two-phase material by nanoindentation.

50. **Smirnova E.O., Smirnov S.V., Veretennikova I.A., Fomin V.M., Bolesta A.V.** Mechanical properties of epoxy primer with silicon dioxide nanoparticals at the microlevel.
51. **Smolin I.Yu., Eremin M.O., Makarov P.V., Buyakova S.P.** Simulation of pore space structure and mechanical behavior of porous ceramics.
52. **Sobyanin K.V., Shardakov I.N.** Aircraft engine parts optimization using coupled transient thermo-mechanical analysis.
53. **Sokolov A.K., Shadrin V.V., Svistkov A.L., Terpugov V.N.** Mullins effect in the calculation of the stress-strain state of a car tire.
54. **Sprio S., Dapporto M., Tampieri A.** Highly osteointegrative, self-hardening biomimetic bone cements for vertebral regeneration.
55. **Sviyazheninov E.D.** Internal combustion engine ignition low-rpm transducer.
56. **Veretennikova I.A., Smirnov S.V.** A model of damage and fracture of the intermediate layer in metal materials produced by explosive welding during plastic deformation.
57. **Vjatkin A.A., Sabirov R.R., Kozlov V.G.** Effect of viscosity on convection and heat transfer in rotating horizontal cylindrical layer of liquid.
58. **Yaroshevich N.P., Yaroshevych O.N., Sylyvonyuk A.V.** Research of self-synchronization of the two biharmonic exciters on the bearing body that made plane vibrations.

Young Scientists Session "Modern ways In Mechanics (MWM) - 2014"

1. **Aleshchenko S.P., Korolev I.K., Freidin A.B., Vilchevskaya E.N.** Finite element simulation of a chemical reaction front propagation round a cylindrical hole in an elastic solid.
2. **Alfimov A.V., Aryslanova E.M., Chivilikhin S.A.** Modeling of the diffuse double-layer interaction between multiple identical spherical zinc oxide colloid nanoparticles in water.
3. **Alikina A., Stvolova S., Zubko I.** Finding equilibrium lattice parameter and internal energy dependencies on specimen size and temperature for metals with cubic crystal structure.
4. **Arkhipova N.I., Erofeev V.I.** Rod model specified in problems on the propagation of elastic waves in the laminated element designs.
5. **Aryslanova E.M., Alfimov A.V., Chivilikhin S.A.** Numerical and analytical modelling of porous alumina growth during anodization.
6. **Begun A.S, Kovtanyuk L.V.** Calculation of residual deformations at rotary motion of the elastoviscoplastic material.
7. **Brazgina O.** Hybrid material and spatial description for two-phase solid-fluid material.
8. **Chernyakov G.A., Kuleshov A.S.** Motion of a dynamically symmetric paraboloid on a perfectly rough plane.
9. **Demidov I.V.** Kapitza pendulum's motion at unconventional values of parameters and small dissipation coefficient.
10. **Dudko O.V., Lapteva A.A.** Features of reflection of deformation waves from the rigid boundary of a spherical layer in an multimodulus elastic medium.
11. **Dyakova V.V., Polezhaev D.A.** Temporal evolution of patterns of sand in a rapidly rotating cylinder partially filled with liquid.
12. **Galimzyanova K.N., Polonik M.V., Rogachev E.E.** Possibility to relieve residual stresses during annealing.
13. **Grigoriev A.S., Shilko E.V., Skripnyak V.A., Smolin A.Yu., Psakhie S.G.** Multiscale numerical study of fracture and dynamic strength characteristics of heterogeneous brittle materials using the MCA method.

14. **Grigorieva P., Markov N., Lapin R.** Simulation of the formation of earth-moon system from a protoplanetary cloud in the sun gravitational field.
15. **Grishchenko A.I, Semenov A.S, Melnikov B.E, Semenov S.G.** Influence of structural parameters of the masonry on effective elastic properties and strength.
16. **Gubenko M.M., Morozov A.V., Lyubicheva A.N.** Experimental determination of the contact characteristics during indentation of soft materials by video tactile pneumatic sensor.
17. **Gusarova V.V., Filimonov M.Yu., Vaganova N.A.** Computer simulation construction and operation of northern oil and gas fields.
18. **Ivanova O.A.** Unsteady approach to numerical simulation of conductor motion.
19. **Khurshudyan A.** On some problems of designs structural and topology optimization.
20. **Kolchanov N.V., Putin G.F.** Nonlinear regimes of convection in a horizontal layer of colloidal magnetic fluid.
21. **Kolchanova E.A., Kolchanov N.V.** Onset of convection in a two-layer system fluid – porous medium under modulated temperature gradient.
22. **Korchuganov A.V., Zolnikov K.P., Kryzhevich D.S.** Nucleation of radiation-induced plasticity in stressed crystals.
23. **Kotov V.V., Arseniev D.G., Polyanskiy V.A., Smirnova N.A.** Optimization of biomorphic vibration control.
24. **Kuzmina K.S., Marchevsky I.K.** On numerical schemes in 2d vortex element method for flow simulation around moving and deformable airfoils.
25. **Lobachev A.M., Lukin A.V., Modestov V.S., Popov I.A.** Calculative justification of safety of the reactor block brest od-300 case at seismic load.
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HYDRODYNAMIC EFFECTS EMULSIONS AND BIOLOGICAL DISPERSIONS IN MICROCHANNELS WITH DIFFERENT CONFIGURATIONS

Akhmetov A.T., Rakhimov A.A., Valiev A.A.
Institute of mechanics of URC, RAS
alfir@anrb.ru

The dynamic blocking phenomena is added to the main hydrodynamic property of high viscosity, compared with a viscosity continuous phase at inverse emulsions and biological dispersions flow in microchannels. The stationary flow of emulsion decelerates in time on some orders at a constant pressure drop in microchannel. It should be noted, that for emulsion the phenomena is discovered in a wide range of averaged pressure gradients up to 3 GPa / m and can not be described by capillary forces between the current medium and the surface in microchannels. The mentioned mechanism of dynamic blocking is based on friction between approaching microdroplets of water (with nanoscale covers of surfactant), its structurization and deformation.

The dynamic blocking phenomenon was initially discovered for flow of water-in-oil emulsion with technical emulsifier. It was found that it appears for the flow of emulsions with simple chemicals: distilled water (74 %), hydrocarbon phase was decane (22 %) and emulsifier "Span 80" (4 %). To identify components of forming structures we used a water soluble dye (0.1% of fluorescein). The emulsion structure was investigated by high-resolution microscope, emulsion is polydisperse droplets sizes are 1–8 microns.

Detailed studies of emulsion flow showed the dynamic blocking phenomenon in various types of microchannels, i.e. Hele-Shaw cell (forward and radial flow), single capillary (axial-symmetric flow), microchannel with different configurations prepared with method of soft lithography, micromodel (transparent complex structure of microchannels made by photolithography technique) and core samples. The most evident emulsion transformation was observed in the Hele-Shaw cell flow but it appeared that the most convenient and easy-to-use way for comparing of hydrodynamic properties of emulsions flow in microchannels was axial-symmetric flow in cylindrical capillary. Behavior of individual droplets in the flow could be observed in microchannels fabricated by soft lithography.

In experiments carried out in short capillary with length of 100 μm was found non-linear growth of emulsion flow rate with increasing pressure drop that is explained by water sublayer formation from coalescing water droplets at high shear rates.

Research of specifics of the dynamic blocking phenomenon showed that blocking caused by processes at the entrance of microchannel . The concentration of emulsion increases at the entrance of microchannel, droplets approach each other, appears "friction", pressure drop practically all falls at the entrance section of capillary, drops deforms, velocity decreases considerably. If at this time we will decrease pressure then degree of drop deformation has to decrease, interaction between them weaken and velocity of the flow will increase. These experiments demonstrated the validity of such suggestion.

The dynamic blocking phenomenon was also observed in case of blood flow through microchannel. The only difference is that the blocking in case of blood is not such stable as in case of water-hydrocarbon emulsions. This fact apparently is associated with non-spherical shape of red blood cells and with the fact that interaction of nano-dimensional lipid envelope of blood cells differs from interaction of water droplet's interfaces covered by surfactant molecules. Also, flow of blood in microchannel significantly depends on flow direction relative to the direction of the gravitation (up or down). When the flow is down the blocking is very stable, if flow is up then after the blocking happens blood sedimentation leads to resumption flowing and self-oscillating flow regime is observed. Observed dynamic blocking phenomenon of blood flow in cylindrical microchannel can be hypothesized as one of possible causes for heart attack and stroke in circulatory system of patients with stenosis of blood vessels

Hydrodynamic features of water-in oil emulsion in microchannels include: 1) the transformation of emulsions, 2) an appearance of the dynamic blocking which is associated with the occurrence friction between of nanoscale covers of the surfactant in the points of contact of water droplets, their deformation and subsequent structuring through redistribution of the pressure field in front of the microchannel, 3) non-linear growth flow rate emulsion with increased pressure gradient, 4) the increasing of flow due to decreasing pressure in a condition of dynamic blocking

STATIC AND DYNAMIC TECHNIQUES FOR NONDESTRUCTIVE ELASTIC MATERIAL PROPERTIES CHARACTERISATION

Akishin P. Y.[1], Barkanov E. N.[1], Wesolowski M.[2], Kolosova E. M.[3]
1 - Riga Technical University
2 - Koszalin University of Technology
3 - Southern Federal University
a_lena_ch@mail.ru

Modern composite materials have promising perspectives for an application in the advanced composite repairs of pipelines. Their technical data could be estimated by using conventional fracture methods or nondestructive technique. In the case of high costs of advanced composites, their experimental testing with conventional fracture methods looks as less effective due to the destructive nature of such experiments. On these reasons different nondestructive techniques have been adapted or developed for a characterisation of advanced composite material properties. There are static approach using three-point-bending test and two dynamic methods, namely, impulse excitation method and inverse technique based on vibration tests.

Tree-point-bending test and impulse excitation method use beam-like specimens for a characterisation of the elastic material properties. Tree-point-bending test allows the determination of Young's modulus of the material in the longitudinal direction of specimen which is calculated in terms of the measured centre deflection, applied load and geometry of a beam. To keep this approach nondestructive, only the elastic behavior of composite beams is allowed. It can be obtained usually for strains less than 0.5%.

Vibration test based on the impulse excitation is adapted for a determination of the elastic properties of small beam samples. This method originally developed for the testing of heavy concrete specimens can be applied for a lightweight structure providing the non-contact vibration excitation and sensing, so that no additional mass will corrupt the resonance frequencies. Beam like specimens used in this method have specific resonances that are determined by the frequency equation. In order to compute the elastic properties, it is necessary to establish dimensions, density and experimental fundamental frequencies in bending and twisting of the beam with free-free boundary conditions.

The basic idea of the inverse technique based on vibration tests of plate-like specimens is that simple mathematical models (response surfaces) are determined only by the finite element solutions in the reference points of the plan of experiments. The identification parameters are obtained minimising the error functional, which describes a difference between the measured and numerically calculated parameters of structural responses.

The present techniques have been successfully applied for a characterisation of the orthotropic material properties of laminated composites. Later these nondestructive techniques have been adapted for a testing of small-dimension specimens to study the elastic properties of aluminum alloys with different carbon nanotubes volume content.

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CYLINDRICAL DROP IN OSCILLATING ELECTRIC FIELD

Alabuzhev A.A.[1,2]
1 - ICMM UB RAS, Perm, Russia
2 - PSU, Perm, Russia
alabuzhev@mail.ru

The forced oscillations of a cylindrical drop are considered in the present work. The drop is suspended in the different fluid and confined by two parallel rigid plates, subjected to oscillating electric field. The equilibrium contact angle is right. The external electric field plays the role of source of motion and forces the contact angle to change in time. Hereafter, we assume that the external force is time periodic. To describe the motion of the contact line uses a modified condition Hocking: the contact line velocity is proportional to the contact angle deviation and the velocity of the fast relaxation processes whose frequency is proportional to the frequency of the electric field. The coefficient of proportionality is the Hocking constant.

The surface distortion and the frequency characteristics depending from Hocking constant, frequency and amplitude of an external electric field and the geometric parameters of the system are investigated. It is shown that with increasing constant Hawking effect of the electric field becomes more significant than the dissipative effects in the mechanical motion of the contact line. It increases the oscillations amplitude and is a cause of resonance. The effective boundary condition leads to dissipation and the oscillation amplitude is always limited without electric field. If the external electric field is oscillating, there are also "antiresonance" frequency as in the conventional mechanical vibrations drops.

Behavior of a gas bubble instead of a liquid droplet discussed also. The gas state described by polytrophic process. Bubble was surrounded by an incompressible fluid of finite volume with a free lateral surface.

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FINITE ELEMENT SIMULATION OF A CHEMICAL REACTION FRONT PROPAGATION ROUND A CYLINDRICAL HOLE IN AN ELASTIC SOLID

Aleshchenko S.P.[1], Korolev I.K.[1], Freidin A.B.[1,2,3], Vilchevskaya E.N.[1,2]
1 - Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg, Russia
2 - Saint-Petersburg State Polytechnical University, St. Petersburg, Russia
3 - Saint-Petersburg State University, St. Petersburg, Russia
aleshchenkosp@gmail.com

We present a numerical solution of a plane problem of mechanochemistry considering a chemical reaction front propagation in the vicinity of a cylindrical hole in an elastic solid. The reaction similar to the oxidation of silicon is sustained by the diffusion of a gas constituent through the transformed material. The reaction front velocity is determined by the normal component of a chemical affinity tensor that depends on stresses which in turn depend on the reaction front position [1-3]. We execute the theoretical model developed using finite-element software package. First, we verified the numerical procedure comparing numerical and analytical solutions for the case of a body with a cylindrical hole under all-round tension. Then we study how the front propagates in the cases of various loading conditions. We demonstrate different scenarios of chemical reaction front propagation under different external stresses and temperatures.

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MODELING OF THE DIFFUSE DOUBLE-LAYER INTERACTION BETWEEN MULTIPLE IDENTICAL SPHERICAL ZINC OXIDE COLLOID NANOPARTICLES IN WATER

Alfimov A. V., Aryslanova E. M., Chivilikhin S. A.
St. Petersburg National Research University of Information Technologies, Mechanics and Optics
alfimov.anton@gmail.com

The extensive applications of nanomaterials such as nano colloids in various scientific, industrial and customer products areas makes the understanding of their synthesis, transformations and behavior when released into the environment an important task of modern science [1]. According to the widely used DLVO (Derjaguin, Landau, Verwey, Overbeak) theory [2] the definitive mechanism behind the transformations of the colloidal solutions of nanoparticles is the particle coagulation process governed primarily by the electrostatic repulsion due to the overlap of electric double layers.
The paper is devoted to the theoretical description of interaction forces between zinc oxide nanoparticles in the water during the initial stage of the slow coagulation process. Slow coagulation occurs when the repulsion forces between particles are significant enough that they can’t be neglected, while still allowing the coagulation with a certain probability. During the initial stage of this process the forming agglomerates consist of a small number of nanoparticles and the deagglomeration is possible. This means that it is necessary to explicitly describe the multiparticle interactions in these agglomerates to accurately model the conditions of their growth, de-aggregation or size stabilization.
In the presented work a method of modifying the standard linear superposition approximation (LSA) [3, 4] for the Debye-Huckel equation describing the potential distribution in a system of two interacting particles is suggested to extend it’s applicability to a multiple particle cases. The modification of the LSA method is based on using the effective potential distribution instead of a potential distributions of an isolated particle. The calculation of the effective potential distributions of interacting particles is based on a proposed phenomenological charge regulation model, which assumes that the dense counter-ion layer of a particle can be presented as a layer of counter-ions with constant concentration, penetrable by the diffuse layer.
The thickness of said layer is determined by the balance between the work of electrostatic attraction force of particle’s charged surface on the counter ions versus the energy of thermal motion and attraction to other particles. Thus the thickness of the dense ion layer is dependant on the particle’s surroundings, and its variation will result in corresponding changes of the charge on the outer surface of the dense layer.

As a result, the developed model allows to analytically derive the expressions for linearly additive interaction energies in a system of multiple nanoparticles using the LSA formulation by Ohshima [3] by solving a system of N linear algebraic equations for every geometrical configuration of N interacting particles.

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FINDING EQUILIBRIUM LATTICE PARAMETER AND INTERNAL ENERGY DEPENDENCIES ON SPECIMEN SIZE AND TEMPERATURE FOR METALS WITH CUBIC CRYSTAL STRUCTURE

Alikina A., Stvolova S., Zubko I.
Perm National Research Polytechnic University, Perm, Russia
jubilee.66@mail.ru

The purpose of the present work is to obtain estimations of thermomechanical properties of metal monocrystals with cubic lattice and finding their dependencies on specimen size and temperature. The lattice static approach is used for solution of the problem, and metallic bonding is modelled by the embedded atom method with modified empiric potential based on the Mie's family interatomic potentials. For the aim of the crystal temperature control the computational-statistical approach to studying thermo-mechanical properties for the finite sized crystals is presented. Interaction between all atoms of the specimen is taken into account. We suggested imitating heat oscillations of the atoms by applying random heat perturbations with the fixed amplitude A on the system of the atoms under the uniform distribution of directions for the atoms shifts in space. The question of the correct temperature introduction in the lattice statics approach is discussed.

An expression for equilibrium interatomic distance for any crystal lattice of metals (heated or not) is obtained for the considered potential. Also an expression for the minimum of potential energy at any heated crystal configuration is found. The equilibrium curves of the potential energy density dependencies on the atom perturbation amplitude A for the FCC and BCC metal are found in computation. These curves have one explicit point of intersection at the sufficiently large value of A and possess a tendency for the second intersection under further increasing of the heat oscillation amplitude A. These common points of the considered curves are treated as phase transition points. They allow identifying parameters of the heating model in the lattice statics approach.

All considered parameters of crystals are strictly depend on specimen size, so from mechanical point of view nanoparticles are made of different material in compare with macroscopic specimens in spite of the fact that chemically they are the same.

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THE EFFECT OF COPPER CONTENT, ANNEALING TEMPERATURE, AND AGING TIME ON THE HARDNESS OF ALUMINUM ALLOYS USING ARTIFICIAL NEURAL NETWORKS ANALYSIS

Al-Lubani S.E.
Al-Balqa Applied University, Jordan
slubani@huson.edu.jo

In this study the effect of annealing, aging temperature, aging time and copper content on the hardness of aluminum alloys, using mathematical modeling tools of Artificial Neural Networks (ANN).

Worked out model should be used for prediction of hardness only in particular groups of alloyed copper, mostly because of the discontinuous character of input data.

A data established for different series of aluminum alloys Neural network with the back-propagation (BP) learning algorithm had been applied to predict hardness. Annealing temperature, aging temperature, aging time and copper content have been defined as the input Parameters of ANN. The output layer of the ANN model consists of hardness. This model can predict the hardness within an average error less than 1%.

DISLOCATIONS AND INCLUSIONS IN PRESTRESSED SOLIDS

Argani L.P.[1], Bigoni D.[1], Mishuris G.[2]
1 - Department of Civil, Environmental and Mechanical Engineering - University of Trento (Italy)
2 - Institute of Mathematics and Physics - Aberystwyth University (UK)
luca.argani@ing.unitn.it

The theory of dislocations and inclusions in solids has been thoroughly developed for elastic materials, unloaded in their natural state. We extend this theory to cover the possibility that the material is prestressed, through a generalization of solutions found by Eshelby [1–3] and Willis [4], by introducing an incremental formulation for incompressible materials, in which the nominal stress is related to the incremental displacement gradient, within a constitutive framework (which embraces Mooney-Rivlin and Ogden materials and also material models describing softening [5]) under the plane strain constraint, even if several of the presented results remain valid within a three-dimensional context [6]. Anisotropy strongly influences near dislocation stress fields and almost all crystals are anisotropic, so that anisotropy has been the subject of an intense research effort [7–9] and has been recently advocated as a way to study dislocation core properties [10,11].
Our interest is to analyse the effect of orthotropy induced by prestress on dislocation (and inclusions) fields, within the general framework of incremental non-linear elasticity [12], so that our investigation is addressed to ductile materials subject to extreme strain, where the nucleation of a clustering of dislocations into a 'super dislocation' perturbs a material that has a low stiffness, so low that the differential equations governing the incremental equilibrium are close to the boundary of ellipticity loss.
When this boundary is approached (from the interior of the elliptic region), our solution for edge dislocations (but also, in general, for inclusions) reveals features of severely deformed metals near the shear band formation. In this situation we show that emission of a dislocation (which can be also viewed as a 'super dislocation') dipole produces incremental fields strongly localized along the directions of the shear bands, formally excluded within the elliptic region. This may induce a cascade of dislocation clustering, which may explain the fact that the amount of slip that takes place on an active shear band is three orders of magnitude greater than could be produced by the passage of a single dislocation [13].

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MICRO-STRUCTURAL EVIDENCE OF CRACK PREVENTION IN ALN CRYSTALS GROWN ON GRADUALLY DECOMPOSING SIC SUBSTRATES

Argunova T. S.[1], Gutkin M. Yu.[2,3,4], Mokhov E. N.[1], Nagalyuk S. S.[1], Je J. H.[5]
1 - Ioffe Physical-Technical Institute RAS, St. Petersburg, Russia
2 - Department of LED Technologies, ITMO University, St. Petersburg, Russia
3 - Department of Mechanics and Control Processes, St. Petersburg State Polytechnical University, Russia
4 - Institute of Problems in Mechanical Engineering RAS, St. Petersburg, Russia
5 - Department of Materials Science, Pohang University of Science and Technology, Republic of Korea
argunova2002@mail.ru

Wide bandgap semiconductors GaN and AlN represent great interest for the production of optoelectronic and high power electronic devices. AlN is a native substrate material for III-nitride epitaxy. Physical vapour transport growth of AlN on SiC has advantages over other methods because of a small lattice mismatch between AlN and SiC and the availability of large area SiC substrates. The latter makes it possible to obtain AlN crystals up to 2 inches in diameter [1]. However, their crystalline quality is seriously limited by stresses coming from the lattice mismatch (of ~1%), a thermal gradient in the growing crystal, and, mainly, the difference in the thermal expansion coefficients of SiC and AlN. In fact, the grown AlN crystals often crack while cooling down [2-5], so the optimization of the growth technique to prevent AlN cracking is nowadays an important problem. Theoretical modeling of stress distribution as well as x-ray diffraction and Raman characterizations showed that AlN crystal quality improved as its thickness increased [2, 4]. An ideal way to eliminate thermal stresses is a complete evaporation of substrates that would lead to thick freestanding AlN crystals. However, a more realistic way is a gradual decomposition (hence thinning) of the substrates at high temperature [6]. In this communication, we report the micro-structural evidence of crack prevention in AlN crystals grown on gradually decomposing SiC substrates.

AlN crystals were fabricated by the sublimation sandwich method in Ta crucible [1]. On the first (growth) stage, the temperature was 1870-1890° C. Then the temperature in the chamber was increased up to 2010° C. On the second stage, the substrate was decomposed with the rate 60-100 µm h^{-1}, while the layer continued growing with the rate of 100-200 µm h^{-1}. In fact, the substrate could be removed during ~10 h of growth. The grown crystals were investigated by synchrotron radiation (SR) imaging. The experiments were performed at 6D X-ray micro-imaging beamline in Pohang Light Source of South Korea, the 3rd generation SR source operating at 3 GeV. X-ray diffraction topography and phase contrast setups were arranged in a sequence in polychromatic SR light. Topography is sensitive to lattice strain, while phase-contrast of micro-objects is formed by fast density gradients. The combination of the methods allowed us to evaluate an overall crystal quality from Laue-topographs, to reveal dislocations and their arrangements, to observe pores and microcracks. The micro-structures were discussed in view of theoretical analysis of thermal stress distribution across the AlN-on-SiC structure with gradually decreasing thickness of SiC substrate. It was shown that, in accordance with theoretical estimates, the structural quality of AlN crystals grown on gradually decomposing SiC substrates was much higher compared with those grown on SiC substrates of constant thickness. In particular, the cracking was practically suppressed in the bulk of AlN crystals, although we observed dislocations and some pores.

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ROD MODEL SPECIFIED IN PROBLEMS ON THE PROPAGATION OF ELASTIC WAVES IN THE LAMINATED ELEMENT DESIGNS

Arkhipova N.I., Erofeev V.I.
Mechanical Engineering Research Institute of the Russian Academy of Sciences
united-friends@bk.ru

The article shows that sophisticated (non-classical) core models can be used to describe the dynamic processes in layered structural elements . Arguments are the example of a two-layer rod committing longitudinal vibrations .

The compound rod considered is a combination of two bars contacting each other. The contact interaction force is assumed to be linear-elastic. The motion of the rods is described by a system of equations: at an initial time, a pulse of the cinematic or force nature is applied to the left end of the rods, the right end being free.

The above system can be reduced to a single equation in terms of the median line displacement of one of the rods. A similar equation can be derived in Mindlin-Herrmann's model describing longitudinal oscillations of the rod. Thus, longitudinal oscillations of a compound rod can be described by Mindlin-Herrmann's equation of longitudinal oscillations of a hypothetical rod. Reduction to Mindlin-Herrmann's model is possible if the parameters of the compound rod satisfy the following condition: the product of the density and the cross-section area of the first rod are thrice as much as that of the second one. For the system of parameters to be simultaneous, it is also necessary that the longitudinal and shear wave velocities are equal. In that case, the thickness of the equivalent rod will increase with increasing the force of elastic interaction of the rods and will decrease with decreasing the linear density of the first rod. The correcting coefficients in Mindlin-Herrmann's model are related with the parameters of the initial rods, allowing one to derive the expression for the shear wave velocity.

In the particular case, if the density of one of the rods is considered to be small, the equation set will be reduced to the equation of longitudinal oscillations of a rod in Bishop's model. In that case, the parameters of the compound rod have to satisfy the following condition: the relation of Young modulus of the second rod to that of the first one is to be bigger than the relation of the cross-section area of the first rod to that of the second one, while the polar radius of inertia and Poisson's coefficient of the equivalent rod are to be determined by relations.

The longitudinal and shear wave velocities in a rod in Bishop's model are expressed in terms of the longitudinal wave in the initial rod.

The wave energy in homogeneous dispersing systems is known to be transferred at a group velocity [1].

A dynamic equation of a rod characterized by a Lagrangian depending on the longitudinal displacements and their partial derivatives was derived. The energy density and the flow density of the wave energy are derived from the energy transfer equation and phase-averaged. The notion of the wave energy transfer velocity is introduced, representing the ratio of the average value of the energy flow density to the average value of the wave energy density. The displacements obey the progressing harmonic wave law, which is used to determine frequency, wave number and group velocity. Thus, the wave energy velocity and the group velocity are shown to be equal; hence the elastic wave energy is transferred over layered structural elements at the group velocity as well.

A compound rod is then considered; the contact interaction force is assumed to be linear visco-elastic. The motion of the rods is also described by a system of equations. The system can be reduced to a single equation in terms of the median line displacement of one of the rods. It is noted that an analogous equation can be derived in Mindlin-Herrmann's system.

Thus, the longitudinal vibrations of a compound rod, both for the elastic and visco-elastic contact interaction, are described by Mindlin-Herrmann's equation of longitudinal oscillations of a hypothetical rod.

A nonlinear-elastic compound rod is also considered. The motion of the rods is described by an equation system: with elastic and viscous interaction forces. As in the above cases, the system is reduced to a single equation in terms of displacements of one of the rods.

Then notation in dimensionless values is introduced, partial derivatives are expressed and the notations are used. After the transformations, the equation for the dimensionless value is obtained. This equation can be reduced to non-linear generalized Mindlin-Herrmann's equation, which later, following the transformations, will be rewritten in the form of a differential equation describing the oscillations of a non-harmonic oscillator with quadratic nonlinearity [2]. The parameters of the differential equation are evaluated, and the roots of the denominator are determined.

Two cases are considered: that of a positive and that of the negative soliton [3]. In each case, the amplitude and the oscillation time are determined. Each form of these solutions is represented on the diagrams. It can be concluded that: in the case of a positive soliton, the oscillation amplitude increases and the oscillation time decreases with the velocity, which is characteristic of a classical soliton; whereas in the case of a negative soliton, the oscillation amplitude decreases and the oscillation time increases with the velocity, which is characteristic of a non-classical soliton.

In the case of a classical soliton, the investigation of the behavior of the oscillation amplitude showed that, if its parameters in the formula are related in such a way that one of them contained in the numerator increases, the rest of them contained in denominator decrease, then the oscillation amplitude increases.

For the case of a non-classical soliton, the behavior of the oscillation amplitude was also studied. It was found that, if the parameters in the formula are related in such a way that, one of them contained in the numerator increases, the rest of them contained in denominator decrease, then the oscillation amplitude increases.

Thus, the propagation of solitary waves in a nonlinear elastic compound rod has been demonstrated. Depending on the velocity, waves are divided into classical and non-classical ones. The behavior of the oscillation amplitude for a classical and a non-classical soliton has also been studied.

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CONSUMPTION OF FRACTURE ENERGY IN SPEED AND FREQUANCY EXPERIMENTS

Arutuynyan A.R.
Sankt-Petersburg State University
Robert.Arutyunyan@paloma.spbu.ru

Results of experiments on investigation of fracture energy consumption in speed and frequency experiments at static and cyclic loadings presented. The energy consumptions are defined in accordance with the nonlinear law of summation of the damages, expressed in terms of relative value of energy consumptions. From the received results follows that the fracture energy consumptions essentially depend on the application sequence of speeds and frequency loadings. In speed experiments the plane specimens, made of polymethylmethacrylate, were tested at alternation of two levels of speeds loadings (1 mm/min. and 8 mm/min.). Experiments were carried out at room temperature for the specimens of the following sizes: the length of the working part was 60 mm, the width was 10 mm and the thickness was 5 mm. The speed loadings experiments at alternation of two levels of frequencies were performed on Lloyd 30k PLUS testing machine. Preliminary results of experiments on cyclic loadings over plane specimens from polymethylmethacrylate of frequency loadings (10 Hz and 60 Hz) are also presented. The frequency experiments were performed on Si-Plan SH-B testing machine. From the received experimental results follow that the energy consumptions at fracture are essentially depended on the regimes of speed and frequency loadings and they should be taken into account in design and exploitation of various equipments for processing and milling of the solid materials.

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FRACTURE PROBLEM OF BRITTLE AND QUASIBRITTLE MATERIALS

Arutuynyan R.A.
Sankt-Petersburg State University
Robert.Arutyunyan@paloma.spbu.ru

In the world scientific literature numerous investigations are carried out on development of fracture criteria of brittle and quasibrittle materials. At the same time the creep fracture or static fatigue problem for these materials is investigated not enough. To solve this problem the conception of damage and fracture of Kachanov-Rabotnov is applied. It was taken into account, that imperfectness and microinhomogeneity of brittle and quasibrittle materials have casual character and at formulation of creep fracture criterion the probability methods are applied. It is considered that the specimen made of the brittle and quasibrittle materials consist of elements with the different initial states of damage. Distinctions of the damaged state of elements are determined by such factors, as porosity, phase composition, presence of micropores and microcracks of different size and other. So the damage distribution in small microvolumes are considered as the random The kinetic equation for development of damage parametrs with the random initial size distribution is proposed. The time to facture, i.e. achievement of critical size of one of damaged elements, can be also considered as random. Thus, the statistical models, based on the hypothesis of weak link, and at formulation of the creep fracture criterion the Weibull's conception of brittle fracture are applied.

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NUMERICAL AND ANALYTICAL MODELLING OF POROUS ALUMINA GROWTH DURING ANODIZATION

Aryslanova E. M., Alfimov A. V., Chivilikhin S. A.
NRU ITMO
elizabeth.aryslanova@gmail.com

Currently the scope of anodic aluminum oxide (AAO) use expanded from protection against corrosion, electrical protection, thermal protection to a development of a template for the synthesis of various nanocomposites. Such as: synthesizing nanotubes with matrix method [1-5]: 50-60 nm thick films, with an ordered system of nanopores (diameter of 40-100 nm) is used for synthesizing oriented carbon nanotubes using pyrolysis of dichloromethane (CH_2Cl_2) under an inert atmosphere of argon at 500 °C the synthesis varies from six minutes to 4 hours [6]; the ability to control parameters of the porous structure of Al_2O_3 can be used as filters, carriers for catalysts [2-5]; films with high regularity of the porous structure are increasingly used for creating nanoscale structures in electronic, magnetic, and photonic devices [7]; with sorption of silver ions in the matrix of porous alumina, followed by chemical deposition nanocomposites are synthesized with biochemical activity properties [8].

The composition of these regions varies and depends on the conditions of anodization. The inner part of the cell may include the electrolyte anions, where the "skeleton" is made of pure hydrated alumina [9]. The diameter and the distance between them can vary (pore diameter - from 2 to 350 nm, the distance between the pores - from 5 to 50 nm), using different electrolytes, voltage and anodizing time [3, 10].

In the anodizing process, aqueous solutions of acids (oxalic acid, phosphoric acid, chromium, etc.) moderately dissolve oxide Al_2O_3. The process is carried out in a vessel with the electrolyte, which houses the anode (aluminum) and a cathode (inert conductive material), which are respectively connected to the positive and negative power supply output. Thus on the metal film is formed, the top layer of which is a microporous partially hydrated metal oxide, under which is the lower layer - anhydrous microscopically thin glassy oxide film has considerable hardness.

Currently, there are various models of the growth of a porous film of aluminum oxide, but not the models that take into account the effect of the electrolyte layers of aluminum and the growth rate of aluminum oxide, as well as in the models described not influence the effect of surface diffusion. This paper presents a model that accounts for these effects.

As a result of the created model, equations were found for changes in disturbance of aluminum oxide for the initial stage of anodizing process for aluminum-alumina and alumina electrolyte borders, with the effect of surface diffusion of aluminum oxide.

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INVESTIGATION OF INFLUENCE OF INTERPHASE BOUNDARIES CHARACTERISTICS ON PECULIARITIES OF MECHANICAL RESPONSE OF METAL-CERAMIC COMPOSITES

Astafurov S.V.[1,2], Shilko E.V.[2,1], Dimaki A.V.[2,1], Psakhie S.G.[2,1]
1 - Tomsk state university, Tomsk, Russia
2 - Institute of strength physics and materials science SB RAS, Tomsk, Russia
svastafurov@gmail.com

Metal-ceramics alloys are representatives of particle strengthened composite materials. They are characterized by high values of mechanical and operational characteristics such as strength, hardness, durability, crack resistance, thermal stability, etc. This makes metal-ceramic composites very attractive for a wide application in various industrial fields as materials used in extreme conditions (Chawla and Chawla, 2006). In particular, such materials are widely used in the manufacture of metalworking tools. So, an important direction in modern deformable solid mechanics is study and structural design of metal-ceramic composites for the purpose of improvement their operating characteristics. A promising way to improve mechanical characteristics of metal-ceramic composites is a purposeful formation of high-strength multiscale phase structures in the surface layers by pulsed electron-beam irradiation [1]. For example, such surface treatment of sintered alloy 50 vol.% TiC-50 vol.% NiCr leads to a considerable increase in the mechanical and service characteristics of the surface layer. Results of experimental investigations showed that increasing of the operational characteristics of the modified composite is associated with the formation in the surface layers of the multimodal (multiscale) internal structure. One of its main elements are relatively wide transition zones at the titanium carbide-metallic binder interfaces. These zones are characterized by concentration gradient of chemical elements (Ti, C, Ni and Cr) and as a consequence, the gradient of mechanical properties with increasing distance from the surface of the inclusion.

Interfaces between the reinforcing particles and metal binder are one of the main elements of the internal structure of metal-ceramic composites. Thus, the interphase boundaries in the metal-ceramic composites are important structural elements having their own set of dimensional, structural and mechanical characteristics. Therefore, the formation of wide interphase boundaries in the surface layers of metal-ceramic composites after of electron-beam treatment should be one of the main reasons for increasing of operational characteristics of the material. Experimental study of the effect of this factor on the properties of metal-ceramic composites is quite difficult problem. So, it can be efficiently solved with help of computer modeling using particle-based methods. The present paper is devoted to development of a structural and rheological model of metal-ceramic composites in the framework of movable cellular automaton method [2-4]. To achieve the objectives of the paper a two-dimensional structural and rheological model of the composite material was developed in the framework of movable cellular automaton method. In this model NiCr-based metal-ceramic composite is considered as a plastic binder with integrated brittle high-strength spherical TiC inclusions of mesoscopic scale size. Each of constituents is modeled by ensemble of movable cellular automata with appropriate rheological parameters.

Analysis of the simulation results showed that the presence of wide transition zones at the interfaces of the ceramic inclusions and the metallic binder increases the strength, ultimate strain and fracture energy of the composite. This effect is associated with a significant decrease in stress gradient on the wide interphase boundaries characterized by a smooth change of the mechanical properties of the material in the transition zones. It is necessary to note, that mechanical and operational characteristics of the surface layers of metal-ceramic composites after electron-beam irradiation (strength, hardness, wear resistance, etc.) greatly depend on the parameters of the treatment (pulse duration, energy density of the electron beam, etc.). This effect is connected with peculiarities of the internal structure and, consequently, the mechanical properties of formed interphase boundaries during electron-beam irradiation. Thus, formation of surface layers characterized by a smooth changing of mechanical properties during the transition from the surface of the ceramic inclusions into volume of the metallic binder leads to increase in strength and deformation characteristics of the material.

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THEORETICAL INVESTIGATION OF INFLUENCE OF MULTIMODAL INTERNAL STRUCTURE ON MECHANICAL CHARACTERISTICS OF INTERMETALLIC ALLOYS

Astafurov S.V.[1,2], Shilko E.V.[1,2], Dimaki A.V.[1,2], Psakhie S.G.[1,2]

1 - Tomsk state university, Tomsk, Russia

2 - Institute of strength physics and materials science SB RAS, Tomsk, Russia

svastafurov@gmail.com

It is well known that alloys based on Ni3Al intermetallic compound are characterized by a high melting point, low density, high values of heat and corrosion resistance. This makes them attractive for use in modern friction units. Increase of strength and durability of intermetallic alloys is possible by repeated grinding of their grain structure. This is possible by means of severe plastic deformation of the intermetallic compound in a narrow time interval of its existence in the combustion wave of a powder mixture of nickel and aluminum. Existing experimental results showed that the plastic deformation of the product of high-temperature synthesis leads to the formation in intermetallic compound Ni3Al of multiscale grain structure containing multigrain (grains consisting of subgrains of submicron dimension). This leads to multiple increase in the ultimate strain and strength of the intermetallic compound. This paper is devoted to theoretical investigation of the influence of the multimodal internal structure on the mechanical characteristics of hard alloys based on the intermetallic compound Ni3Al. The study was carried out on the basis of computer-aided simulation by movable cellular automaton method (MCA). For investigation of influence of multigrain structure on mechanical response and fracture mechanisms of the intermetallic compound Ni3Al a two-dimensional structural-rheological model was used. This model explicitly takes into account the main features of the internal structure of the material.

Analysis of the results of computer-aided simulation showed that increase in the strength and deformation characteristics of the intermetallic compound Ni3Al, obtained in the process of high-temperature synthesis with plastic deformation of the product of the synthesis, is connected with the change of mechanical properties of main elements of the internal structure of the material. Thus, increase in the ultimate strain of the material is primarily due to the formation in its volume of relatively ductile (as compared with the conventional coarse Ni3Al grains) multigrains. Note that the reason for increased ductility of multigrains is that subgrains have structure and composition similar to the single crystal of Ni3Al and, as a consequence, a lower strain hardening coefficient and higher strength characteristics as compared with the conventional coarse grains of the intermetallic alloy. This allows them to undergo significant plastic deformation without fracture. Another important factor which influences on the strength of the intermetallic alloy is the increase in the strength of the grain boundaries. The reason for this is due to the fact that increase in the value of severe plastic deformation of the product of high-temperature synthesis leads to greater compaction of the reacting mixture and hence reduced porosity of the synthesized material.

MATHEMATICAL MODEL OF THE ELECTROMECHANICAL SYSTEM 'VIBRO-TRANSPORTING MACHINE' WITH NON-LINEAR EQUATIONS IN THE ELECTRIC PART

Rumyantsev S.A., Azarov E.B., Shihov A.M.

USURT

SRumyantsev@math.usurt.ru

The mathematical model of the electromechanical system 'Vibro-transporting machine' with linear equations system of drive induction motors offered by the authors in papers [1,2] is not efficient enough to describe transient dynamic processes, appeared when starting the vibro-transporting machine.

During investigations, carried out by numerical experiment method with mathematical model, it was ascertained that differential equations of induction

motors with fixed factors, which are part of the mentioned system, describe the operation of vibro-transporting machine in steady operation mode. However when describing transient processes, which accompany machine start and acceleration, the linear model gives inadequate results [2].
It is obvious that when modeling the start of transient processes it is necessary to take into consideration variableness of motors' physical properties range and therefore variableness of factors range (i.e. current rotor angular rate dependence).
In the report it is presented a new dynamics model of electromechanical system 'vibro-transporting machine – electric motors', which considers the effect of current displacement in rotor winding bars of induction motors. This model is considerably non-linear both in mechanical and electric part, which allows to describe more precisely the starting transient processes, accompanying the stage of motor acceleration.

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LOCALIZATION IN MECHANICS AND NATURE

Babeshko V.A., Evdokimova O.V., Babeshko O.M., Grishenko D.V.
Southern Scientiific Center RAS
babeshko41@mail.ru

It has been established that it is convenient to describe a number of natural anomalous processes, which consist in localizing the energy within certain spatial regions, as a result of manifestation of a natural virus. The natural virus makes it possible to reveal the conditions of occurrence of anomalies and, thus, to search for various ways of decreasing fatal natural processes. Introduction of natural virus is a result of detecting new regularities in the natural processes, which are reasonably adequately describes by mixed boundary-value problems in a great variety of fields. It is convenient to represent these regularities by reproducing the concept of a natural virus, and to interpret the occurrence of anomalies as its manifestation at different levels up to an anomalous state of the natural processes under consideration.
Thus, natural viruses are some kind of indicators of the state of natural processes, when the cause and effect relation of such a state given in terms of physical parameters of the process is mathematically described reasonably well instead of revealing only qualitative and certain quantitative estimates of the process.
It can assert that the distribution of the natural-process energy is reasonably uniform in a region when the virus does not manifest itself. As the virus manifests itself, the process energy is localized in one or several zones of the region. the degree of localization depends on the virus-manifestation level. At the limit, the localization results in anomalous behavior of the natural process in the indicated zone or outside of it depending on the natural-process type. As examples of such processes, we can mention the following: waterspouts (tornadoes), when the energy originally distributed in a sufficiently large region is localized within the zone of the narrow whirlwind cylinder – the tornado trunk; storm phenomena accompanied by intense chaotic motion of air and water masses in a certain zone and a significant calmness outside of it; the occurrence of considerably directed displacement in the contact zones on the deformed-medium surface and their smallness outside of the zone; and the localization of temperatures directly related to the localization by the thermal energy. There are other examples as well.
It succeeded in conducting the investigation with the use of the block-element method, which enabled us to establish new mathematical relations describing the anomalous natural regularities.
We found the conditions of manifestation of the virus and its properties from the example of reasonably widespread natural processes containing the normal natural virus.
Separate fragments of the work were carried out with the support of grants RFBR (12-01-00330), (12-01-00332), (13-01-96502), (13-01-96505), (13-01-96508), (14-08-00404), (13-01-12003), project NSh - 1245.2014.1, program of the department of EMMPM and presidium of RAS, implemented by South Scientific Centre of RAS

MESOMECHANICAL ANALYSIS OF DEFORMATION AND FRACTURE IN STEEL WITH A BILAYER IRON-BORIDE COATING

Balokhonov R.R., Romanova V.A., Martynov S.A.
Institute of Strength Physics and Materials Science, SB, RAS
rusy@ispms.tsc.ru

The deformation and fracture of a coated material with an interlayer is investigated. A dynamic boundary-value problem in a plane strain formulation is solved numerically by the finite-difference method. The mechanical responses of a steel substrate, interlayer material and iron-boride coating is simulated by means of an isotropic strain-hardening model and a fracture criterion taking into account crack initiation and growth in regions experiencing tensile stresses. Numerical experiments on tension and compression of two- and three-phase microstructures were conducted. The average mechanical properties of the interlayer material are considered. The coating-interlayer and interlayer-substrate interface geometries correspond to configurations found experimentally and are accounted for explicitly in the calculations. Local regions of bulk tension are shown to form near the interfaces even under simple uniaxial compression of coated materials, which controls the fracture mechanisms at the mesoscale level. The influence of the interlayer on macroscopic homogenized strength of coated materials and on localized plastic flow and cracking patterns is examined.

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COMPUTATIONAL ANALYSIS OF DEFORMATION AND FRACTURE LOCALIZATION IN ALUMINUM WITH LASER DEPOSITED COMPOSITE AL-TIC COATING

Balokhonov R.R., Schwab E.A., Romanova V.A.
Institute of Strength Physics and Materials Science, SB, RAS
rusy@ispms.tsc.ru

Investigated is the deformation and fracture of "composite Al-TiC coating – aluminum substrate" composition. Boundary-value problems in 3D and a plane strain formulation are solved numerically by the finite-element and finite-difference methods, respectively. An algorithm to create 3D shape of TiC inclusions was developed. The Al-TiC interface geometry corresponds to the configuration found experimentally and is accounted for explicitly in the calculations. To simulate the mechanical response of an aluminum substrate and a composite coating use was made of and elastic-plastic model with isotropic strain hardening and a fracture model taking into account crack initiation and growth in the regions of bulk tension. The local regions of bulk tension are shown to arise near the interfaces even under simple uniaxial compression of the composite that controls the mechanisms of strain and fracture localization at the mesoscale.

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OSCILLATIONS OF BRANCHED SELF-SIMILAR SYSTEMS

Banakh L. Ya., Banakh L.Ya.
Mechanical Engineering research Institute, Moscow, Russia
banl@inbox.ru

Fairly broad class of structures in nature and technology consists from the self-similar structures, in which each cell in a certain scale repeats the structure of previous cell. Here, the translational symmetry is accompanied by a similarity transformation (scaling) of adjacent cells. We study the vibrational properties of such structures and in particularly the dichotomous lattice at different similarity coefficients. A number of static and dynamic features for lattice at its vibrations are revealed. It is shown that the lattice has a wave solution and this is true for both linear and nonlinear systems. For linear case the dispersion equation is received. The dichotomous lattice is a frequency bandpass filter and its bandwidth is found. And also the area location of its natural frequencies is received. There are multiple natural frequencies equal to the partial frequency of forming element; the frequency multiplicity depends on the rows quantity in the lattice. These multiple frequencies are within the lattice bandpass and consequently they are very dangerous because increase the system vibroactivity, as well as may cause its instability. The examples for calculation natural and forced oscillations of dichotomous lattice with various rows quantity are given. For example for 4-raws lattice the frequency multiplicity equal to 5.

As for the lattice static properties, then it was shown that under certain similarity coefficients the distance between the rows of lattice remains unchanged and lattice can move as a solid.

For dichotomous nonlinear lattice with an elastic coupling with an odd type of nonlinearity (eg, cubic) it was showed that its in-phase natural form are described by a chain of homogeneous elements, similar to the chain of Fermi-Pasta-Ulam, but on the nonlinear elastic foundation. In limit for distributed systems it may be described with help of some generalization of KDV equation.

STRENGTH ANALYSIS OF AXISYMMETRIC SHELLS MOVING IN DEFORMED MEDIA AT HIGH SPEED

Banichuk N.V., Ivanova S.Yu., Makeev E.V.
Institute for Problems in Mechanics RAS
banichuk@ipmnet.ru

The study concerns the problem movement of rigid axisymmetric shell (penetrator or striker) in deformed media. The model of thin-walled shell of revolution is formulated and the two-term quadratic expression is used for estimation of the resistance force as a function

of striker velocity in high-speed penetration processes. General analytical representations are found for shell acceleration and arising membrane stresses. Dynamical strength analysis is performed and presented in particular cases of axisymmetric shells of different shapes.
The work is performed under support of RFBR (grant 14-08-00016-a), RAS Program 12, Program of Support of Leading Scientific Schools (grant 2954.2014.1).

INVERSE TECHNIQUE FOR CHARACTERISATION OF ELASTIC AND DISSIPATIVE PROPERTIES OF MATERIALS USED IN A COMPOSITE REPAIR OF PIPELINES

Barkanov E. N.[1], Chebakov M. I.[2]
1 - Riga Technical University
2 - Southern Federal University
chebakov@math.sfedu.ru

Polymeric fillers, adhesives and laminated composites are the constituent materials in most cases used in the advanced composite repair systems to bring an efficiency of damaged section up to the level of undamaged pipeline. Unfortunately the technical data of such materials provided by manufacturers do not contain all necessary information to predict the behaviour of advanced composite repairs using different analysis tools. For this reason, an inverse technique based on simple vibration tests has been developed to characterise the elastic, hysteretic and viscoelastic material properties. In the case of viscoelastic materials, this novel approach allows to preserve the frequency and temperature dependencies of the storage and loss moduli in a wide range of frequencies and temperatures. The computational effort has been substantially reduced by using an optimisation based on the planning of the experiments and the response surface technique in order to minimize the error functional.
The developed inverse technique uses vibration tests and consists of the experimental set-up, the numerical model and the material parameters identification procedure. The first step involves the planning of the investigation depending on the number of measured parameters and experiments. Next, a finite element analysis is applied at the reference points of the experimental design and the different dynamic parameters of the structure are calculated. In the third step of this technique, these numerical data are used to determine simple functions using a response surface method. Simultaneously, vibration experiments are carried out to measure the natural resonance frequencies and corresponding loss factors of the tested samples. The identification of the material properties is performed in the final step of the method by minimising the error functional, which describes the difference between the experimental and numerical parameters of the structural responses.
The present inverse technique has been tested on metallic plates and successfully applied to characterise orthotropic material properties of laminated composites and viscoelastic properties of adhesive materials. A very good agreement between experimental and numerical results was obtained. The numerical experiments have shown that the accuracy of the developed inverse technique and identified material properties only depends on the accuracy of the physical experiments. The experimental errors mainly appear to be due to badly simulated boundary conditions, an added mass from exciting devices, air damping, and measurement noise.
It is important to note that our current approach, like any other inverse approach based on vibration tests, has a non-destructive character and does not require special specimens for testing. The identified mechanical properties of adhesive materials generally reflect all the features of the technological processes used for the advanced composite repair.
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DEFORMATION OF THE ORTHOTROPIC SPHERICAL LAYER UNDER NORMAL PRESSURE

Bauer S.M., Smirnov A.L.
St. Petersburg State University
a_l_smirnov@mail.ru

The purpose of the presented research is to develop of the biomechanical model describing the behavior of the eye shell under intravitreal injection, precisely the effect of the intravitreal injection on the internal pressure.
The eye shell is assumed to be a transversal isotropic or orthotropic, thin, elastic, 3-dimensional shell of constant thickness. In this sense considered problem is the generalization of the classical Lame problem for the spherical layer made of non-isotropic material. It is assumed that the Young's modulii are close but different either in tangential and transversal directions $E_3 = \mu E_1 = \mu E_2$ (transversal isotropy) or in all three directions $E_3 = \mu E_1 = \mu(1+\varepsilon)E_2$,where $\mu, \varepsilon << 1$.
The biomechanical model of the thin transversal isotropic shell under internal pressure predicts an almost linear decrease in the internal pressure with injection.
Equations and boundary conditions for the shell made of material with general orthotropy are obtained. Then in assumption that the material is almost isotropic equations for the zeroth and first approximations together with the boundary conditions are derived. For transversely isotropic material that is close to isotropic the asymptotic formula describing the change of the

shell thickness under normal pressure is found.
The restrictions on the elastic constants are used to plot the 2D and 3D admissible domains in the parameter space.

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CALCULATION OF RESIDUAL DEFORMATIONS AT ROTARY MOTION OF THE ELASTOVISCOPLASTIC MATERIAL

Begun A.S, Kovtanyuk L.V.
Institute of automation and control processes
asustinova@mail.ru

The elastic properties of material are ignored usually in the mathematical modeling of the intense deformation. Reversible strains are considered negligible small in comparison with irreversible strains. However, the elastic properties can lead to significant changes in the shape and volume of the deformed material during unloading and to the formation of residual stress fields in these processes. The residual stresses have a significant effect on the performance characteristics of the finished products. Thus, the consideration of the elastic properties of materials is necessary in the calculation of technological process of the metal forming.
In this paper we develop the approach of the theory of the large elastoplastic deformations [1] to the case of the viscometric flows. The viscoplastic flow of the incompressible elastoviscoplastic material between two the rigid coaxial cylindrical surfaces is analyzed under rotation each of them. The cases of the adhesion and the slip of material on the rigid walls are studied. The following processes are examined: the elastic deformation, the development of the viscoplastic flow, the deformation under the constant speed of rotation, braking viscoplastic flow and unloading. Qualitative and quantitative differences in behavior of the material are determined for different conditions of the contact with rigid walls. We received the laws of the movement of the elastoplastic boundaries in the development and braking of viscoplastic flow. The parameters of the stress-strain state at all stages of deformation are calculated.

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TOWARDS A THERMO-VISCO-ELASTIC CONSTITUTIVE CONTACT MODEL FOR TIRE-ROAD INTERACTION

Beyer R., Nackenhorst U.
Leibniz Universität Hannover, Institute of Mechanics and Computational Mechanics
beyer@ibnm.uni-hannover.de

The reduction of the rolling resistance of tires is an important issue in the progress of minimizing the fuel consumption of vehicles. Here, truck tires are of special interest, as even small improvements offer a large economical saving potential. In order to reach this aim, the thermo-mechanical interaction of the tread block with the rough road surface needs to be understood in detail. This knowledge is of crucial importance for the development of sophisticated tire designs and road surface textures.
In every revolution of the tire each tread block undergoes a large, high-frequent local deformation when it comes into contact with the rough road surface. Here the tips of the highest surface asperities of the road penetrate the tread rubber. Due to the inelastic properties of the bulk material these deformations cause a lot of local dissipation. In the context of rolling resistance the energy loss on the meso-scale, meaning the low frequent parts of the surface roughness, is of special interest as most of the dissipation occurs there. Due to the low conductivity of tread rubber and the tire road interface, the dissipated energy causes an increase of local temperature.
In literature the occurring phenomena have often been described by self-affine surface layers. In the theory of surface layers the problem is simplified assuming small deformations and linear visco-elastic half-space, which is not sufficient for the problem at hand. By these approaches often the temperature dependency is neglected.
The proposed constitutive contact model is aimed to homogenize the physical phenomena occurring on the meso-scale in the contact interface. It then allows an accurate calculation of the rolling resistance contribution of the single tread blocks in macro-scale tire models. Here, the focus lies on the penetration of the tread rubber by the largest asperities which induces the major part of rolling loss. The homogenization of the penetration is computed from statistical parameters describing a measured road surface. In analogy to the thermo-visco-elastic constitutive law of the bulk material, the constitutive contact model is formulated in the regime of finite deformations coupling a thermo-hyperelastic material model with a generalized Maxwell-model. Here, the strains need to be expressed in terms of the homogenized local penetration of the material by the asperities, which results in the characteristic nonlinear contact compliance.
In the same manner, the homogenized dissipation is calculated from the evolution of the internal strain-type

variables. The dissipation is then applied as a heat source within the material. With this thermo-mechanical description of the contact interface the rolling resistance is computed. The material parameters for this model can be identified either from experimental data or from detailed meso-scale simulations.

FORMING OF CERAMIC POWDERS

Bigoni D., Bosi F., Dal Corso F., Misseroni D., Piccolroaz A.
University of Trento, Italy
bigoni@ing.unitn.it

Cold forming of a ceramic powder to obtain a fully dense green body involves the transition between a granular and a fully dense material. The constitutive description of this process involves the use of elastoplastic coupling with state variables capable of describing density variation, gain in cohesion, together with pressure-sensitivity and nonassociativity of yielding. A constitutive model is successfully formulated, implemented in a computer code, calibrated on experiments and validated on simple densification processes.

STRUCTURES RELEASING ENERGY

Bigoni D., Bosi F., Dal Corso F., Misseroni D., Piccolroaz A.
University of Trento, Italy
bigoni@ing.unitn.it

Eshelbian or configurational forces are related to the release of energy in elastic structures where a (smooth and bilateral) constraint can move. These forces are derived both via variational calculus and, independently, through an asymptotic approach. Their action on elastic structures is counterintuitive, but is fully substantiated and experimentally measured on a model structure that has been designed, realized and tested. These findings open a totally new perspective in the mechanics of deformable mechanisms, with applications to buckling and instability and to design deformable mechanisms.

VIBRATIONAL SEGREGATION – SIMULATION, EXPERIMENT, AND APPLICATION TO CREATE NEW CLASSIFYING MACHINES

Blekhman I.I., Blekhman L.I., Vaisberg L.A., Vasilkov V.B., Yakimova K.S.
IPME RAS
iliya.i.blekhman@gmail.com

Fundamental physical factors determining particle segregation in granular materials under vibration have been considered. Three main types of vibrations are examined on the base of alien particle movement: horizontal circular, horizontal straight and vertical straight vibrations. Formulas for direction and segregation rate are obtained for each type of vibration on the base of vibrational mechanics approach. These formulas take into account the effect of relatively heavy particles heaving in the medium of smaller particles under vibration. The effect was called “wedge effect”. Sometimes this effect is called also “Brazil Nut Effect”. The experiments performed show that the wedge effect is more pronounced for the case of vertical straight vibration. The effect of horizontal segregation in the direction of side walls of the vessel is discovered and explained. New type of a vibrating classifier has been suggested and patented on the base of the effect.

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ENHANCING THE PERFORMANCE OF SOFT DIELECTRIC GENERATORS USING CERAMIC FILLERS

Bortot E., Springhetti R., Gei M.
DICAM - University of Trento
eliana.bortot@unitn.it

An outstanding issue in the field of dielectric elastomers is the design of materials with enhanced electromechanical coupling able to improve the mechanical-to-electrical energy conversion in soft generators. To this aim, an interesting option is represented by random composites, where ceramic fillers with a high dielectric constant are dispersed in a silicone matrix.
At the moment the most promising reinforcing materials to be employed as a disperse phase, already tested for soft dielectric actuators, are lead magnesium niobate-lead titanate (PMN-PT) and lead zirconate-titanate (PZT). In particular, two different composites based on a poly-dimethyl-siloxane (PDMS) matrix are here taken into consideration. The first one is PDMS reinforced with a 10% in volume of PMN-PT powder, the second one is reinforced with a 1% in volume of PZT.
The performance of a soft dielectric generator is computed employing a typical four-step cycle, where nominal load and electric charge are alternately held constant.
The amount of energy extracted during this cycle is limited by various mechanisms of failure, namely electric breakdown, ultimate stretch, loss of tension and electromechanical instability. The optimal cycle is identified by solving an optimization problem with electromechanical constraints associated with these limits. In this way we estimate the performance improvement achieved by the composite device with respect to the homogeneous one. In comparison with

pure PDMS, the PDMS-10%PMN-PT allows an increase of more than 60% in the harvested energy per unit volume, while PDMS-1%PZT shows a minor improvement, in the range of 23.5-37.4%.

NUMERICAL ANALYSIS OF CRACKS AND RIGID LINE INCLUSIONS IN ELASTIC PLATES

Bortot E., Springhetti R., Dal Corso F., Gei M.
University of Trento - DICAM Dept. of Civil, Environmental and Mechanical Engineering
eliana.bortot@unitn.it

The stress state near a thin rigid inclusion (stiffener) in an elastic matrix is similar to that found in the problem of a crack. In both cases, a singularity in the stress field arises at the tip of the crack/stiffener. Obtaining a good approximation of this stress concentration form a numerical viewpoint is not a trivial problem, since the stress gradient in the proximity of the tip is very high.
For the problem of a crack or a rigid line inclusion in an elastic plate, in the small strain regime, good numerical results can be achieved using a spider-web mesh with quarter point element at the tip, in order to enforce the singularity of the stress field. In the mesh design, the key parameter is the choice of the element number in the circumferential direction.
In the finite strain regime, the spider-web mesh is likewise effective, where mixed finite elements should be employed but no quarter point elements are needed.
In this contribution we will present numerical results for the problem of a central crack/stiffener, subjected to loading mode I and II in small-strain and finite-strain regimes, and the interaction between cracks/stiffeners lying on the same plane or on different ones. Comparison with the full-field solution for a single stiffener and with available experimental observations will be performed.

THE ANALYTICAL MODEL OF A PERIODONTAL MEMBRANE IN THE FORM OF AN ELLIPTICAL HYPERBOLOID

Bosiakov S. M., Mselati A. F.
Belarusian State University
bosiakov@bsu.by

One of the main questions of orthodontics is the prevention and correction of malocclusion, as well as other dentoalveolar anomalies. The important task is to predict of the initial and long-term displacements of teeth, especially their initial displacements. The initial tooth movement appears under the action of short-term loads. After the load is removed the tooth goes back to its original place.
Teeth are surrounded by the periodontal ligament, which is a thin membrane. It consists of the collagen fibers that provide attachment of the tooth to the alveolar bone. The contact between the tooth root and the alveolar bone is absent under normal conditions. Action of load on the tooth crown is transmitted to the alveolar bone by the strains of the periodontal ligament. As a result of the biological response of alveolar bone the orthodontic tooth movement occurs. Based on the high elasticity of the periodontal tissue in comparison with the bones and teeth most authors suggest that it determines the initial tooth movement. Regions of the largest hydrostatic stresses are primary to bone remodeling during orthodontic tooth movement. In most cases of mathematical modeling of the system «tooth - periodontal ligament» the root of the tooth is approximated by the circular or elliptical paraboloid. A comparative finite element analysis shows that the calculations of the initial displacements of the tooth root in the periodontal ligament for the real shape of single-root tooth and paraboloid differ insignificant. More precisely the geometric shape of the tooth can be described by equations of the elliptical hyperboloid with taking into account the parameter characterizing the rounding of apex. The aim of this work is to develop an analytical model of the periodontal ligament of constant thickness with the external and internal surface in the form of the elliptical hyperboloid.
The geometric shape of the tooth root is described by the equation of the elliptical hyperboloid. The internal surface of the periodontal ligament coincides with the external surface of the tooth root. The distance in the normal direction between the outer surface of the periodontal ligament and the outer surface of the tooth root is constant. The external surface of the periodontal ligament is fixed in the dental alveolus. The periodontal tissue is modeled by the isotropic linear elastic nearly incompressible material with a Poisson's ratio equal to 0.49. This means that the periodontium begins to flow around the surface of the tooth root when the root is displaced to the dental alveolus wall. Therefore, it is assumed that the displacements and the strains of the periodontal membrane in the normal direction to the external surface of the tooth root are proportional.
The coordinates of the centres of resistance are defined for a single-root tooth, and shown that the single centre of resistance for a symmetrical root is absent. The angles of inclination of the force line to the horizontal plane are defined for translational displacements of the tooth in two coordinate planes. Analysis of the influence of the root cross-section eccentricity on the position of the centres of resistance and the inclination angles of force to the horizontal plane is carried out.
The hydrostatic stresses in the periodontal ligament are defined for the translation of the tooth root in the horizontal and vertical planes. The ranges of the favourable force for orthodontic tooth movement and bone remodeling are determined based on the optimum values of stresses in the periodontal ligament.

TESTING PROTOCOL AND EXPERIMENTAL INVESTIGATION ON GREEN BODY

Bosi F.[1,2], Cocquio A.[2], Cova M.[2]
1 - Dept. of Civil, Environmental and Mechanical Engineering, University of Trento – Italy
2 - R&D Department, Sacmi Imola s.c., Imola (BO) – Italy
federico.bosi@ing.unitn.it

Establishing testing protocols for the definition of the mechanical behaviour is fundamental to calibrate the material parameters appearing in the constitutive modelling.
Uniaxial strain, equi-biaxial flexure, high pressure triaxial compression and extension tests have been performed on samples obtained from cold compaction of ceramic powder used in the process of tiles manufacturing.
The green body samples are realized considering two different humidity (5.5% - 7.5%) and one forming pressure (PC=40 MPa), values corresponding to those used in the industrial forming of ceramic powders.
In order to improve the powder compaction and ceramic production process, an advanced modeling of the green body, based on a constitutive elastoplastic framework (Bigoni and Piccolroaz, Int. J. Solids Struct., 2004, 41, 2855-2878), will be calibrated using the obtained experimental results.
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MECHANICAL CHARACTERIZATION OF THE ELASTO-PLATIC BEHAVIOUR OF ALUMINUM SILICATE SPRAY DRIED POWDER DURING COLD COMPACTION

Bosi F.[1,2], Piccolroaz A.[1], Gei M.[1], Dal Corso F.[1], Cocquio A.[2]
1 - Dept. of Civil, Environmental and Mechanical Engineering, University of Trento – Italy
2 - R&D Department, Sacmi Imola s.c., Imola (BO) – Italy
federico.bosi@ing.unitn.it

Mechanical experiments have been performed for green bodies obtained from cold compaction of an aluminum silicate spray dried powder, usually employed in the industrial production of tiles. Two types of powder, differing in the water content and representing the values applied in the forming of traditional ceramics, have been used to realize green body samples through a cylindrical mould.
The mechanical characterization of the plastic response of the material is addressed to the most important features: (i.) the elastic domain as limited by the yield locus; (ii.) the failure envelope; the evolution laws of (iii.) void ratio and (iv.) cohesion with the change of forming pressure.
The experimental data on the plastic behavior of green bodies is shown to be representable through the elasto-plastic theoretical framework and are fundamental for a proper modelling, simulation and optimization of the production process of traditional and advanced ceramics.

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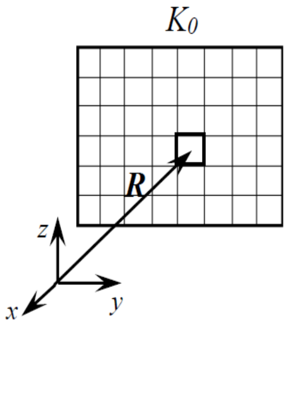
HYBRID MATERIAL AND SPATIAL DESCRIPTION FOR TWO-PHASE SOLID-FLUID MATERIAL

Brazgina O.
Saint Peterburg State Politechnical University, Russia
olyck@yandex.ru

Two different approaches are used for material deformation processes modeling: material and spatial description. In the material description body deformation is considered relatively some initial configuration K_0, where each point has its referential coordinates R. The position and all the physical properties of this point are defined as a function of current position r in the deformed configuration K_t. The key point is the assumption that local topology does not change, i.e. close points remain close during deformation processes. But such approach is not suitable for fluid or bulk substances, where body motion is accompanied by particle mixing, so position definition in initial configuration is impossible. Sometimes this is typical for plasticity. So in these cases spatial description is used, where all physical parameters are defined as velocity and spatial position functions.



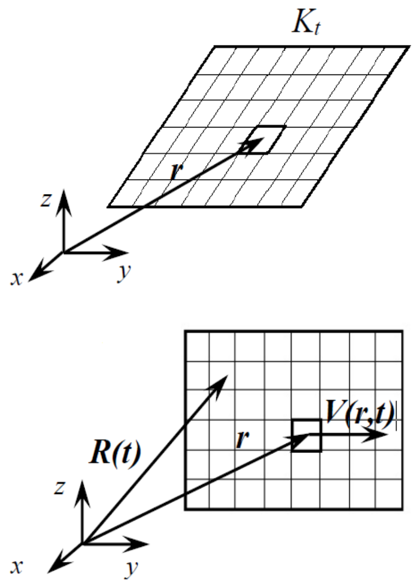


Fig.1: *a) material description of continuum*; *b) spatial description of continuum.*

In this work comparison of stress-strain functions using energy balance equation and Cauchy-Green equations is provided. Stress and strain tensors are defined in terms of energy and they coincide in both approaches. Hybrid material and spatial approach is developed for two-phased material: the first phase is solid, the second is fluid. Therefore the material approach is used for the solid description and spatial for fluid description. Material derivative for fluid phase is written with solid motion velocity influence.

All the balance equations are conducted for fluid phase with the assumption of relative motion comparatively solid phase motion.

NON-HOMOGENEOUS RADIAL DEFORMATIONS IN THE PROBLEM OF TORSION OF HYPERELASTIC CIRCULAR CYLINDER

Brigadnov I.A.[1], Naumenko K.[2]
1 - National Mineral Resource University (University of Mines), Russia
2 - Otto-von-Guericke-University Magdeburg, Institute of Mechanics, Germany
brigadnov@mail.ru

The classical Saint Venant's theory of torsion does not describe the well-known Poynting effect [1], that is the appearance of the axial force if the circular specimen is subjected to a twist in a hard device or the axial elongation in the case of soft loading by a torque. This effect can be analyzed within the non-linear theory of elasticity by the use of Rivlin's universal solution for pure shear deformation of a homogeneous and isotropic non-linear elastic material [2]. The results show that the axial force and the change in the length of a cylindrical specimen are proportional to the the square of the specific twisting angle (twisting angle over the unit length of the specimen) and agree well with experimental data.

Not only the axial but also the radial deformation effects can be observed as the twisting becomes essential. The variational asymptotic solutions given in [3] indicate that the radial strain is proportional to the square of the twist and is non-linearly distributed over the radial coordinate for solid and hollow circular cylinders. However, the analysis presented in [3] is limited to linear-elastic materials. For large angles of twist, for non-linear elastic materials and for the hard device torsion both the radial and the axial strains are expected to be non-uniform with respect to axial coordinate such that ring-type wrinkles may arise on the surface of the specimen. Non-uniform radial deformation effect is not analyzed in the available theories of torsion [4]. Although cross section warpings are considered for prismatic solids, these effects are not essential for cylinders and cannot be related to the radial deformation.

In this paper we recall governing equations of the non-linear theory of elasticity to study the torsion of circular solid bars. We generalize Saint Venant's hypotheses by including the non-homogeneous longitudinal and radial deformation. Applying the general variational principle we reduce a three-dimensional problem to the one-dimensional one with respect to the axial coordinate. The investigated variational functional includes two independent functions - the function of radial/surface deformation and the function of the longitudinal deformation and two independent variables - the normalized torque and the normalized axial force. We consider a class of non-linear elastic materials that exhibit the power law type dependence of the strain energy density on the magnitude of the deformation gradient. For different values of the exponent p several classical potentials can be considered. As an extension of the previous work to the non-linear torsion of circular solid bars we analyze the following problems:

- According to the classical results the axial force or the change in the length of are related to the square of the specific twisting angle. The classical solution is limited for Treloar (neo Hookean) materials with p=2 [5]. Below we address an analysis for a class of materials with $p>1$, because for p=1 the limit load and discontinuous mapping exist [6]. For hard device torsion derive an asymptotic formula that estimates the axial force and the reaction torque for large angles of twist.
- For hard device torsion we analyze the radial deformation effects. For p=2, i.e. for Treloar (neo Hookean) materials we derive the second order essentially nonlinear differential equation for the radial deformation function. To study the general case we perform a numerical finite element analysis by Matlab and LS-DYNA commercial CAD.

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NONLINEAR THEORY OF DEFORMATION OF CRYSTAL MEDIA WITH COMPLEX STRUCTURE OF LATTICE: PLANE DEFORMATION

Aero E.L., Bulygin A.N., Pavlov Yu.V.,Reynberg N.A.
Institute of Problems in Mechanical Engineering RAS
bulygin_an@mail.ru

In recent years continual nonlinear theory of elastic and inelastic deformations was developed for crystal media with the complex structure of a lattice consisting of two sublattices [1], [2]. Shift of the center of inertia of atoms of an elementary cell is described by a vector **U** (acoustic mode) while relative shift of the atoms inside cell is described by a vector **u** (optical mode). The shift of sublattices can be arbitrar large in contrast to the classical theory [3]. It is supposed that the energy of interaction of sublattices is the periodic function of the rigid shift of sublattices **u** .

The equations of motion for **U** (x, y, z, t), **u** (x, y, z, t) have the form of six coupled nonlinear partial differential equations. They describe processes (formation of defects, phase transitions, lattice fragmentation, etc.) which are realized, in particular, in a vicinity of a crack. These processes aren't described by the classical theory of elasticity. That is why the development of numerical and analytical methods of the solution of the equations of the nonlinear theory in relation to the problems of fracture mechanics is very desirable.
The equations describing plane deformation of crystal media with a cubic lattice structure are obtained. The equations for acoustic mode are solved by introduction of the Airy function which in nonlinear theory satisfies an inhomogeneous equation. Plastic deformations of a lattice play the role of an inhomogeneous source. Microstress field **u** is found from the system of two coupled double sine-Gordon equations with a variable amplitude. Connection between the structure of the lattice and potential of interaction of sublattices is studied for the case of one-dimensional deformation for the potential $\Phi(u) = 1 - \cos u + \delta(1 - \cos 2u)$. Exact solutions are obtained. The analysis of the phase portraits of the equations allows us establish a connection between the structure of microdeformations and the potential of interaction of sublattices.

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SOUND WAVE PROPAGATION IN COHESIVE POWDERS AT LOW CONSOLIDATIONS

Ruiz-Botello F.[1], Castellanos A.[1], Tournat V.[2], Grekova E.[3]
1 - Dpto. Electrónica y Electromagnetismo, Universidad de Sevilla, Sevilla, Spain
2 - Laboratoire d'Acustique, Université du Maine, Le Mans, France
3 - Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, St. Petersburg, Russia
castella@us.es

In previous experiments on the propagation of sound waves in cohesive powders (reported in APM 2011) we studied the ballistic velocity of ultrasound waves at consolidations above 1.25 kPa and solid fraction above 0.47. In this study we use a new experimental setup that allows us to investigate sound propagation at lower consolidations. The emitter excites the powder slab with harmonic signals of low amplitude, slowly increasing from 1 kHz to 80 kHz. The receiver gives us the transfer function for the system. The sound velocity is obtained from the first few resonance peaks of the transfer function. We detect also a few bands and peaks of strong attenuation. We report sound velocities and bands of attenuation for various cohesive powders as function of particle size and the number of taps used to increase the solid fraction of the powders. The results show the important role of cohesive forces and the network of contacts in these loosely consolidated fine powders. A tentative explanation for the occurrence of the attenuation band gaps will be advanced in terms of the reduced Cosserat theory.

MULTI-SPECIES SIMULATION OF NEGATIVE CORONA PULSES IN OXYGEN

Durán-Olivencia F.J.[1], Pontiga F.[1], Castellanos A.[2]
1 - Dpto. Física Aplicada II, Universidad de Sevilla, Av. Reina Mercedes 4, 41012 Sevilla, Spain
2 - Dpto. Electrónica y Electromagnetismo, Universidad de Sevilla, Av. Reina Mercedes s/n, 41012 Sevilla, Spain
castella@us.es

In certain electronegative gases, like oxygen, negative corona appears as pulsations (Trichel pulses) with a well defined frequency. These pulses are characterized by a very short rise time, of the order of a fraction of nanosecond, and duration of tens of nanoseconds. The repetition frequency of Trichel pulses depends on the applied voltage, ranging from tens to hundreds of kilohertz. The development of these pulsations has been the object of a number of past studies but, frequently, they ignore the complex plasma-chemistry initiated by electrons which are produced during the ionization of oxygen molecules. In contrast, the present work proposes a multi-species study of Trichel pulses between a spherical cathode and a grounded plane with the inclusion of electrons, ions (O_2^+, O_4^+, O_2^-, O^-, O_3^-), and neutral species in ground or in excited states (O_2, O_3, O, $O(^1D)$, $O_2(^1\Delta_g)$ and $O_2(^1\Sigma_g)$). The interaction among these species is described by a plasma-chemical model that incorporates processes such as ionization, electron attachment and detachment, electron impact dissociation and excitation, charge transfer, and clustering. In addition, secondary emission at the cathode by the impact of positive ions is also considered, as well as the neutralization of ions as they arrive to the electrodes, and the recombination of species impinging the discharge chamber. The electrical discharge has been modelled using a fluid description, and the problem has been numerically integrated by applying a finite-element method. Therefore, the spatial and temporal distributions of charged and neutral species are obtained by solving the continuity equations of species coupled with Gauss' equation. The results of the simulation reveal the interplay between the different ions during the development of each Trichel pulse, and the rate of growth of important neutral species, like ozone and singlet states of oxygen produced by the corona discharge.

MOTION OF A DYNAMICALLY SYMMETRIC PARABOLOID ON A PERFECTLY ROUGH PLANE

Chernyakov G.A., Kuleshov A.S.
Lomonosov Moscow State University
glchern@gmail.com

We consider the classical problem of nonholonomic system dynamics – the problem of motion of a dynamically symmetric body bounded by a surface of rotation on a fixed perfectly rough plane. We prove that this problem can be completely solved in quadratures in the case when the moving body is a paraboloid of revolution. The qualitative description of motion of a paraboloid on the plane is given. The trajectory of the point of contact M on the surface of paraboloid is the curve consisting of periodically repeating waves and tangent to two parallels of the paraboloid. The trajectory of the point of contact on the supporting plane has the same pattern and it is situated between two concentric circles. During the motion of the paraboloid the point of contact M touches these two circles in turn. The steady motions of the paraboloid on a perfectly rough plane are found and their stability is investigated. It is proved that all the steady motions of the paraboloid (permanent rotations and regular precessions) are stable.

THE STOKES EQUATIONS IN THE SPECIAL NON-INERTIAL SYSTEM OF REFERENCE

Chivilikhin S. A.
St. Petersburg National Research University of Information Technologies, Mechanics and Optics
sergey.chivilikhin@gmail.com

Deformation of viscose liquid isolated volume due to external forces in case of small Reynolds number can be describing through quasi-steady-state Stokes equations. These equations are applicable if total external force and total external moment of force are equal to zero [1]. We demonstrate that these conditions are too restrictive. For example, for a small drop of high viscous liquid falling in the gravitation field the total force is not zero, but equal to the weight of the drop. Therefore, we cannot use the quasi-stationary Stokes approximation to describe the evolution of the drop's shape due to capillary forces using laboratory system of reference. But in a non-inertial system of reference which falls together with the drop with the same acceleration, the total force is equal to zero. Therefore, we can use the Stokes approximation in this system of reference.
In general case, if the total force and the total moment of force are not equal to zero we can eliminate them using the non-inertial reference system. This system connected with a rigid-body which moves due to the same force and moment of force [2]. It is important for applicable the Stokes approximation, that Reynolds number in this non-inertial system of reference will be small.
We illustrate this approach on the example of motion and deformation of 2D volume of viscous fluid in a force field.

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RIEMANN WAVES IN ELASTOPLASTIC MEDIA WITH HARDENING

Chugainova A.P., Kulikovskii A.G.
Steklov Mathematical Institute
anna_ch@mi.ras.ru

Riemann waves (simple waves) are investigated within the von Mises elasto-plasticity model with hardening. It is assumed that preceding processes have brought the medium into a state corresponding to a certain point on the loading surface. The conditions under which a Riemann wave overturns during its evolution, i.e., the conditions for the formation of discontinuities, are indicated.

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VALIDATION OF RIGID INCLUSION MODEL FOR THE ANALYSIS OF REINFORCED COMPOSITE MATERIALS

Dal Corso F.[1], Shahzad S.[1], Misseroni D.[2], Noselli G.[3]
1 - University of Trento, Italy
2 - University of Liverpool, UK
3 - SISSA, Trieste, Italy
francesco.dalcorso@ing.unitn.it

Similarly to the case of voids, analytical solution in linear elasticity predicts singular stress fields at the vertexes of rigid polygonal inclusions having sharp angles, so that the corresponding stress field could become more critical than that for homogeneous materials.
Photoelastic experiments are performed to validate the rigid inclusion model used in the modelling of reinforced composites and based on the assumptions about infinite stiffness of the inclusion and its complete adhesion with the matrix phase. In particular, the photoelastic fringes are observed for two-component resin samples containing stiff inclusions of different shapes (linear, rectangular and rhombohedral) when subjected to an uniaxial stress test.
A very good quantitative agreement is observed between the linear elastic solution and the photoelastic experimental results, confirming the singular behavior of the stress fields close to the rigid inclusion tips and the validity of the rigid inclusion model.

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MULTISCALE MODELLING OF CERAMIC COMPOSITES

Dal Corso F.[1], Bacca M.[2]
1 - University of Trento, Italy
2 - University of California Santa Barbara, USA
francesco.dalcorso@ing.unitn.it

Multiscale modelling is a fundamental tool in the advanced design of high performance composites based on ceramic matrix.
Under the dilute approximation, a closed-form expression for the non-local constitutive tensor of an equivalent second gradient material is derived from homogenization of heterogeneous Cauchy elastic materials.
Considering the case of phases having non-isotropic tensors of inertia, it is shown that the nonlocal constitutive tensor for the homogenized material depends on both the inertia properties of the RVE and the difference between the effective and the matrix local elastic tensors. Results show that: (i) a positive definite higher order equivalent material arises only when the inclusion phase is softer than the matrix and (ii.) orthotropic nonlocal effects follow from homogenization of a dilute distribution of aligned elliptical holes and, in the limit case, of cracks.
This research has been supported by FP7 Marie Curie IAPP project INTERCER2 (PIAP-GA-2011-251475).

CONSTITUTIVE MODELLING OF ROCK-LIKE MATERIALS FOR INDUSTRIAL APPLICATIONS

Dal Corso F.[1], Piccolroaz A.[1], Poltronieri F.[1], Romero-Baivier S.[2]
1 - University of Trento, Italy
2 - Vesuvius Group S.A., Belgium
francesco.dalcorso@ing.unitn.it

An elasto-plastic model is presented for the prediction of the mechanical behaviour of rock-like materials based on a simple class of hardening laws. The model can describe a smooth transition from linear elastic to inelastic behavior. Implementation of the model in a numerical code and simulations of mechanical tests successfully show robustness and capability of describing experimental results on rock-like materials.
The model is equipped with temperature-dependent mechanical properties useful to describe the mechanical behaviour of refractory materials at high temperature.
Simplicity in calibration, fast convergence and stability turn the model to be effective for industrial applications.

The authors gratefully acknowledge support from the European Union FP7 project "Mechanics of refractory materials at high-temperature for advanced industrial technologies" under contract number PIAPP-GA-2013-609758-HOTBRICKS.

STABILITY OF AN INCLINED TRAVELING HEAVY CABLE

Dehadrai A.R., Sharma I., Gupta S.S.
Mechanics & Applied Mathematics Group, Department of Mechanical Engineering, Indian Institute of Technology Kanpur, India
abhinavd@iitk.ac.in

We analyze the stability of a heavy inextensible cable traveling at constant velocity at an angle against gravity. The governing equation for transverse in-plane vibrations are derived using Newton’s second law or Hamilton's principle. Modal and transient solutions are obtained computationally at different velocities of operation and inclination angle. The margin of stability is identified from the critical values of the velocity. This margin will be validated with simple lab-scale experiments. Further, energy balance confirms that the system's energy in absence of dissipative forces is not constant; indicating that the system is nonconservative. Effects of external damping on the stability of the system is also analyzed.

1 Introduction

TRAVELING CABLES are often used to drive mechanisms such as elevators in skyscrapers and mines (ground and under water), conveyor belts, automobile chain-drive, cableways, etc. These cables can be inclined at various angles to gravity. Understanding the dynamics of cables employed in these applications is important to arrive at the critical speed of operation for designing proper control systems. Dynamics of horizontally traveling strings, or cables, and beams is well addressed in available literatures, [1-9]. We study the dynamics of a cable moving at constant velocity between fixed rollers and inclined with respect to the vertical. Such a system has been sparsely investigated before. We establish criterion for instability by looking for the system's critical velocity using computational modal and transient analyses. We are attempting to validate these critical points via simple experiments. Through energetics we justify that the system's stability, in presence or absence of damping, is not sufficiently characterized by its nonzero energy rate. Wickert and Mote [9] reached a similar conclusion for a horizontal system. Our basic model includes external loading, due to aerodynamic/hydrodynamic forces along with gravity.

2 Governing equation and numerical solution

A traveling heavy cable between two pairs of small, rigid and inertially fixed rollers is shown in Fig. 1. The inertially fixed Cartesian coordinate system is shown located between the base rollers. The distance between the centers of the rollers is L and the acceleration due to gravity acting vertically downwards is g. The cable has mass density ρ and its cross section is A_c. The tangential velocity of each material particle of the cable is v. Distributed external forces acting on the cable are also shown in Fig. 1. The transverse in-plane displacement of a generic material point of cable, located at a distance x along the X-axis, at time t, is taken as $y(x,t)$. The governing equation along with boundary condition derived using Newton's second law or Hamilton's principle is

$$\left(v^2 - \frac{T(x)}{\rho A_c}\right)\frac{\partial^2 y}{\partial x^2} + 2v\frac{\partial^2 y}{\partial x \partial t} + \frac{\partial^2 y}{\partial t^2} + \left(\frac{V(x)}{\rho A_c} - g\right)\frac{\partial y}{\partial x} = \frac{H(x)}{\rho A_c},$$

with $y(0,t) = y(L,t) = 0$, (1)

where $T(x) = T_0 + \rho A_c g x - \int_0^x V(x)\,dx$, and T_0 is the known tension at the cable's lower end. The Galerkin projection method [2] is employed for solving Eq. (1). Towards that end we assume $y(x,t) = \sum_n b_n(t)\,\psi_n(x)$ over the entire domain. Transient and modal solution are obtained by solving the discretized equations numerically at different values of velocity for various values of inclination ϕ. Note that the shape functions $\psi_n(x)$ are chosen as *sine* functions which satisfy the homogeneous boundary conditions. Values of the critical velocity for various ϕ are identified by the first occurrence of positive real part of any eigenvalue of system of equation. At this velocity the transient solution shows exponential growth -- implying instability.

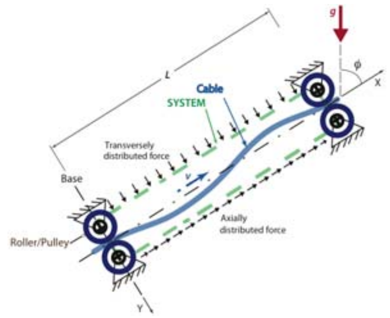

Figure 1: Obliquely traveling heavy cable, under external loading, between small fixed end-rollers.

3 Energetics and experimental verification

Energy analysis of a vertical system (i.e. $\phi = 0$) shows that the rate of change of total energy of the system with time is nonzero. There is energy influx and efflux from the boundaries and power input by the gravity into the system. The latter contribution diminishes with increasing inclination. It is absent for a horizontal system [9] (i.e. $\phi = \pi/2$). In any case, the nonzero energy rate is an insufficient criterion to explain the instability of a traveling cable system.

We have built an experimental set-up, in which a bicycle chain is run between fixed sprockets. A motor whose speed is adjustable drives one of these. The inclination of the system may also be set to any desired angle. We expect to see whether the critical velocity obtained from numerics matches with that observed through this experiment.

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KAPITZA PENDULUM'S MOTION AT UNCONVENTIONAL VALUES OF PARAMETERS AND SMALL DISSIPATION COEFFICIENT

Demidov I.V.
Institute of Problems of Mechanical Engineering RAS
dvsmallville@gmail.com

The present research deals with the analysis of Kapitza pendulum's motion at non-traditional values of parameters. We consider the case when the frequency of the external loading is of the same order with the eigenfrequency of the pendulum in the absence of this loading. It is assumed that vibration intensity is relatively low. A new modification of the method of direct separation of motions (MDSM) is employed to study the corresponding equation, which in considered case contains a small parameter in the form of the dissipation coefficient only. A stability condition of the pendulum's upper position, which can be reduced to the classical one in the case of the conventional values of parameters, is obtained. Results obtained by the MDSM were verified by series of numerical experiments.

SIMULATION OF SORPTION OF CARBON DIOXIDE IN THE POROUS COAL BY MEANS OF HYBRID CELLULAR AUTOMATON METHOD

Dimaki A.V.[1], Dmitriev A.I.[1,2], Polevshchikov G.J.[3]
1 - Institute of Strength Physics and Materials Science SB RAS, 634021, Russia, Tomsk
2 - Tomsk State University, 634050, Tomsk, Russia
3 - Institute of Coal SB RAS, 650065, Russia, Kemerovo
dav@ispms.tsc.ru

In the paper we numerically simulate the sorption of CO_2 in coal specimen under conditions of the real experiment, using the hybrid cellular automaton (HCA) method. In the framework of the HCA method the medium is considered as a superposition of two interpenetrating layers, one of which is represented by an ensemble of interacting movable cellular automata (MCA), and the other – by the finite-difference mesh. Earlier HCA method was tested on the problem of simulation of deformation and fracture of heterogeneous materials with implicit accounting of redistribution of gaseous/liquid components, contained in pore volume. Here we continue the development and improvement of the model of sorption processes by means of accounting of the fact that the coal and CO_2 can form a solid solution.

In the framework of preformed simulation, the impermeable vessel, containing compacted coal particles, was considered. At the beginning of simulation, the concentration of gas in pore volume of coal was equal to zero. The gas pressure in the vessel was equal to 8 bar. The calculation consisted of two phases: 1) the saturation of porous coal with the gas and 2) the desorption of gas from coal after relieving the pressure in the vessel to atmospheric pressure. The gas pressure in the vessel was measured. The obtained results are in qualitative agreement with experimental data on the sorption of gas in the coal.

The developed method of simulation of fluid-saturated porous media (hybrid cellular automaton method) can be used to estimate the parameters of coal porosity (open and closed) on the basis of experimental dependences of the gas pressure in the vessel on time. An important direction for further development of the model is the consideration of the temperature change as in the solid skeleton as in the gas in vessel.

COMPUTER-AIDED SIMULATION OF THE MECHANICAL RESPONSE OF WATER-SATURATED SANDSTONE ON THE BASIS OF THE HYBRID CELLULAR AUTOMATON METHOD

Dimaki A.V.[1], Astafurov S.V.[1], Shilko E.V.[1,2], Psakhie S.G.[1,2]
1 - Institute of strength physics and materials science SB RAS, 634021, Tomsk, Russia
2 - Tomsk State University, 634050, Tomsk, Russia
dav@ispms.tsc.ru

There is the effect of a liquid in pore volume of geological materials on the strength of samples of such materials. Theoretical study of porous materials saturated with liquid should be carried out with application of coupled models that take into account the mutual influence of deformation and fracture of the solid skeleton and redistribution of fluids in pore volume. We propose the approach to the description of the mechanical behavior of this class of materials based on a combination of particle method and mesh method, allowing explicitly take into account the above-mentioned effects.

In the framework of the hybrid cellular automaton method a system under consideration is represented as two interpenetrating layers, one of which is formed by an ensemble of interacting movable cellular automaton (MCA), and the other – by finite- difference mesh. MCA ensemble simulates the mechanical response of solid skeleton. Also the problem of redistribution of fluid in the pore volume is solved on MCA layer. At that, it is assumed that the size of micropores and cracks in the volume of the solid skeleton is much smaller than the size of the mobile cellular automaton. Finite-difference mesh is applied to describe the redistribution of fluid in the macropores (in other words, discontinuities that exceed the size of the movable cellular automaton) as to approximate the boundary between solid skeleton and macropore and to simulate the fluid transport macroscopic pores and porous solid skeleton.

In the framework of MCA method the mechanical response of elastic-plastic material is described within the model of plasticity with non-associated flow law and von Mises yield criterion (Nikolaevsky model), that allows adequate description of a mechanical response of materials with dilatational plasticity, including the accounting of contributions of underlying scale levels. The Nikolaevsky model of plasticity has been implemented on the basis of Wilkins algorithm that reduces the solution of elastic-plastic problem to the solution on an elastic problem with consequent correction of interaction forces between particles in such a way to keep a value of local pressure constant: The model of fluid transfer is based on the following assumptions: 1) the fluid is compressible; 2) adsorption of the liquid on surfaces of voids and capillary phenomena are not taken into account 3) pore pressure of fluid is considered as the driving force of filtration.

The developed model has been used to study the dependence of the strength of porous geological material (sandstone) on an initial value of porosity, initial pressure of water in the pore volume and the loading rate under uniaxial compression. The modes of loading, leading to changes in the effective strength of the samples, have been found.

STUDY PATTERNS OF MICROSTRUCTURE FORMATION DURING FRICTION STIR WELDING

Dmitriev A.I.[1,2], Kolubaev E.A.[1], Nikonov A.Yu.[1], Rubtsov V.E.[1], Psakhie S.G.[1]
1 - Institute of Strength Physics and Material Science, SB RAS
2 - Tomsk State University, Tomsk Russia
dmitr@ispms.tsc.ru

Friction stir welding is a relatively new technology used in various branches of modern engineering. The basis of this technology is the friction of the rotating cylindrical tool specially shaped between the two ends connected or overlapping metal plates. When implementing of FSW technology in various economical sectors the important task is to study the mechanisms and identify the physical laws and factors leading to the formation of structural inhomogeneities and discontinuities in seam. The paper analyzes the basic mechanisms of the structural state of the material subjected to intensive plastic deformation and heating. To investigate the atomic mechanisms occurring at similar loadings modeling at atomic scale was carried out. Displaying resemblance of simulation results with experimental data. Results of work can be the basis for new knowledge about the processes in metals with friction stir welding.

ABOUT THE ROLE OF TRIBOFILMS FORMED DURING AUTOMOTIVE BRAKING. RESULTS OF NANO-SCALE MODELING

Dmitriev A.I.[1,2], Oesterle W.[3]
1 - Institute of Strength Physics and Materials Science SB RAS
2 - Tomsk State University
3 - Federal Institute for Materials Research and Testing, BAM, Germany
dmitr@ispms.tsc.ru

Automotive brake pads consist of many components but it is still not entirely clear which role each of the elements of this complex composition play to provide the specified regimes of sliding. Despite of the very large variety of possible brake pad formulations, the demanded performance properties are quite clear and strict: i) Stable coefficient of friction (COF) in the range 0.4-0.5 irrespective of environmental conditions, ii) wear as low as possible and iii) noise and vibration harshness (NVH). The objective of our modelling efforts was to obtain a better understanding of the sliding behaviour and associated friction properties and to study the impact of internal and external parameters on these properties. The method of movable cellular automata (MCA) was used. The third bodies were considered as aggregates of linked nanoparticles which may decompose and form a layer of granular material, the so-called mechanically mixed layer (MML), if certain fracture criteria are fulfilled. The basic model structure which consists of Fe_3O_4 nanoparticles with 13 % graphite inclusions was used. The mechanical properties of the oxide were varied between brittle and ductile behaviour corresponding to room temperature and high temperature behaviour. The mechanical properties of the soft ingredient were varied ± 50 % of the properties of graphite. The influence of a variety of model parameters on the evolution of the friction coefficient was found. Comparison of simulation results with experimental data was done on those tests where it was possible from the side of the experimental study. The simulation results show good agreement with experimental data.

DETERMINATION OF BOUNDARY CONDITIONS OF CRITICAL STATE OF SHEAR INSTABILITY OF THE MATERIAL SURFACE UNDER FRICTION

Dmitriev A.I.[1,2], Kuznetsov V.P.[3], Tarasov S.Yu.[1]
1 - Institute of Strength Physics and Materials Science, SB RAS
2 - Tomsk State University, Tomsk Russia
3 - Kurgan State University, Kurgan Russia
dmitr@ispms.tsc.ru

Modern research found that frictional interaction almost any structural materials leads to the formation in the surface layers of nanoscale structures. This is due to the instability of the shear subsurface material. The essence of shear instability is the change of the shear deformation mode on rotational mechanism of grain boundary sliding. This paper analyzes the conditions of shear instability when there is a critical change in the properties and structure of the surface layer of the material at high loading rates. The studies were performed using both experimental measurements and computer simulation. Observed regularities can be used to understand the details of mechanisms of friction and wear in order to get new frictional materials.

GENERATION OF PULSE-CYCLIC FLOWS IN A LIQUID

Drozhzhin A.P., Teslenko V.S.
Lavrentyev Institute of Hydrodynamics SB RAS
drozh@hydro.nsc.ru

To obtain high-velocity jet flows in a liquid, devices are developed and tested by using the methods of combustion of gas mixtures directly in water.
The perspectives of the developed pulse-cyclic methods of combustion of burning gases in a liquid are shown for a number of applications. Among these applications may be principally new heat generators, underwater movers, devices for cleaning underwater objects, etc.
As an example the results of investigations of pulse processes generated by the combustion of propane-oxygen and hydrogen-oxygen mixtures on the thrust wall are presented. It is shown that for different geometries of combusted gas bubble on the thrust wall two or three force pulses are generated. It occurs due to bubble pulsations. The period of pulsations depends on the geometry of the thrust wall.
The work is supported by the RFBR (grant No. 13-08-00838).

FEATURES OF REFLECTION OF DEFORMATION WAVES FROM THE RIGID BOUNDARY OF A SPHERICAL LAYER IN AN MULTIMODULUS ELASTIC MEDIUM

Lapteva A.A.[1], Dudko O.V.[1,2]
1 - Institute of Automation and Control Processes of Far-Eastern Branch of RAS
2 - Far Eastern Federal University
lanastal@mail.ru

Structural materials with different mechanical response in tension and compression are widely used in modern engineering industry. This feature appears even in the field of elastic deformations. The absence of normal isotropy in these materials makes certain qualitative features in the propagation of boundary disturbances. This fact should be taken into account when formulating and solving boundary value problems. In this paper the results of investigations of the propagation of spherical waves in an elastic medium having different resistance to tension and compression are presented. The external boundary of an elastic multimodulus spherical shell is loaded, which leads to the motion of the boundary points. The boundary loading is defined by the polynomial function. At the initial time under loading the deformations wave separates from the boundary layer. After the wave the material becomes compressed or stretched according to the load direction. If the displacements on the boundary are negative, then a shock wave compresses the environment. If the displacements on the boundary are positive, the wave causes a tension environment. At some time the shock wave reaches the internal boundary of the spherical layer, which is rigidly fixed. Previously, the authors have solved a similar problem of reflection of a plane shock wave from the rigidly fixed boundary of a multimodulus elastic layer. In the problem with spherical layer the dependence of the solution on the index of the highest degree of polynomial loading function is the fundamental difference from the planar case. If the function is linear, the spherical deformations wave reflects from the rigidly fixed boundary layer, and it's leading to the further expansion or contraction of the environment, according to a given loading. The solution with a quadratic function of loading is of particular interest. In this case, after the first wave front in the multimodulus medium the converging spherical surface occurs, on which the first invariant of the strain tensor changes sign. Therefore the effect of the interaction of the outgoing spherical deformations wave reflected from the inner spherical boundary with a converging surface, which changes the sign of the first invariant, must take into account in solving. In the case of spherical symmetry, the first invariant depends on the radius, displacement and displacement gradient. Different ratio of these values leads to different variants of emerging wave patterns.

TEMPORAL EVOLUTION OF PATTERNS OF SAND IN A RAPIDLY ROTATING CYLINDER PARTIALLY FILLED WITH LIQUID

Dyakova V.V., Polezhaev D.A.
The laboratory of vibrational hydromechanics of Perm State Humanitarian Pedagogical University, Perm
dyakova@pspu.ru

The dynamics of liquid and granular medium in a rapidly rotating horizontal cylinder (length L = 8.0 cm, inner radius R = 6.3 cm) is studied experimentally. It is found [1] that liquid – sand interface is unstable to the appearance of the spatially periodic patterns in the form of azimuthally periodic hills extended along the axis of rotation. Depending on the experimental conditions, the temporal evolution of patterns is different: regular patterns retain their initial form or transform to irregular dunes.

When the cylinder is partially filled with liquid (and sand) and rotates sufficiently rapidly, the liquid performs small oscillations under gravitational force. Under resonance conditions when the frequency of the driving force coincides with the natural frequency of the fluid the inertial waves are excited. In the experiments with water-glycerol mixtures (kinematic viscosity varies in the range between 1 and 30 cSt) in the studied range of the relative filling V/V_0 = 0.1 – 0.6 (V – fluid volume, V_0 – cavity volume) the propagating waves with azimuthal wavenumbers l = 1 – 5 are observed [2]. The intensive liquid oscillations lead to the onset of Kelvin - Helmholtz instability on the interface between liquid and granular medium and hereafter to the excitation of the spatially periodic patterns in the form of azimuthally periodic hills. The liquid oscillations affect the temporal evolution of the hills. The regular patterns generated in the threshold of onset of Kelvin - Helmholtz instability retain their initial shape and size for the duration of the experiments (several tens of minutes). When the amplitude of liquid oscillations is large, the regular hills transform into irregular dunes within a few minutes. The observations show that the regular hills have symmetrical slopes and are almost stationary in the rotating frame. On the contrary, dunes are irregular, asymmetrical and drift in the azimuthal direction.

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STABILITY ASPECTS OF PRESSURIZED MEMBRANES

Eriksson A.
KTH Royal Institute of Techology, Sweden
anderi@kth.se

We have studied the response to pressurization in thin membranes, primarily closed ones. The membranes are subjected to pressurization from gases or fluids, with density and compressibility as distinguishing aspects. The precise method for introducing the pressure is important in stability investigations: for many practically interesting cases, the pressure-expansion relation shows a limit-point instability, whereas the relation between gas amount and expansion will be monotonous, [1].

Membranes have been analytically modelled, but most of the results presented have come from finite element based simulations, with a triangular element, and local plane-stress assumptions. The element will thereby have constant stress and strain conditions in its internal. The assembled structure is given in a Total Lagrangean framework, using only translation degrees of freedom.

We have shown that the two-parameter Mooney-Rivlin model can show a critical response when an element model is subjected to bi-axial tensile stressing. This critical response can lead to non-unique deformations above a certain stress level, dependent on the method for introducing edge loads. From a pragmatic viewpoint, the movability of the loading can be seen as having a stabilizing effect. We have shown that this form of critical response can not exist for material models where only the first invariant of strain is used in the strain energy density function, [2].

The response to gas pressurization can show limit point and bifurcation instabilities. We recently have focused on the pressurization by fluids. Other forms of instabilities will result from the hydrostatic pressure distribution, dependent on the normalized fluid density. The used hyper-elastic models play important roles in not only the quantitative but also the qualitative response.

Pressurization with fluids also sets a main focus on the membrane wrinkling problem. Compared to a gas-based pressurization, where almost any initial structural configuration will tend to a uniformly tensioned sphere, the partially fluid-filled membranes will often consist of compressed parts, where wrinkling can occur. We will show how different wrinkling criteria from literature will lead to different conclusions for simple membranes subjected to hydrostatic pressure. Results from simulations close to wrinkling situations are extremely sensitive to the computational discretization.

As pressurized membranes are often completely defined by a low number of design parameters, their optimization can be seen in an uncommon setting, focusing on the constraints on response, i.e., on stiffness, stress and stability. Tracing these by generalized path-following in a parameterized space reduces the problems encountered with most optimization algorithms when dealing with severely non-linear structures, e.g., with their non-unique responses to loading, [3].

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NUMERICAL MODELING OF THE BONE TRANSFORMATION ENDURING A MECHANICAL LOAD

Maslov L.B., Etheve J.-B.
Ivanovo State Power Engineering University
leonid-maslov@mail.ru

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 structural transformation 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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THE INFLUENCE OF STRUCTURAL FEATURES OF COMPOSITE MATERIAL ON ITS MACROSCOPIC PROPERTIES

Evlampieva S.E., Svistkov A.L., Parkaeva E.A.
Institute of Continuous Media Mechanics UB RAS, Perm, Russia
evl@icmm

In filled elastomers, inclusions are randomly distributed, agglomerate and form a filler network. This provokes interest in clarifying factors that influence the macroscopic properties of the material. A two-dimensional problem is best suited to this purpose, because it is easily solved and provides the same qualitative picture as in the case of a spatial problem, whereas the parameter values determined qualitatively are much smaller.
In the present work, we study numerically structural stresses and strains in the ensembles consisting of hundreds of randomly distributed inclusions. The ensembles have the form of round perfectly rigid particles. The two-dimensional problem (plane state) is solved. The matrix is an incompressible Hookean matrix. An analytical iterative method that is based on the theory of functions of a complex variable is applied to study the specific features of the structure of the composite.
Numerical calculations are performed to study the stress-strain state and effective properties of ensembles consisting of inclusions distributed differently in the elastomeric composite. The relationships between the effective Young's modulus and the filler concentration are obtained for regular networks, chaos, filler networks, and particle aggregates. It is shown that the Young's modulus is in the gap between the regular triangular location of inclusions and the regular rectangular location of inclusions, and it increases many times in the case of high filler concentrations. The comparative analysis of the calculated results has been carried out, and the corresponding diagrams have been

plotted.

The work was supported by RFBR grant No 12-08-00740-a and by grant No C-26/627 for International Research Teams of Ministry of Education and Science of Perm Kray, RAS program No 12-T-1-1004.

THE INFLUENCE OF STRUCTURAL FEATURES OF COMPOSITE MATERIAL ON ITS MACROSCOPIC PROPERTIES

Evlampieva S.E.[1], Svistkov A.L.[1], Parkaeva E.A.[2]
1 - Institute of Continuous Media Mechanics UB RAS, Perm, Russia
2 - Perm State National Research University
evl@icmm.ru

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RMS ENVELOPE MOMENT BEAM DYNAMICS VIA NONLINEAR/NON-GAUSSIAN EFFECTS

Fedorova A.N., Zeitlin M.G.
MMM, IPME RAS, V.O. Bolshoj pr., 61, 199178, St. Petersburg, Russia
zeitlin@math.ipme.ru

We consider some moment type reductions of the nonlinear Vlasov-Maxwell equation to RMS/rate envelope equations for second moments related quantities. Our analysis is based on the variational-multiresolution approach for rational (in dynamical variables) approximation. It allows to control contribution to complex dynamics from each level of the resolution of the underlying hidden hierarchy of scales and represent solutions by the exact multiscale decomposition via nonlinear eigenmode expansions describing non-gaussian effects very important in the area of high-power beam dynamics. Our approach demonstrates the advantages of the framework based on the constructing of proper well-localized bases in functional realizations of phase spaces, providing the best convergence properties of the corresponding expansions without any perturbations or/and linearization procedures and taking into account the non-gaussian features of the underlying complex dynamics.

ABOUT ENDOCHRONIC APPROACH, "HORIZONTAL" AND "VERTICAL" SCALING AT DEFORMATION AND DESTRUCTION MODELLING OF RHEOLOGY COMPLEX MEDIA

Fedorovsky G.
Saint-Petersburg State University, Russia
g.fedorovsky@spbu.ru

Possibilities of application and development of endochronic concepts for the mathematical description of determining characteristics of nonlinear tenacity-elasticity-plastiticity are considered. "Simple", "complex" and "functional" (with memory) "horizontal" scaling of time is used [1], in view of various physical-chemical-mechanical influence (temperature, humidity, radiation irradiation, ageing, stresses, deformations, etc.). Variants of employment of "vertical" transformation [2] of determining characteristics are analyzed. The estimation of use of scales with the various hierarchical structure is made, allowing to model adequately and effectively monotonous and nonmonotonous processes of deformation, in view of linear and nonlinear tenacity-elasticity-plastiticity, with accelerated and slowed down responses of media. Such approach has given a possibility to generalize various known theories of nonlinear creep, relaxation and plasticity (technical, Boltsman-Volterra-Perso, Rabotnov, Moskvitin), and also to carry out uniform comparison of working capacity of different theories on the parameters of endochronic method.

Criteria of endochronic estimation of structural condition, damageability and destruction of media [3] are considered at quasy-statical and dynamic load, in particular in case of splitting destructions. Reduced time and its scales for an estimation of long durability in case of a constant and variable loading is considered. It has allowed to generalize known theories of durability (Gul, Zjurkov, Regel, Slucker, Tomashevsky, sedate theory, etc.), and also to carry out uniform comparison of efficiency of various theories on structure of scales.

It is necessary to note, that the scales considered in the work are structural characteristics of media, since they reflect change and reaction of structure of media on influences. Application of reduced time, scales allows to carry out forecasting of short and long mechanical processes in media, to carry out successful planning and do express-tests.

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ON INVESTIGATION OF PROCESS OF CHANGING ANGLE OF NUTATION OF ROTATING CARRYING BODY IN AN ISOLATED SYSTEM

Filimonikhin G. B., Filimonikhina I. I.
Kirovograd national technical university
filimonikhin@narod.ru fii@online.ua

Is studied dynamics of isolated mechanical systems consisting of a rotating carrying body and attached to it bodies on which during relative motions act viscous resistance forces. Such systems simulate the process of reducing or increasing by dampers, auto-balancers or antennas, solar panels; liquid tanks etc. the angle of nutation of spacecraft which orientation in space is stabilized by rotation [1-8].

Solved the problems: by allocation procedure of steady motions of the system; by definition of the conditions of their conditional asymptotic stability (under the law of

conservation of motion of center of mass and conservation of angular momentum of the system); by study of transient processes. Were applied methods of research of dynamics and conditional stability of steady motions of mechanical systems with the first integrals including cyclic.
In these studies were taken into account peculiarities of mechanical systems and tasks for solving. This allowed to concretize: the choice of the generalized coordinates, form of the main dynamic quantities, differential equations of motion and first integrals, equations of steady (stationary) motions; the conditions of conditional asymptotic stability of these motions.
Using concretized methods, by the same methodology, investigated the dynamics of a rotating carrying body with different types of auto-balancers, dampers of the nutation angle, rods which simulate antennas, etc. [5-7]. Conditions are found under which the nutation angle will be damped and eventually the carrier body will permanently rotate about the longitudinal axis. The damping rate of the nutation angle is appreciated.

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THE VIBRATIONS OF THE SYSTEM OF COAXIAL CYLINDERS PARTIALLY SUBMERGED INTO THE WATER

Filippenko G.V.
Institute of Mechanical Engineering of Russian Academy of Sciences, St.Petersburg, Russia
g.filippenko@gmail.com

The problem of oscillations of elastic constructions partially submerged into the water is one of the actual problems of modern techniques. Ships, oil platforms, sea airports are the examples of such bodies. However the exact calculation of such body's vibrations is rather complicated. So it is useful to explore the possible oscillations in these objects taking as an example more simple mechanical systems.
The aim of this work is to build the exact solution of free oscillations problem of the built-up construction: the system of coaxial cylinders. This system is partially submerged into the liquid. The free oscillations problem of this system is considered in the rigorous mathematical statement. The dispersion equation and corresponding forms are analyzed.

COUPLED PROBLEMS OF MECHANOCHEMISTRY: STATEMENTS AND SOLUTIONS

Freidin A.B.[1,2,3], Vilchevskaya E.N.[1,2]
1 - Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg, Russia
2 - Saint-Petersburg State Polytechnical University, St. Petersburg, Russia
3 - Saint-Petersburg State University, St. Petersburg, Russia
alexander.freidin@gmail.com

We consider a stress-assist chemical reaction front propagation in a deformable solid undergoing a localized chemical reaction between solid and gas constituents. The reaction is sustained by the diffusion of the gas constituent through the transformed solid material. Basing on the expression of the chemical affinity tensor derived in [1, 2] as a consequence of mass, momentum and energy balances and entropy inequality we formulate a kinetic equation in a form of the dependence of the front velocity on the normal component of the chemical affinity tensor. Then we specify the expressions for the case of linear elastic solid constituents. We introduce the notion of the equilibrium gas concentration and reformulate the kinetic equation in terms of current gas concentration at the reaction front and equilibrium concentration that depends on stresses at the front. We predict the locking effect – blocking the reaction by stresses at the reaction front if the equilibrium concentration at the reaction front is greater than the concentration at the outer surface of the body. Then we specify the expressions for the case of linear elastic solid constituents and following [3] consider in detail a planar chemical reaction front propagation in an elastic plate subjected to uniaxial tension or compression. We study how the velocity of the chemical reaction front and the locking effect depend on chemical reaction parameters and external loading.

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POSSIBILITY TO RELIEVE RESIDUAL STRESSES DURING ANNEALING

Galimzyanova K.N.[1], Polonik M.V.[1,2], Rogachev E.E.[2]
1 - Far Eastern Federal University
2 - Institution of Russian Academy of Sciences Institute of Automation and Control Processes of Far-Eastern Branch of RAS
polonik@mail.ru

Accumulation of residual stresses in materials occurs in metal manufacture and hardening. The residual stress is caused by all sorts of heterogeneity present in metals. Level of such stresses and their distribution in the vicinity of a single defect continuity is calculated in [1]. A prerequisite of this process was static definability of plastic flow [2-3]. In this paper, using the example of a thick-walled pipe with the accumulated irreversible strains there was described another possibility to determine the parameters of an elasto-plastic process on the outcome of the discharge and possible level of residual stresses relief in the annealing process. The annealing is simulated by the quasi-static process of additional deformation under slow heating, keeping at a certain temperature, and slow cooling.

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COMPUTER MODELING OF THE INTERACTION BETWEEN AFM PROBE AND NANO-STRANDS ARISING IN THE POLYMER AT ITS DESTRUCTION

Garishin O.K., Lebedev S.N.
Institute of Continuous Media Mechanics UB RAS
gar@icmm.ru

Atomic force microscopy (AFM) is one of the most promising instruments of investigation materials at the nanoscopic level. You can use it to study not only the topology of the internal structure of materials, but also their local physical properties which, as experience shows, can be substantially different from what we see at the macro level. AFM is used for polymeric materials especially successful: As a rule, an AFM probe is made of a much more rigid material, which allows to consider it practically non-deformable compared with the polymer. Indentation of hard probe into the soft polymer surface to a considerable depth allows us to investigate its nonlinear elastic properties under large deformations. Standard software supplied for the interpretation of the results of scanning atomic force, mainly based on models using the classical solution of the Hertz contact a rigid sphere and a plane linear elastic half-space. This is sufficient in most cases. However, there are situations when the Hertz solution should be used with great caution. For example: 1) "soft" nonlinear elastic materials, when an AFM probe falls into the sample to a greater depth, and 2) contact of the probe and the surface is not normal. This work is devoted to theoretical investigation of such cases, namely - contact AFM probe and nanostrand as long nonlinear elastic fiber.

Experimental studies of the nanostructure of elastomers and elastomeric nanocomposites in prescission state were conducted in ICMM UB RAS (I.A. Morozov, V.N. Solodko). It is established that, nanowire strands with mechanical properties different of the base material formed in the apex of microfracture in stretched sample.

The calculation of the elastic modulus strands by standard methods in this case gives great mistake, as contact between the probe and the surface does not occur the normal and material is nonlinear elastic. To estimate arising from this error, the following modeling studies were carried out.

Contact boundary value problem of pressing the AFM probe in free hanging nonlinear elastic nano strand as a long horizontal cylinder with a rigid cantilevered at the ends was solved. Length and diameter of the strand were taken in accordance with the real experimental data. Solution sought in three-dimensional formulation finite element method. It was believed that the probe affects the strand perpendicular to its axis. As a result, the dependencies between the elastic reaction force on the indenter F, indentation depth probe into the material uz, the distance from the end of the strand L and the magnitude of the nanofiber deflection in contact cross section dz. It was found that value of dz far exceed the uz. Thus, when the probe presses on the strand middle in a plane passing through its axis, the depth of indentation in the material was only 4-6% of the total deflection of nanofiber. In cases where an AFM probe impacted strand is not in the axial plane, the there was a significant shift of the nanostrand in lateral direction, and the direct embedment depth was less.
Hence we can conclude that the problem of interaction between the AFM probe and polymer nano strand requires more thorough and comprehensive study. Standard methods of atomic force microscopy in this case need considerable refinement.

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NEW PHASE NUCLEATION DUE TO COLLISION OF TWO NON-STATIONARY WAVES

Gavrilov S.N., Shishkina E.V.
IPME RAS, Saint Petersburg, Russia
serge@pdmi.ras.ru

The possibility of a new phase nucleation in a one-dimensional body (a bar of a finite length), caused by two non-stationary waves collision is investigated from the standpoint of the modern theory of phase transitions. Stress is assumed to be a piecewise linear function of strain, containing a "negative slope segment", thus the strain energy appears to be non-convex. Due to non-stationary loadings applied at the ends of the bar two waves appear and propagate from the ends of the bar to its middle. As a result of these waves collision a new phase nucleus appears in a neighborhood of the middle cross-section of the bar. Three important particular limiting cases are investigated analytically, e.g., a new phase inclusion is of the same stiffness as the initial one, much less stiffness and much greater one. It is proved that in the first two cases the solution corresponding the proposed simplest scenario of phase transformations always exists. For the third case the simplest scenario of phase transformations can not be realized for some values of parameters.

APPLICATION OF "THERMAL SPIKE" FOR CONTROL OF SUPERSONIC FLOW PAST BLUNT AND POINTED BODIES

Georgievsky P.Yu., Levin V.A.
Institute of Mechanics of Moscow State University, Russia
georgi@imec.msu.ru

The numerical investigation of supersonic flow past blunt and pointed bodies (sphere, cone – cylinder combination, ogive-type body) in the presence upstream of a body of very small energy deposition region and consequently thin temperature wake ("thermal spike") was performed.
Previously authors have demonstrated that the basic reason for wave drag reduction of bodies in the presence of an energy deposition localized in small regions of upstream supersonic flow was the reorganization of flow structure and the formation of front separation zones ahead of bodies. In the case of steady supersonic flow past body a static pressure inside isobaric front separation zone is determined by a total pressure in a temperature wake downstream of the energy deposition region but not by a wake thickness. Consequently finite wave drag reduction theoretically can be achieved due to the energy deposition in arbitrary small region and for arbitrary thin temperature wake. It is the essence of "thermal spike" conception as a method of wave drag reduction of bodies.
However for unsteady formulation of the problem if the energy deposition was suddenly switched on in a small region upstream of a body then intensive pulsations of front separation zones were appeared during numerical simulations. It was revealed in the present paper that the periodical pulsations of mass charge inside front separation zone were conditioned by periodical process of capturing of a local high enthalpy stream that was appeared during the interaction of a bow shock wave with a high temperature wake and subsequent blow out of extra gas from a zone. The method of dynamic transformation of the energy deposition region size on the assumption of some criteria conservation was proposed. As a result the capturing of the local high enthalpy stream was eliminated so that quasi-stationary front separation zones were formed.
To realize irregular regimes with front separation zones for well streamlined pointed bodies it was necessary to create subsonic high temperature wake with low total pressure. To do so the energy input was realized in a region elongated along ambient flow direction. However in a case when the energy deposition was suddenly switched on in upstream flow the effect of pressure decreasing was local – it was revealed only in very small area near the symmetry axes with linear size proportional to temperature wake thickness. Therefore when the size of the energy deposition region was approached to zero, than the wave drag reduction effect was disappeared. To realize global reorganization of

flow structure and formation of large quasi-stationary front separation zones the above mentioned method of dynamic transformation of the energy deposition region was applied.

Some problem both for blunt and pointed bodies was the development of Kelvin–Helmholtz instability inside front separation zone surface shifting layer which was appeared as vortex generation. Nevertheless it was verified by numerical simulation that pulsations were not destructible for the irregular flow structure and front separation zone. Pulsations amplitude was much less than in the case of pulsations of mass charge inside front separation zones.

During numerical simulations front separation zones were observed when the cross linear size of front separation region was 100 times smaller than middle section of a body cross size. In this case the saved power because of wave drag reduction was 200 times greater than input power. Thus the "thermal spike" conception was confirmed: both for blunt and well streamlined pointed bodies the possibility of finite wave drag reduction due to the energy deposition in very small regions (arbitrary small for extreme case) was demonstrated.

Investigations were carried out during 2012 – 2013 as a project in frames of Program of Fundamental Investigation of Russian Academy of Sciences No. 25 "Fundamental Problems of Mechanics and Close Sciences in Researches of Multiscale Processes in Nature and Technics".

NUMERICAL SIMULATION OF THE SHAPE MEMORY EFFECTS IN SEMI-CRYSTALLINE POLYMERS IN THE NON-UNIFORM STRESS-STRAIN STATE

Golotina L.F., Glot I.O.
ICMM UB RAS
golotina@icmm.ru

The class of semi-crystalline polymers encompasses a wide variety of solid polymeric materials. The deformation behavior of these polymers is distinguished by their ability to realize the shape memory effect, that is, to retain for some time the residual strain state and then to return to its original shape upon exposure to some temperature. In semi-crystalline polymeric materials, the mechanisms responsible for the shape memory effect are defined to a great extent by their high-molecular constitution and essentially differ from the mechanisms governing this effect in ceramics and metals. In the former case these mechanisms are initiated by the relaxation transition in the amorphous stage (glass transition).

The focus of the paper is the investigation of the specific features of the shape memory effect developed in semi-crystalline polymeric materials in the non-uniform stress-strain state. The study is carried out based on numerical modeling of thermomechanical behavior of polymeric materials. A mathematical model is a combination of two coupled problems – thermophysical problem, which defines the interrelation between the non-stationary processes of crystallization, glass transition and heat generation and thermomechanical problem, which relates the stress-strain state with heat generation, crystallization and glass transition. The proposed model has been realized in the context of the differential and variational problem formulations. Numerical implementation of the model has been accomplished using the finite element method. The results, demonstrating the specific features of the development of the shape memory effect in semi-crystalline polymers in the non-uniform stress-strain state, are presented.

The study was supported by the RFBR (grants 13-01-00553, 13-01-96038, 12-08-00832).

TO ANALYTICAL STUDY OF TRANSIENT PROCESSES IN ROTOR SYSTEMS WITH PASSIVE AUTO-BALANCERS

Goncharov V. V., Filimonikhin G. B.
Kirovograd national technical university
matkora@yandex.ru filimonikhin@narod.ru

The most comprehensive review of the literature on the study of the process of balancing of rotor during its work by passive auto-balancers is given in [1]. Inclusion of this review and other publications [2-4] shows that today too few works in which this process is studied analytically. In the studies determined only conditions for the onset of auto-balancing for two-ball auto-balancers, and transient processes are not investigated.

So is suggested the technique of analytical studies of the process of auto-balancing which suitable for auto-balancers with any number of corrective weights and which includes the following steps [5].

1. Derivation of simplified differential equations of motion of the rotor's system, linearized relative as to the entered small parameter (ratio of the auto-balancer's mass to the mass of the rotor), so the generalized coordinates and velocities, determining the deviation from the equilibrium position of the rotor.
2. Introduction of dynamic variables characterizing the process of auto-balancing - the generalized coordinates that define the motion of the rotor and the parameters determining the total imbalance of the rotor and the auto-balancer. Upon the occurrence of auto-balancing these variables are equal to zero, i.e., the rotor is balanced by auto-balancer, rotates around its longitudinal axis, and it deviation from the equilibrium position is zero.
3. Drawing up a closed system of differential equations for the introduced dynamical variables by combining

simplified differential equations of motion of the rotor system. This yields a linear system of differential equations with periodic or constant coefficients, which depends upon the symmetry of rotor, it supports and the choice of coordinates.
4. Investigation of the stability of the trivial solution of the resulting system and estimate the rate of arrival of the rotor system to it. For offensive of auto-balancing it is sufficient that the trivial solution being asymptotically stable.
The proposed technique is tested on a number of rotor systems, in which rotor makes the plane motion, has a fixed point, performs spatial movement and is balanced by one or two auto-balancers.

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REDUCED COSSERAT MEDIUM WITH LOCAL ANISOTROPY: A MODEL FOR POWDERS AT LOW CONSOLIDATION?

Grekova E.F.[1], Ruiz Botello F.[2], Castellanos A.[2], Tournat V.[3]
1 - Institute of Problems of Mechanical Engineering of Russian Academy of Sciences, Russia
2 - University of Seville, Spain
3 - University of Le Mans, France
elgreco@pdmi.ras.ru

Granular materials have some specific features that are difficult to introduce rigorously in theories. One of them is so called “local anisotropy”, coupling shear and volumetric deformation at the local level. Being isotropic at large scale, granular material may slide under local compression. This feature cannot be introduced in classical isotropic homogeneous theories. Anisotropic theories would give the anisotropy also at large scale. Another feature of granular materials observed experimentally is the rotation of grains occurring in dynamic processes. To take both effects into account in the simplest possible way, we suggest to consider a powder in terms of reduced Cosserat model with anisotropic coupling between shear—rotational and volumetric deformation. In the reduced Cosserat model each point-body performs independent translations and rotations, but nothing works on the gradient of angular velocity. We consider solid-like behaviour and look for wave propagation at small amplitude, therefore we limit ourselves by linear elastic theory. Anisotropic coupling of this kind, if small, influences qualitatively the behaviour of the medium only near certain frequencies, and for large waves the medium looks isotropic. On the other hand, Cosserat theory permits to introduce this coupling satisfying the principle of material objectivity.
We consider the wave propagation for the case of infinitesimal coupling (in more details that it was done at APM 2004) and also consider some cases for the finite anisotropic coupling. We see that it causes localisation of a part of the wave in a certain zone of frequencies and find out these characteristic frequencies where the effect is mostly pronounced. We compare this with experimental results for wave propagation for various powders at low consolidation.

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SIMULATION OF THE FORMATION OF EARTH-MOON SYSTEM FROM A PROTOPLANETARY CLOUD IN THE SUN GRAVITATIONAL FIELD

Markov N., Lapin R., Grigorieva P.
St. Petersburg Polytechnical University, Russia
nimfadoras@mail.ru

This paper describes simulation of the formation of the Earth-Moon of the protoplanetary cloud in the gravitational field of a central body. This is a continuation of the project "Earth-Moon", which resulted in the formation of a dust cloud, given as an ellipsoid, a binary system, similar to the Earth-Moon system. The relevance of this problem is to confirm the new theory of the origin of the Earth-Moon. In this work the used method is Barnes-Hut method, modified previously specially for this work. Previously it was tasked to simulate the formation of the Earth-Moon system from the cloud, given as a ring and the ellipsoid in the gravitational field of the massive central body, and to identify the characteristics of the evolution of configurations with different parameters, and to identify the optimal initial geometric configuration form of the cloud. The ultimate goal of the project - to get the values of parameters that will form a binary system with parameters, similar to the Earth-Moon system in the gravitational field of the Sun. The main result obtained in the simulation of the formation of a protoplanetary cloud - the formation of system with multiple clusters, similar in structure to the solar system. It was found that clustering system comes either from collapsing of the cloud, or by the presence in the initial distribution of small areas in which the filling density of the particles is greater than in the rest of the cloud. Combining these factors may produce a large number of clusters, which degenerated into a system similar to the solar. Therefore it can be concluded that it is appropriate to consider the cases in which a small number of clusters is produced, ideally two clusters. So, in consideration of deeper gas effect on the evolution of the system, the case was considered in which the two bodies are obtained. With this approach, the probability of obtaining a dual system is bigger. In this research we studied the evolution of cloud taking into consideration gas particles, there was made a comparison of the results with previous results calculated excluding gas; composed of stable clusters, depending on the parameters of the clouds.

MULTISCALE NUMERICAL STUDY OF FRACTURE AND DYNAMIC STRENGTH CHARACTERISTICS OF HETEROGENEOUS BRITTLE MATERIALS USING THE MCA METHOD

Grigoriev A.S.[1], Shilko E.V.[1,2], Skripnyak V.A.[2], Smolin A.Yu.[1,2], Psakhie S.G.[1,2]
1 - Institute of Strength Physics and Materials Science of SB RAS, Tomsk, Russia
2 - National Research Tomsk State University, Tomsk, Russia
grigoriev@ispms.tsc.ru

The hierarchy of principal structural scales (microscopic, mesoscopic and macroscopic) can be formally identified in the internal structure of most materials. To model materials with heterogeneous internal structure at the different structural scales the so-called "multiscale approach" can be efficiently used. In the framework of this approach a representative volume of the material is determined for each structural scale from the lowest to macroscopic one. According to the results of theoretical study (analytical description or numerical simulation) of the response of representative volume the integral rheological function and the values of its parameters (including strength) are defined. Constructed in this way rheological models are used as input data for the components of the structure (regions with different structural and phase composition) of a higher structural/spatial scale. Sequential implementation of this procedure from the lowest scale up to macroscopic one provides construction of a macroscopic rheological model of material.

It is known, the characteristics of the material are determined not only by the features of the internal structure, but also greatly depend on the load type and load rate, in particular. Therefore, the search of adequate methods for obtaining the strength characteristics of materials is one of the most important trends in modern science. This is due to the fact that even at low load rates the effect of strain rate on the results of the experiment is observed, while the dynamic impact the strain rate factor is determinative. Numerical simulation is a great way to show what determines the material properties in every particular case, the effect of boundary conditions on investigated material behavior, etc.

In the present work the multiscale approach to the construction of multiscale rheological models is implemented within the numerical method of movable cellular automata (MCA) belonging to the group of computational particle-based methods. The formalism of this method combines mathematical formalisms of discrete element method and the approach of cellular automata. The non-associated flow law with Drucker-Prager failure criterion is used as the rheological model in the formalism of MCA (Nikolaevsky's plasticity model). The model parameters (such as compressive and tensile strengths, dilation and internal friction coefficients) are the functions of both accumulated inelastic strain and strain rate.

Multiscale approach is applied to construct a multiscale structural model of zirconium alumina concrete (ZAC) with reinforcing particles of electrofusion zirconium dioxide and barium-alumina cement binder. Herewith, the internal structure of investigated material on macroscopic and mesoscopic structural scales is taken into account. It should be noted that the topicality of the study of mechanical properties of ZAC is connected with the big prospects of its application in nuclear reactor protection systems including protection against seismic hazard.

As a result of numerical simulation using multiscale approach, the mechanical properties (including parameters of the rheological model and strength values) of zirconium alumina concrete were obtained for both macroscopic and mesoscopic scales (for representative volumes of zirconium alumina concrete at the macroscopic and mesoscopic scales). The effect of strain rate on material behavior was analyzed in case of uniaxial compression and tension. Shown that at the strain rates corresponding to the dynamic regime of loading the method of experimental realization of the specified kind of stress state (uniaxial compression or tension, nonequiaxial compression and so on) plays the determining role in the studying the strength properties of material.

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INFLUENCE OF STRUCTURAL PARAMETERS OF THE MASONRY ON EFFECTIVE ELASTIC PROPERTIES AND STRENGTH

Grishchenko A.I, Semenov A.S, Melnikov B.E, Semenov S.G
Saint-Petersburg State Polytechnical University
gai-gr@yandex.ru

Masonry is two phase composite material consisting of brick and mortar joints, generally arranged periodically. Studying influence of the masonry structural parameters on her deformation characteristics is important for designing and retrofitting masonry structures. At the present stage the computer simulation are used as a viable alternative to otherwise expensive and time-consuming laboratory and field experiments.
The masonry, representing an elastic mortar and elastic bricks, is analyzed with aim to evaluate mechanical and strength properties. By means of the direct finite element simulation and homogenization the analysis of variation influence in the heterogeneous material microstructure characteristics (influence of brick aspect ratio and orientation angle) on the local stress-strain state and mechanical properties of the representative volume element of considered composite has been fulfilled.

EXPERIMENTAL DETERMINATION OF THE CONTACT CHARACTERISTICS DURING INDENTATION OF SOFT MATERIALS BY VIDEO TACTILE PNEUMATIC SENSOR

Gubenko M.M., Morozov A.V., Lyubicheva A.N.
A. Ishlinsky Institute for Problems in Mechanics RAS
maxgubenko@mail.ru

An indentation technique is one of effective methods to determine the elastic modulus of materials using information about contact geometry, indenter shape and applied load. This work presents a device and a method which allows to estimate elastic modulus of soft materials through indentation them by video tactile pneumatic sensor. The device is a sealed metal cylinder fixed by one of its endings to the load sensor. Another side of cylinder ends with the soft silicone membrane which has semispherical shape of 5 mm radius. A video camera, an optical proximity sensor and a LED are located under this membrane. The proximity sensor provides measurements of displacement of the central point on the membrane and the LED permits regulating of illumination in the chamber to provide better visualization of contact area by video camera. Finally, an extra air pressure in the chamber may be obtained in the range from 6 to 15 kPa. The pressure in the system is measured by a sensitive air-gauge and can be adjusted by a pressure regulator. Possibility of changing the pressure under the silicone sensor tip allows varying the stiffness of the video tactile pneumatic sensor. Thus using this device permits to measure contact characteristics during indentation of various materials which elastic modulus are significantly differ from each other.
During penetration of the transparent membrane into the investigated material the video camera captures the images of the contact area, and after that the contact radius can be measured. The boundary of the contact area is well determined on the image by the reflected light on the bended membrane surface. The dependences of the contact area radius v.s. the displacement of the central point of the membrane were obtained by applying the developed experimental method to different contact pairs, contact surface conditions and values of the internal pressure.
The contact interaction between hollow elastic semisphere and a sample is considered using finite element method as well. The axisymmetric contact problem was solved in geometrically nonlinear formulation, as the large strains were observed in the tests. The material models were taken linear elastic for the sensor head as well as for samples. The paper compares the calculations and experiments which shows good agreement of the results.

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FINITE-ELEMENT MODELING OF SEMI-ELLIPTICAL FATIGUE CRACK GROWTH USING DAMAGE ACCUMULATION APPROACH.

Guchinsky R. V.[1,2], Petinov S. V.[1,2]
1 - IPME RAS
2 - St.Petersburg Polytechnic University
ruslan239@mail.ru

Simulation of surface fatigue crack growth for residual life assessment of structural elements is almost entirely based on the application of Linear Elastic Fracture Mechanics (LEFM). Thereby it is generally assumed that the crack front does not essentially change its shape, although it is not always confirmed by experiment. Furthermore, LEFM approach ignores plastic strain – one of the leading factors associated with the material degradation and fracture. Also, evaluation of stress intensity factors meets difficulties associated with changes in the stress state along the contour of the crack front .
Approach using Strain-life criterion and based on the finite element modeling of damage accumulation was proposed for simulation the evolution of surface cracks. It takes into account the crack closure effect, the nonlinear behavior of damage accumulation and material compliance increasing due to the damage

advance. Suggested damage accumulation technique was applied to the semi-elliptical crack growth from the initial defect in the steel compact specimen. The simulation results are in good agreement with the experimental data.

COMPUTER SIMULATION CONSTRUCTION AND OPERATION OF NORTHERN OIL AND GAS FIELDS

Filimonov M.Yu.[1,2], Gusarova V.V.[2], Vaganova N.A.[1]
1 - Institute of Mathematics and Mechanics of Ural Branch of the Russian Academy of Sciences
2 - Ural Federal University
Valia.gusarova@yandex.ru

Before starting development of oil and gas fields in areas of permafrost distribution, according to the approved standards, it is required to carry out a large series of numerical calculations for modeling of temperature fields in frozen soil from various sources of heat (for example, production wells), or cold (cooling devices) for soil thermostabilization. Particularly, in drilling sites designing a thawing radius (a zero isotherm from the well lower than layer of seasonal changes of temperature in soil) has to be found for all times of operation of the well for 30 years. A three-dimensional mathematical model [1-3] considering the most essential factors, influencing on distribution of temperature fields in soil, a numerical algorithm and software packages «Wellfrost» and «TermoFrost» («TermoFrost» package is focused on cloud computations with using super computer) are developed for this purpose. The software packages were tested for eight Russian oil and gas fields located in a zone of permafrost. The computed results are in a good agreement with experimental data.

Usually simulation of thermal fields has to be processed in a large three-dimensional computational area (up to 100 meters) therefore a detailed grid is required for providing necessary accuracy. Its size determines a processing time of calculation and requirements to the characteristics of computer. It is necessary to carry out remote calculations with using large-nodes computer complexes and to develop «in the clouds» technologies for organization of numerical calculations for the users, who aren't possessing special knowledge of organization of such calculations. Particularly, a climatic dataset (with respect to the open NASA databases) was developed to make it easier the process of input of the initial parameters which are responsible for climatic characteristics, corresponding to the chosen latitude and longitude. This climatic base is included in the cloudy interface.

CIRCULAR PRISMATIC LOOPS OF MISFIT DISLOCATIONS IN BULK AND HOLLOW CORE-SHELL NANOPARTICLES

Gutkin M. Yu.[1,2,3], Kolesnikova A. L.[3], Krasnitckii S. A.[2], Romanov A. E.[4,5,1]
1 - Department of LED Technologies, ITMO University, St. Petersburg, Russia
2 - Department of Mechanics and Control Processes, St. Petersburg State Polytechnical University, St. Petersburg, Russia
3 - Institute of Problems in Mechanical Engineering, Russian Academy of Sciences, St. Petersburg, Russia
4 - Togliatti State University, Togliatti, Russia
5 - Ioffe Physical Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia
m.y.gutkin@gmail.com

In the last decade, much attention has been attracted to core-shell nanopaticles (NPs) demonstrating a wide range of potential applications in advanced nanotechnologies [1-6], e.g. in optoelectronics, photonics, spintronics, catalysis, sensors, solar cells and biomedicine. NP cores are mostly bulk nanoscale solids [1-3], although some cases of hollow cores have already been demonstrated as well [4-6]. Due to the differences in crystal lattice parameters and thermal expansion coefficients of the materials constituting core-shell NPs, their formation is always accompanied with appearance of residual (misfit) elastic strains and stresses which can relax by different mechanisms [7, 8]. One of possible mechanisms of the misfit stress relaxation is the generation of circular prismatic loops of misfit dislocations around the core. A first-approximation analysis of the case, when such a misfit dislocation loop (MDL) lies in the equatorial section of a bulk core-shell NP, was done in [8]. The special cases of fine cores and thick shells and thick cores and thin shells were considered separately and then combined to predict a general diagram of structural stability of the NP with respect to the MDL generation.

Recently we have found strict solutions of the boundary-value problems in the theory of elasticity for circular prismatic dislocation loops placed coaxially in bulk and hollow elastic spheres [9]. This has allowed us to reconsider rigorously the problems of MDLs placed in arbitrary planes around either bulk or hollow cores in elastically homogeneous core-shell NPs. We have calculated the energy changes due to the MDL generation and shown that its appearance is energetically favorable when the lattice misfit is larger than a critical value. The critical misfit is a function of the NP sizes and the MDL position along the core axis. It is shown that the most preferable place for the MDL formation is the equatorial plane of the NP. For a given MDL, there is a minimal critical misfit value such that for a misfit value smaller than this minimal value, the MDL formation is unfavorable for any geometry of the NP. For a given misfit value larger than that minimal value, the MDL formation is favorable in an interval of the interface-to-outer radii ratio. This interval extends with increasing outer radius of the NP and shrinks with increasing the radius of its inner hole. The minimal critical misfit and the critical shell thickness strongly increase with the inner-to-outer radii ratio when this ratio is larger than 0.8. This gives a potential opportunity to produce coherent (MDL free) hollow core-shell NPs by using thin-wall shells with inner-to-outer radii ratio larger than 0.8 as supporting cores.

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STUDY OF THE BEHAVIOR AND THE TENSILE AND IMPACT FAILURE OF POLYCRYSTALLINE 43000 ALLOY SUBJECTED TO VARIATIONS IN HOMOGENIZATION TEMPERATURES.

Hakem A.[1], Bilek A.[2], Bouafia Y.[1]
1 - LaMoMS Laboratory, University of Mouloud Mammeri, Tizi-Ouzou, 15000 Algeria
2 - Mechanical Engineering Department, UMMTO, Tizi-Ouzou, 15000 Algeria
a_hakem1951@yahoo.fr

The purpose of this study is to determine the influence of the variation of the homogenization temperature and the different industrial processes of sand casting and metal shell casting by gravity at room temperature or under pressure, mechanical as well as manual, of various mechanical components used by SNVI (Unit Foundry Aluminum Rouiba) and ENEL (Unit Engines Fréha Tizi -Ouzou) on the damage behavior by impact and by uniaxial loading, the Brinell hardness, the micro hardness and the microstructure of a foundry alloy (chemical designation: AlSi10Mg, digital designation: 43000the).

The addition of 10 % silicon and a low percentage of magnesium (Mg ≤ 1%) to the aluminum represents the main agents for improving mechanical properties in addition to specific heat treatments which show different kinds of precipitates that hinder the movement of dislocations.

The physical characterization, chemical in general and mechanical in particular, is crucial for the design of various metal components subjected to various loads in mechanical devices.Therefore one can not calculate or design these parts without identifying and quantifying their characteristics. To determine these caracteristics we simulate static or dynamic tests, usually performed on standard specimens.

The AlSi10Mg alloy, which is the aim of our study, is a steel type containing some magnesium added in small amounts (0.17 to 0.40) % Mg to allow structural hardening and efficient use in applications with high mechanical characteristics of the selected homogenization temperatues states noted: TH500°C, TH540°C, TH560°C and TH570°C. This alloy contains 10 % silicon which provides very good properties for implementation by casting (average flowability, low volumetric shrinkage upon solidification , the shrinkage decrease in the solid state and the expansion coefficient). It is used for complex shapes with very small thicknesses (~ 5 mm) in medium mechanical requirements.

CALORIMETRIC STUDY OF FLUOROPLASTIC CONTAINING NANOTUBES OF CARBON

Revo S.[1], Dorbani T.[2], Zahaf A.[2], Hamamda S.[2], Boubertakh A.[2]
1 - National Taras Shevchenko University of Kyiv, Ukraine
2 - Laboratoire TTSM Université Constantine 1, Algérie
shamamda@yahoo.com

The purpose of the present work is to study the effect of nanotubes of carbon introduced in the polymer matrix F4.

The calorimetric study of the fluoroplastic containing 20wt.% multi-walled nanotubes reveal the presence of an anomalous which appears at about 340°C. This new position of the peak, characteristic of the glass phase, compared to the F4 matrix shows that this material becomes resistant to the thermal chocks. The latter phenomenon suggests that the degradability of the matrix F4 containing the multi-walled nanotubes has been delayed. Other complementary experiential results confirm the good stability at high temperatures of our nanocomposite material.

Dilatometric measures have shown that the thermal expansion coefficient of the latter material is clearly below that of pure F4 matrix. This behavior shows that there has been a reinforcement of intermetalic bands.

The obtained mechanical properties results, such as, are listed below:

-The compression strength is 20% higher compared to that of the F4 matrix.

-Friction coefficient of 25 to 30% lower than that of similar material and that of the F4 matrix.

-Wear resistance is 100 times greater than that of F4 matrix.

THE DIFFERENT RESULTS WHICH HAVE BEEN OBTAINED BY DIFFERENT TECHNIQUE OF INVESTIGATION ARE IN GOOD AGREEMENT. A NEW CONSTITUTIVE FORMULATION IN RUBBER ELASTICITY

Huang Zh.
Department of Mechanics, College of Engineering, Peking University, Beijing 100871, China
huangzp@pku.edu.cn

In this lecture, a new framework to formulate thermo-elastic constitutive relations of rubbery materials undergoing finite deformations is presented. The strain-energy function for incompressible materials is extended to incorporate the effects of compressibility and temperature changes. The novelty of this framework is that only a few material functions and material parameters to be fitted with the experimental data are required, and these functions and parameters have clear physical meaning. In order to show the effectiveness of the proposed formulation, an illustrative incompressible material model is employed. As an example, the Gent-Gent model for incompressible rubbers is chosen in this lecture. A new expression of the Helmholtz free energy of rubberlike materials, which takes into account the material compressibility and thermal effect, is then derived. In this generalized Gent-Gent model, only one material function and six material parameters are introduced. It is further shown that the generalized Gent-Gent model can be used to predict the stress-strain behaviour over the entire range of deformation. Even for incompressible materials, the strain-energy function in this lecture is different from that given by Gent himself. The generalized Gent-Gent model can also adequately describe the thermal-mechanical coupling effect, in which thermoelastic inversion phenomena occur.

INVESTIGATION OF ELECTROCONVECTION OF POORLY CONDUCTING LIQUID IN THE MODULATED ELECTRIC FIELD UNDER UNIPOLAR CHARGE INJECTION WITH THE CATHODE

Il'In V. A., Mordvinov A. N.
Perm State University
ilin1@psu.ru, mordvinovan@gmail.com

The electroconvection of isothermal poorly conducting liquid is investigated in the modulated electric field of the horizontal capacitor under the unipolar charge injection. The charge density on the cathode is proportional to an electric field intensity in the capacitor. The electrohydrodynamic (EHD) approximation is used. The diffusion of a charge is not taken into account. The injective charge in a liquid interact with an external electric field therefore a liquid can come in movement even in weightlessness.
The linear analysis of stability is done and the nonlinear regimes are studied. The nonlinear problem is solved with the help of finite differences method. The influence of modulation amplitude and frequency on dynamics of nonlinear regimes is investigated. The processes of a charge transport through volume of liquid are studied.

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INVESTIGATION OF ELECTROCONVECTION MODELS OF IDEAL DIELECTRIC IN THE ALTERNATING ELECTRIC FIELD OF THE HORIZONTAL CAPACITOR

Il'in V. A.
Perm State University
ilin1@psu.ru

The electroconvection of ideal dielectric in the alternating electric field and gravity field is investigated in frameworks low-mode and many-mode models. The electrohydrodynamic (EHD) approximation is used. It is supposed that dielectrophoretic mechanism of instability plays significant role. The electroconvection models are obtained by the Galerkin-Kantorovich method for the stress-free and hard boundary conditions. The regular and chaotic oscillations is investigated with help of Fourier analysis. The scenarios of transition to chaotic behavior are analyzed for arbitrary frequencies.
The averaging procedure was used in order to obtain the electroconvection model of ideal dielectric for hard boundaries in high frequency electric field. The linear and nonlinear analysis of this electroconvection model is done.
This work was supported by the Russian Foundation for Basic Researches (Grant № 14-01-31253).

UNSTEADY APPROACH TO NUMERICAL SIMULATION OF CONDUCTOR MOTION

Ivanova O.A.
Bauman Moscow State Technical University
ivanovaolgaal@mail.ru

Galloping is high-amplitude low-frequency motion of iced transmission lines conductor induced by the steady wind. The galloping phenomenon must be thoroughly

investigated as it may lead to the line outage; at the same time reproducing galloping on a full scale test line is not an easy task. Therefore it is necessary to develop numerical approaches to simulation of wind induced conductor motion.
The algorithms of numerical simulation of conductor galloping are usually based on the quasi-steady approach to wind loads computation. This means that aerodynamic loads are assumed to be proportional to the stationary aerodynamic coefficients of the conductor cross-section preliminarily obtained through wind tunnel measurements or numerically. But in some complex conditions, e.g. under the action of essentially unsteady wind or in the case of bundled conductor, the quasi-steady approach can lead to significant errors. In this research the unsteady approach is developed which is based on the direct numerical simulation of the flow around conductor cross-sections using meshfree lagrangian vortex element method.
The program using MPI technology is developed, which enables to execute computations effectively on various multiprocessor systems. Some test computations are performed. The results are compared with those known from literature.

THE EVOLUTION EQUATIONS FOR INTENSIVE DEFORMATION PROBLEMS OF THE ELASTIC INHOMOGENEOUS MEDIUM

Ivanova Yu.E., Ragozina V.E.
Institute of Automation and Control Processes of Far Eastern Branch of Russian Academy of Sciences
ivanova@iacp.dvo.ru

Great number of research is devoted to the shock waves properties in nonlinear elastic mediums. From them it is well known that in general the mechanism of the formation and subsequent motion of the strong discontinuities surfaces depends on the properties of the elastic medium, on the preliminary deformations, on the discontinuity intensity and also on the post-impact effect on boundary. The shock wave velocities and the geometry of these surfaces except in the simplest boundary value problems are also included in the number of unknown quantities. Therefore, some boundary conditions are set on the surfaces with beforehand unknown location. Finally, the shock waves in solids ceases to be purely longitudinal or transverse and become mixed.
The matched asymptotic expansions method is one of the most effective theoretical methods for investigation of the generalized solutions of dynamics problems with deformations discontinuity surfaces. Analysis of the outer expansion allows to specify those space-time areas where the nonlinearity is the dominant factor. Simultaneously for these areas it is possible to determine the nonlinear evolution equation. It is simpler than the original problem equations, but retains the basic properties of nonlinear wave process. For example, for the plane longitudinal shock waves it will be the Cole-Hopf equation. For purely transverse plane waves in an incompressible elastic medium the Cole-Hopf equation determines the change in squared intensity of wave process. Account of viscosity leads to the Burgers equation for longitudinal waves and its modification for transverse waves. These evolution equations arise in the study of one-dimensional plane wave propagation in nonlinear elastic mediums at sufficiently large distances from the loaded boundary.
For long-distance solids an additional factor that influences on the wave deformation process can be inhomogeneity of the medium in the direction of shock wave motion. In this paper we consider the weak inhomogeneity of power type. Even in this case it is shown that the accounting of non-linear stress-strain dependence and inhomogeneity of elastic properties can lead to a variety of the evolution equation or the evolution equations system. The most interesting variant of the evolution equation occurs when the shock process intensity and weak inhomogeneity have the same order. The transition to the limiting interior problem of the small parameter method is dictated by the chain of internal problems with the change of all the independent variables and their scales. In this paper we consider the propagation features of the one-dimensional longitudinal and transverse shock waves in the nonlinear elastic inhomogeneity compressible or incompressible mediums.

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CERMAT2 - NEW CERAMIC TECHNOLOGIES AND NOVEL MULTIFUNCTIONAL CERAMIC DEVICES AND STRUCTURES

Jatro I., Piccolroaz A.
Dept. of Civil, Environmental and Mechanical Engineering, University of Trento
irena.jatro@ing.unitn.it

This poster aims to promote the activities carried on within the CERMAT2 – Marie Curie ITN project, to foster interaction among the scientific community and to attract young researchers.
The CERMAT2 project is aimed to train young researchers in understanding the modelling of Solid Mechanics problems applied to the process and design of advanced ceramics in a synergic collaboration between academia and industry, in view of social developments related to enhancement of industrial production and pollution reduction. In the EU, the ceramic industry is employing about 200,000 people and involves a production (including bricks, sanitaryware, tiles, technical ceramics, and refractory

products) on the order of € 28 billion per year. Industries related to the production of traditional ceramics are well developed in Italy (with a € 9 billion turnover), while advanced ceramics are targeted in Germany and UK (a sector with a 20% growth per year). Advanced ceramics find special (biomedical, thermomechanical or nanotech) applications, where they exhibit unchallenged characteristics (for instance, thermal stability, wear resistance and chemical inertia) and, compared to other finishing materials, can minimize environmental impact. Despite the technical and industrial interest, the production of ceramic components is based on poorly understood empirical processes, often difficult to control. As a consequence, the production of rejected items can still be strongly reduced, a target having an impact on both cost reduction and environment preservation. In fact, the employed technologies involve a massive waste of energy and material, so that even a small increase in the mechanical performance of the ceramic structure would yield a reduction in weight of articles with a deep impact on pollution reduction. The optimization of the production process is directly linked to the modelling of the behaviour of powders and binders used during compaction, in the simulation of sintering, and in the design of mechanical characteristics of the final pieces.

INSTABILITIES - INSTABILITIES AND NONLOCAL MULTISCALE MODELLING OF MATERIALS

Bigoni D., Jatro I.
Dept. of Civil, Environmental and Mechanical Engineering, University of Trento
irena.jatro@ing.unitn.it

This poster aims to promote the activities carried on within the INSTABILITIES – ERC Advanced Grant project, to foster interaction among the scientific community and to attract young researchers.
Failure in ductile materials results from a multiscale interaction of discrete microstructures hierarchically emerging through subsequent material instabilities and self-organizing into regular patterns (shear band clusters, for instance). The targets of the project are: (i.) to disclose the failure mechanisms of materials through analysis of material instabilities and (ii.) to develop innovative microstructures to be embedded in solids, in order to open new possibilities in the design of ultra-resistant materials and structures. The link between the two targets is that micromechanisms developing during failure inspire the way of enhancing the mechanical properties of materials by embedding microstructures. The aim is to provide design tools to obtain groundbreaking and unchallenged mechanical properties employing discrete microstructures, for instance to design a microstructure defining a material working under flutter condition. The design of these microstructures will permit the achievement of innovative dynamical properties, defining elastic metamaterials, for instance, permitting the fabrication of flat lenses for elastic waves, evidencing negative refraction and superlensing effects. The objective is the discovery of these effects in mechanics, thus disclosing new horizons in the dynamics of materials.
Microstructures introduce length scales and nonlocal effects in the mechanical modelling, which involve the use of higher-order theories. The analysis of these effects, usually developed within a phenomenological approach, will be attacked from the fundamental and almost unexplored point of view: the explicit evaluation of nonlocality, related to the microstructure via homogenisation theory.

A COLLABORATIVE PROJECT BETWEEN INDUSTRY AND ACADEMIA TO ENHANCE ENGINEERING EDUCATION AT GRADUATE AND PHD LEVEL IN CERAMIC TECHNOLOGY

Bosi F.[1], Mazzocchi E.[2], Jatro I.[1], Dal Corso F.[1], Piccolroaz A.[1], Deseri L.[1], Bigoni D.[1], Cocquio A.[2], Cova M.[2], Odorizzi S.[3]
1 - Dept. of Civil, Environmental and Mechanical Engineering, University of Trento
2 - Sacmi Imola S.C., Imola BO, Italy
3 - EnginSoft Spa, Mattarello- Trento, Italy
irena.jatro@ing.unitn.it

This poster aims to promote the activities carried on within the INTERCER2– Marie Curie IAPP project, to foster interaction among the scientific community and to attract young researchers.
Results of an intensive and effective industry-academia partnership are presented, demonstrating that barriers to inter-sectoral mobility have been overcome, achieving an enhancement in the quality of both graduate and doctoral programmes in engineering.
The industrial and social needs of improving the ceramic production process and of developing novel advanced ceramic multifunctional materials and structures were essential for the creation of a synergetic cooperation between a world leader industry for Ceramics (SACMI), a medium enterprise specialized in Virtual Prototyping (ENGINSOFT) and an academic research group in Solids and Structural Mechanics of the University of Trento. The research collaboration has lasted several years producing a continuous inter-sectoral and inter-disciplinary transfer of knowledge among the partners and maximising in this way their performance, in particular in terms of added value generated through human capital improvements. An additional impact of the above mentioned cooperation has been the award of a Marie Curie-Industry Academia-Partnership & Pathway four years grant focused on boosting skills exchange between the commercial and non- commercial sectors through secondments of academic staff and PhD students to

industry and vice-versa. Moreover, the partnership has led to a significant enhancement in the teaching results, together with an increasing motivation of the students, crucial in the Engineering Education.

INTERCER2 - MODELLING AND OPTIMAL DESIGN OF CERAMIC STRUCTURES WITH DEFECTS AND IMPERFECT INTERFACES

Gei M., Jatro I.
Dept. of Civil, Environmental and Mechanical Engineering, University of Trento
irena.jatro@ing.unitn.it

This poster aims to promote the activities carried on within the INTERCER2 – Marie Curie IAPP project, to foster interaction among the scientific community and to attract young researchers.
The research project INTERCER2 aims to an in-depth scientific understanding of the ceramic production process in order to reduce costs of ceramic component design and manufacturing and to produce ceramic components more reproducibly with improved performance and reliability.
The goal will be achieved by

- *improvement of the powder compaction and ceramic production process;*
- *development of novel advanced ceramic multifunctional materials and structures.*

The Consortium involves five partners: the University of Trento, specialized in Engineering and Computational Mechanics; the University of Liverpool, specialized in Mathematical and Numerical Modelling; the Aberystwyth University, specialized in Applied Mathematics and Materials Physics; SACMI, a leader industry operating in the field of ceramics and covering the entire process of ceramic production, from the powder to the final piece and design of the machineries for production; ENGINSOFT, an expert industry operating in the field of informatics applied to Computer-Aided-Engineering (CAE), Virtual Prototyping (VP), process simulation and the optimization of design and production processes).

HOTBRICKS - MECHANICS OF REFRACTORY MATERIALS AT HIGH-TEMPERATURE FOR ADVANCED INDUSTRIAL TECHNOLOGIES

Dal Corso F., Jatro I.
Dept. of Civil, Environmental and Mechanical Engineering, University of Trento
irena.jatro@ing.unitn.it

This poster aims to promote the activities carried on within the HOTBRICKS – Marie Curie IAPP project, to foster interaction among the scientific community and to attract young researchers.
The HOTBRICKS project is principally aimed to exchange know-how and experience in the modern and challenging field of Nonlinear Solid Mechanics via staff secondment, through the design of thermal shock resistant elements in use for liquid steel technologies, in a close and synergic collaboration between a research academic group (UNITN) specialized in the modelling of nonlinear behaviour of materials and a creative industry (VESUVIUS), leader in the production of refractories for steel, glass and foundry industries and committed to safety and sustainable development.
The goal will be reached by: i) advances in the design of refractory pieces and machines; ii) development of innovative technologies for handling molten materials (steel, glass or other).
The novel technologies will improve problem identification and enhance successful design, with an increase of safety factors.

NUMERICAL SIMULATION OF LOCAL FIELD CONCENTRATION NEAR THE CONTOUR OF A FRACTURE

Jaworski D., Linkov A.M., Rejwer E., Rybarska-Rusinek L.
Rzeszow University of Technology, Poland
dawidj.poczta@gmail.com

The purpose of the talk is to present accurate, stable and robust methods of stress evaluation at areas of strong field concentration in a vicinity of a propagating front of a hydraulic fracture. Natural inhomogeneities in rocks, such as inclusions, pores, faults, etc., are to be taken into account. We consider both 2D and 3D problems. To reach the goal we suggest using: (i) hypersingular boundary integral equations specially tailored to account for displacement discontinuities on surfaces of fractures, microcracks and contacts of structural elements; (ii) higher order approximations of boundaries and density functions; (iii) special singular, (multi-) wedge elements in 2D and special trapezoidal (triangular, rectangular) edge elements in 3D; (iv) analytical recurrent formulae for all integrals employing mentioned approximations.
In 2D problems the calculations are performed using the advantages of complex variables. In 3D problems, in the case of square-root asymptotics, we suggest a highly efficient and accurate, unified analytical method for evaluation of all influence coefficients.
Emphasize, that these methods provide accurate evaluation of stress intensity factors (SIFs). This is of significance for explicit accounting for the strength of a material, evaluation of safety factors (using the theory of extreme values), modeling the propagation of a fracture front and accompanying seismicity, etc.
The results of numerical experiments highlight the efficiency of the methods developed.

GEOLOGICAL FEATURES OF UKRAINIAN SHALE FORMATIONS PROMISING FOR THE PRESENCE OF INDUSTRIAL UNCONVENTIONAL HYDROCARBONS ACCUMULATIONS IN CONNECTION WITH HYDRAULIC FRACTURING

Mykhailov V., Karpenko O., Karpenko I.
Taras Shevchenko National University of Kyiv, Ukraine
sharanskiy@gmail.com

Ukraine continues to hype up the unconventional oil and gas issue. The main prospects are associated with unconventional shale reservoirs and tight sandstones, which imply fracturing for subsequent commercial production. According to new data, Ukraine ranks third in Europe and the thirteenth in the world in resources of unconventional hydrocarbons. Estimated resources are 128 Tcf (3.6 trillion cubic meters). According to the research of Ukrainian geologists shared resources of the Western, Eastern and Southern regions may reach 700 trillion cubic feet. The main prospect is at Eastern oil and gas region (70% of resources) at Carboniferous sediments of Dnieper-Donets Basin, in Western oil and gas region (17%) are allocated in shale formations of Volyn-Podolia, Southern (13%) – at Crimea peninsula and Preddobrudzhe foredeep. Two large international companies Shell and Chevron received wide license blocks, have received permission for exploration and production of unconventional hydrocarbons and have already begun exploratory drilling.
Lithologic and mineral, geochemical and mechanical properties of unconventional reservoirs at Ukrainian oil and gas regions are very diverse due to the extensive lateral and vertical distribution and various genesis. Data which we operate for the study of the above formations were obtained by geophysical and laboratory studies, which were conducted during drilling to other target horizons. We have developed petrophysical techniques for assessing the prospect of sediments for presence of productive unconventional hydrocarbon accumulations. It is necessary to supplement these methods by mathematical mechanism to assess the success of fracturing in promising deposits, based on available data.
In the coming years, the results of the exploration works will give impetus for wide drilling campaigns, followed by hydraulic fracturing, which causes increased attention to this issue.

INVESTIGATION OF ELECTROCONVECTION OF POORLY CONDUCTING LIQUID IN THE ALTERNATING ELECTRIC FIELD OF THE HORIZONTAL CAPACITOR

Il'In V. A., Kartavykh N. N.
Perm State University
kartavih@psu.ru

The electroconvection of poorly conducting liquid in the alternating electric field of the horizontal capacitor is investigated on the base of eight-mode model. The electrohydrodynamic (EHD) approximation is used. It is supposed that electroconductive mechanism of instability plays significant role. This mechanism is associated with an electric charge accumulated in a liquid due to the conductivity gradient inherent in non uniformly heated liquid. The interaction of volume charge with the electric field results in the motion of a liquid. The interaction of the thermogravity and electroconductivity mechanisms of instability is investigated. The case of heating from below is considered.
The nonlinear evolution of convective system is analyzed with help of eight-mode model, which is obtained by the Galerkin-Kantorovich method. The stress-free boundary conditions are considered. The time evolution of solutions is investigated with help of the Fourier analysis method. The direct numerical integration of the amplitude equations demonstrates complex dynamic behaviour, including stationary, periodic and chaotic regimes. The boundaries of regions with different time behaviour of solutions are determined in the space of parameters "modulation frequency – electrical number". The dependence of Nusselt number on magnitude of supercriticality is calculated. It is found that the transition to chaos is realized through period-doubling cascade.
This work was supported by the Russian Foundation for Basic Researches (Grant № 14-01-31253).

BENDING AND TORSION OF NONLINEARLY ELASTIC BODY WITH MICROSTRUCTURE

Karyakin M.I., Mayorova O.A., Pustovalova O.G.
Southern Federal University
karyakin@sfedu.ru

A new wave of interest to the models of continuum mechanics based on the hypothesis of kinematic independence of the displacement and rotation fields, entered into the usage by Cosserat brothers more than a hundred years ago, is associated primarily with the needs of nanomechanics in such models of the elastic behavior of objects that can take into account the structure of the material; furthermore they are relevant

in many areas of biomechanics. The main task of this study was to find such ways of influence on the elastic body which lead to stress-strain states significantly different in the classical theory of elasticity and in the theory of the Cosserat continuum. In particular, such situations can be the basis for the development of experimental techniques for the identification of parameters of constitutive relations of media with microstructure and for the verification of the models used.
We used semi-inverse method of nonlinear elasticity to study two problems, namely the problem of a nonlinear torsion of the circular cylinder and the problem of pure bending of the panel with rectangle cross-section. The problems differ in variants of semi-inverse representation of the displacements and in functions of the specific potential energy of the Cosserat medium, though in all cases the semi-inverse representation contains two functions to be defined (the radial displacement and the micro-rotation angle of the particles of the body), depending only on the one scalar parameter.
The study was focused on the second-order effects. In the problem of torsion it was well known Pointing effect, i.e. length change of the twisting cylinder in the absence of longitudinal force. In the case of bending the variation in the thickness of the panel was investigated.
By direct numerical computations and asymptotical analysis it was shown that for some models describing large strains of micropolar media there exists not quantitative but also qualitative difference in the behavior of solutions of problems for classical and Cosserat continuum.

ON SOME PROBLEMS OF DESIGNS STRUCTURAL AND TOPOLOGY OPTIMIZATION

Khurshudyan A.
Yerevan Sate University, Armenia
asaturkhurshudyan@yandex.ru

The report is devoted to some structural and topological optimization problems, mathematically formulated as coefficient control problems. Several effective techniques of such problems solution are also discussed. Specifically, structural optimization of non–homogeneous infinite layer may leads to propagation of harmonic wave with a phase velocity, equals to phase velocity of harmonic wave propagation in some gauge homogeneous layer. By optimizing the structure of a glue layer, realizing friction contact between elastic finite rod vibrating under influence of boundary dynamical perturbations and fixed rigid base, we can reach to rod vibration damping without attraction of additional forces. Topology optimization of an elastic foundation under rectangular plate bending under influence of moving load may provide to plate vibrations damping at any given moment.

GENERALIZED SPHERICAL WAVES. A SHORT REVIEW

Tagirdzhanov A.M.[1], Kiselev A.P.[2]
1 - St.Petersburg State University, Russia
2 - IPME RAS, Steklov Math. Institute St.Petersburg Department, St.Petersburg State University, Russia
aleksei.kiselev@gmail.com

Spherical waves are classical solutions of the wave equation, known to Euler and d'Alembert. We present a review of generalizations of the classical spherical waves which were introduced in the past four decades. We discuss `complex source' wavefields, focusing on their sources in the real space, both in time-harmonic and non-stationaryversions [1]. We also discuss Sheppard-Saghafi solution [2] and X-waves [3].

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MATHEMATICAL MODELLING OF COUPLED NEWTONIAN AND NON-NEWTONIAN FLOWS FOR BLOOD FLOWS IN THE CARDIOVASCULAR SYSTEM

Kizilova N.N.
Kharkov National University
n.kizilova@gmail.com

Multiscale modelling of the blood circulation system is a challenging problem of the Virtual Cardiovascular Human Project that allows *in silico* medical diagnostics on the patient-specific mathematical models, planning of therapy and surgery, estimation of the results of the treatment and rehabilitation procedures. The problem is also important for different technical systems dealing with suspensions, polymer solutions and other complex fluids exhibiting Newtonian behaviour at the larger scales and non-Newtonian properties at smaller scales. Here a review of the coupled models developed for the cardiovascular system is given and some new approaches to the non-Newtonian fluid flows are proposed.
Flows of the multiphase and multicomponent fluids in

the systems of tubes, ducts, and reservoirs have been studied on different mathematical models. Biological fluids are the most complex in nature exhibiting viscoelasticity, anisotropic viscosity, shear thinning and thickening, and related phenomena. The space scale determines importance of the non-Newtonian properties while the time scale defines the influence of the local flow characteristics on the long time behaviour and properties, like sediment accumulation, crystallization, and phase transitions.
The boundary condition problem for the non-Newtonian fluid models coupled with Navier-Stokes equations and equations for the viscoelastic solid walls has been solved by application of the mass, momentum and energy balance equations at the interfaces of the regions. The parameter-dependent changes in types of the systems of equations are studied and the conditions preserving hyperbolicity of the coupled systems are found.

NON-AXISYMMETRIC EVANESCENT WAVES IN A SWIRLING VISCOUS JET

Klyueva N.V., Soldatov I.N.
Institute for Mechanical Engineering Problems, Nizhny Novgorod, Russia
natali.kl01@gmail.com

Rotation confers on a fluid certain special properties and an incompressible fluid can sustain inertial oscillations. Waves traveling on the surface of a columnar vortex without an axial flow was considered by Kelvin who stated that the columnar vortex is neutrally stable for axisymmetrical and spiral modes. The instability develops if the axial flow in the core is imposed upon the vortex. In this report, we wish to consider a more general case of a swirling hollow viscous jet. Outside jet the inviscid flow is irrotational. At high angular velocities of the core of the vortex, a vacuum funnel is created about the axial region. New features appear when we consider the hollow vortex: waves of new type arise and these waves may be unstable. We also take into account different densities of immiscible liquids in the inner region and in the external region.

NUMERICAL INVESTIGATION OF ADMIXTURE DIFFUSION FROM SURFACE IN POLYCRYSTALLINE PLATE AT THE TENSION

Knyazeva A.G.
Tomsk Polytechnic University, Russia
anna-knyazeva@mail.ru

Two-dimensional model is suggested for diffusion in binary system with explicit separation of individual boundaries or boundary phase. Individual structure element contains the triple junction of boundaries. The symmetry conditions are formulated in the distance from him. On other boundaries (between boundary and volume phases, on the interface between structure element and media containing the admixture), the boundary conditions depends on chosen system. For example, when substances of the base and admixture are indefinitely soluble in each other, the mass fluxes and chemical potentials of substances are equal. In the case of restricted solubility, the flux equality condition is changing with time by the condition of given concentration. When the size of structure element and relation between the areas of boundary and volume phases are known, one can calculate the number of elements in macro specimen. It could by characterized by mechanical properties.
The equilibrium problem for macro specimen is solved analytically or numerically. If mechanical properties do not change, the problem on mechanical equilibrium could by solved taking into account the additional integral condition. Integral mechanical forces and moments are taken equal zero. Given integral loading are taken into account also. The mechanical stresses effect on diffusion by various ways. In the simplest case, the specimen is compressed or strained in the direction of one of axis.
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ONSET OF CONVECTION IN A TWO-LAYER SYSTEM “FLUID – POROUS MEDIUM” UNDER MODULATED TEMPERATURE GRADIENT

Kolchanova E.A.[1], Kolchanov N.V.[2]
1 - Institute of Continuous Media Mechanics UB RAS
2 - Perm State Universiy
ekaterina_shishk@mail.ru

The convective flows in the fluid and the saturated porous medium, cased by the thermal buoyancy variations are widely spread in various natural and industrial processes. They can strengthen the heat and mass transfer in the media. One of the ways to control such flows is the modulation of the temperature gradient.
We investigated the onset of the convection in a two-layer system of a horizontal pure fluid layer and a porous layer saturated by the same fluid and located beneath the first one. The system was subject to the gravity and the time dependent temperature gradient. We restricted our consideration to the case of low frequencies of the gradient modulation, when the modulation period is significantly larger than the time of thermal wave propagation into the layers so that one can neglect the spatial heterogeneity of the temperature gradient.
The convective flow in the fluid layer was described in the framework of the Boussinesq model. The convective filtration of the fluid within the porous medium was

studied by means of the Darcy-Boussinesq model. We used the Floquet theory to explore the linear stability of the “unsteady” equilibrium state corresponding to the zero average fluid flow inside the layers subject to the time dependent temperature gradient. The problem was solved numerically applying the classical shooting algorithm with orthogonalization and the Galerkin method.

The boundaries of the parametric instability with respect to both the synchronous perturbations with the period equal to the period of the temperature gradient modulation and the subharmonic perturbations with the period which is twice larger than the modulation period were obtained. The stability maps for variable amplitudes and frequencies of the modulation were presented at fixed values of the porous medium permeability. It was determined, that the modulation amplitude considerably decreases as the permeability grows. It means that the convective flows in the porous medium of high permeability are more intensive and easier to be excited than ones in the porous medium of small permeability, due to the low resistance of the solid matrix with respect to the flows in such medium. The permeability increase also leads to the reduction of the frequency range corresponding to the resonance regions of the parametric instability.

The results described above were compared for two different laws of the temperature gradient modulation: the sine law of modulation and the step law of modulation.

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NONLINEAR REGIMES OF CONVECTION IN A HORIZONTAL LAYER OF COLLOIDAL MAGNETIC FLUID

Kolchanov N.V., Putin G.F.
Perm State Universiy
kolchanovn@gmail.com

The subject of this study is the gravitational convection in a heated from below horizontal layer of a colloidal magnetic fluid near the threshold of the mechanical equilibrium stability. The colloid was placed in the horizontal layer of thickness 3.0 mm and diameter 58 mm. The upper boundary of the layer was made of a saline plate (LiF). This salt transmits heat radiation from the surface of the fluid. It allows measuring the temperature fields.

In the presence of a solid upper boundary of the layer the mechanical equilibrium in the pure fluid is replaced by thermogravitational stationary flows usually taking the form of the system of rolls. In contrast to the pure fluid, in the colloid except the thermal density gradient there can be the gradients due to the thermal diffusion (the Soret effect) and due to the barometric sedimentation of particles, so that the behavior of the colloidal fluid becomes either periodic or irregular both in space and in time. This statement was confirmed by experiments with magnetic fluids, performed in earlier works. For example, the convective oscillations at which there was a periodic change in the flow direction were found in the connected vertical channels heated from below. In the works devoted to the investigation of the magnetic colloid convection in the horizontal layers heated from below the flows taking the form of a large number of rolls and cells interacting with each other in a complex manner were observed.

Taking into account the thermocouple readings, we plotted the Nusselt number *Nu* as a function of temperature difference ΔT at the boundaries of the horizontal layer of the magnetic colloid. The threshold value ΔT_c close to which the mechanical equilibrium of the colloidal fluid became unstable was defined by means of the plot and equal to 5.8 ^{o}C.

The results of thermal imaging measurements showed, that the mechanical equilibrium broke down at values lower than ΔT_c. The motionless state could be unstable beginning from the value of temperature difference equal to ΔT_c^*=2.2 ^{o}C. We recorded the convective regime near the ΔT_c^* looked like a large-scale vortex covering the entire cavity. The fluid inside the vortex moved parallel or nearly parallel to the upper horizontal wall of the cavity. The regime was observed in the range of values ΔT=2.2-3.9 ^{o}C only when the temperature difference at the layer of the colloidal fluid decreased, i.e. when the fluid returned to the mechanical equilibrium from the uniform mixed state. After two weeks during which the colloid had been remaining motionless, the convection in the layer was excited at ΔT=4.3 ^{o}C as a plenty of convective cells randomly changing their location within the horizontal layer.

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COMPREHENSIVE ANALYSIS OF THE STRUCTURE AND MECHANICAL PROPERTIES OF FILLED VULCANIZATES

Komar L.A.[1], Shadrin V.V.[1,2], Morozov I.A.[1,2], Belyaev A.Yu.[1,2], Mokhireva K.A.[1]
1 - Institute of continuous media mechanics UB RAS
2 - Perm State University
komar@icmm.ru

An extensive experimental investigation was performed to study rubber vulcanizates (85 parts by weight of synthetic rubbers butadiene-methylstyrene CKMC -30 APK + 15 parts by weight of butadiene-styrene CKC-30 APK). Two groups of samples containing, respectively, the particles of carbon black of two different grades P 514 and N 550 were considered.

The structural analysis of the properties of these

samples was carried out using an Atomic Force Microscope. The technique of determination of microstructure parameters was developed previously for the analysis of micro-images of sample surfaces [Morozov I.A. Identification of primary and secondary filler structures in a polymer matrix by atomic force microscopy images analysis methods // Polymer composites, 2013]. Although no strong distinctions were revealed between the microstructures of different types of samples, mechanical tests indicated that the behavior of samples differed significantly. To analyze the factors leading to such differences, we performed a set of experiments on various testing machines.
The results of uniaxial cyclic tests conducted on a universal testing machine Testometric FS100 PT indicate that hysteresis losses, occurring due to scattering of energy, in the samples with carbon black N 550 is much higher than in the samples with carbon black P 514. The relation of the initial elastic moduli of samples containing the particles of carbon black N 550 and that of samples containing the particles of carbon black P 514 is approximately equal to 2. The relations of macrocharacteristics of similar character were obtained for the same groups of samples but studied in the tests carried out on a dynamic mechanical analyzer and a uniaxial machine Zwick Z250.
The experiments conducted on a biaxial testing machine (4-vector test stand with loading axes mutually perpendicular in the same plane) enable us to put forward a hypothesis that the interfacial layers are formed differently on the surface of carbon black particles, and their sliding from the surface of the sample also proceeds differently. The process of sliding is accompanied by the formation of oriented polymer strands with different properties, and hence the samples exhibit quite different macroscopic behavior. This hypothesis, in our view, is most reasonable and does not contradict the effects observed experimentally.

The study is supported by the RFBR (grant 13-01-96016-a), Program of RAS 12-T-1-1004 and the Ministry of Education of Perm Krai (agreement C-26/627).

INVESTIGATION OF DEFORMATION AND FRACTURE OF THE CERAMIC COMPOSITES BASED ON NANOCRYSTALLINE METAL OXIDES. COMPUTER SIMULATION ON THE BASIS OF MOVABLE CELLULAR AUTOMATON METHOD

Konovalenko Ig.S., Toktohoev Ch.O.,
Konovalenko Iv.S., Promakhov Vl.V., Psakhie S.G.
Institute of Strength Physics and Materials Science of Siberian Branch Russian Academy of Sciences, 2/4, pr. Akademicheskii, Tomsk, 634021, Russia
igkon@ispms.tsc.ru

In the framework of movable cellular automaton method (MCA) a multiscale model of ceramic composites based on nanocrystalline metal oxides with phase transformations in their structure during mechanical loading was developed. On the basis of developed model the mechanical behavior of ceramic composites based on nanocrystalline oxides of zirconium and aluminum with different contents components under uniaxial compression was investigated. For numerical investigations 2D square specimens with the size 32 mkm were generated. The volume content of each component was varied from 20% to 80%. At the interface between components assumption of perfect contact conditions was made. Mechanical properties of the model material corresponded to that of nanocrystalline ceramics ZrO_2 (Y_2O_3) and Al_2O_3 with a porosity of 2%. The speed of loading was 0.5 m/s. The problem was solved under plain strain conditions. Accounting for phase transitions in the model was carried out under the proposed phenomenological approach, implying the formulation of the law of inter-automaton interaction corresponding to the irreversible behavior of the material. This law has been chosen so as to correspond to qualitative and quantitative deformation diagrams of ZrO_2 (Y_2O_3) with structural transformations. An increase of fracture toughness of zirconia ceramics under implementation of phase transitions were taken into account by introducing a pair of automaton transition kinetics from the "linked" state to the "unlinked" one. To do this, the crack propagation rate parameter was explicitly introduced at the MCA method. It was capable to slow down the transition of automaton pair to "unlinked" state for several time steps. Usually in the MCA method this transition occurs at the one time step, which corresponds to crack propagation with the speed of longitudinal sound. In this model (for the pairs automata modeling phase transition), the value of crack propagation velocity was lower than the velocity of sound in the material. Within the framework of the model constructed main mechanisms of deformation and fracture of composites were studied. The interrelation of structure, mechanisms of fracture and effective strength and elastic properties of the composite was shown.

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COMPUTER STUDY OF THE DEPENDENCE OF MECHANICAL PROPERTIES OF CERAMICS BASED ON METAL NANOCRYSTAL OXIDES UNDER COMPRESSION LOADING ON PARTIAL CONCENTRATIONS OF PORES WITH DIFFERENT SIZE IN ITS STRUCTURE

Smolin A.Yu., Promakhov V.V., Konovalenko I.S., Psakhie S.G.
Institute of Strength Physics and Materials Science of the Siberian Branch of the Russian Academy of Sciences
ivkon@ispms.tsc.ru

The pore structure of the ceramic material is characterized by the presence in it of pores with different sizes. Pore size distribution function of these materials contains several (in the simplest case of two) maxima. The height and width of each maximum determine a fraction of pore space corresponds to pores with the proper size.

Thus, the materials with a bimodal pore size distribution function and with a certain value of the total porosity can be characterized by a great number of combinations of pore structure parameters: volume ratio of pore space corresponding to the pores of the first and second peak of the function. In this aspect, said material is no longer just a porous body, but it is a construction. The mechanical behavior and properties of this construction are determined by the specified parameters of its structure. In practice, the combination of the parameters of the pore structure and mechanical properties of the material largely determine the scope of its functional application. It does knowledge about the mechanical properties of material in the entire range of these pore structure parameters very actual and required. Thus, in this paper, a numerical study of the dependence of the strength and elastic properties of ceramic materials on the fraction of pore volume corresponding to pores of the second maximum of the pore size distribution function in the total porosity of material was curried out. Calculations were based on multiscale approach, developed in the framework of the of movable cellular automaton method (MCA). Plane MCA-model of ceramic $ZrO_2(Y_2O_3)$, with a pore size comparable with the grain size and bimodal pore size distribution function was developed. Material with round pores was considered. On the basis of computer calculations an analytical estimation for numerical dependence of strength and elastic properties of material under compression loading on its total and partial porosities, corresponding to pores with different size, was found. It was shown that the strength of brittle materials, containing pores of two different sizes, is defined as the value of total porosity and the value of partial porosities, corresponding to one of the maxima of the of pore size distribution function. The difference in the strength of such materials with the same value of total porosity, but with different number of pores with different size can be up to 50%. Effective elastic modulus of the material are determined only by the value total porosity.

This study was partially supported by the Russian Foundation for Basic Research, Project № 12-08-00379-a and by the Grant of the President of the Russian Federation for the state supporting young Russian scientists, Project MK- 5883.2014.8.

APPLICATION OF FEM FOR ESTIMATION OF RESIDUAL STRESS IN FRAMEWORK METALWARE

Smirnov S., Konovalov D., Parchin S., Vyskrebentsev S.
The Russian Academy of Sciences Ural Branch Institute of Engineering Science
konovalov@imach.uran.ru

There was carried out exploited object made from aluminium alloy. Elastic plastic properties of material were estimated by kinetic indentation. The framework metalware was sawn on fragments. After that there was a bend of fragments under residual stress. The residual stress level was estimated in framework metalware by finite-element method.

NUCLEATION OF RADIATION-INDUCED PLASTICITY IN STRESSED CRYSTALS

Korchuganov A.V., Zolnikov K.P., Kryzhevich D.S.
Institute of Strength Physics and Materials Science of Siberian Branch Russian Academy of Sciences (ISPMS SB RAS)
alex.v.kor@gmail.com

The nucleation and evolution of plastic deformation in stressed titanium crystals after generation of atomic displacement cascades are investigated using molecular dynamics simulations. To describe atomic interactions in vanadium, the Finnis-Sinclair many-body potential is employed. Atomic interactions in iron are described by pair potential. Simulated crystallites are shaped as parallelepipeds. Periodic boundary conditions are applied in all directions. Stressed states of crystallites are formed via straining the specimens to allow for their volume to remain constant. Investigation of plastic deformation features was carried out for specimens within a range of stress levels: from 5 to 8 %. To initiate plastic deformation in stressed crystallites, atomic displacement cascades are generated with the primary knock-on atom energies from 0.5 to 25keV.

It has been shown that for every stress level of crystallite there is a threshold primary knock-on atom energy at which generation of an atomic displacement cascade causes plastic deformation of the specimen. It has been found out that structural changes, formed by generation of atomic displacement cascade with the threshold primary knock-on atom energy and higher, are similar to those observed in mechanically deformed specimens.

FEM SIMULATION OF A CHEMICAL REACTION FRONT PROPAGATION NEAR THE STRESS CONCENTRATOR

Korolev I.K.[1], Aleshchenko S.P.[1], Freidin A.B.[1,2,3], Vilchevskaya E.N.[1,2]
1 - Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg, Russia
2 - Saint-Petersburg State Polytechnical University, St. Petersburg, Russia
3 - Saint-Petersburg State University, St. Petersburg, Russia
i.korolev82@gmail.com

We develop a procedure for the numerical simulation of a stress-assisted chemical reaction front propagation. A reaction like the oxidation of silicon is considered. The analytical model of this phenomenon is based on the expression of chemical affinity tensor [1,2]. The normal component of the chemical affinity tensor acts as a configuration force and drives the reaction front. We implement the model using ANSYS software supplied by special means of internal programming language. Numeral simulation allows us to examine the reaction front kinetics near a stress concentrator. We study the reaction front propagation in a plane problem for a thick plate with a semicircular groove under external tension or compression. It is found that applying of different external stresses causes different scenarios of chemical reaction front propagation. Thus, it is demonstrated that applying the tensile external stresses leads to the formation of a "helmet-shaped" oxide front round the groove, while applying external compressive stresses leads to slow oxide growth near the top of the groove and relatively homogeneous growth at some distance from the groover. The quantitative investigation shows that the tensile external stresses increase the oxide growth rate all over the reaction front, while the applying of compressive external stresses leads to decrease of the one. This effect is stronger at the zone of a stress concentrator. This dependence takes place for all range of values of analyzed external stresses: from -400 to 400 MPa.

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MICROSCOPIC APPROACH TO RECONSTRUCTIVE AND MARTENSITIC PHASE TRANSFORMATIONS

Aero E.L., Korzhenevskii A.L.
Institute of Problems in Mechanical Engineering RAS
16aero@mail.ru

It is well known that Landau theory is applicable to those phase transitions (PT) that are accompanied by the change of phase symmetry of the type group-subgroup. It allows to define the order parameter and write the free energy expansion over the parameter powers. However, there is a multitude of PT that have not any group-subgroup symmetry relationship. They are called reconstructive PT. In particular, a large important class of martensitic PT belongs to them. Up to now no general approach similar to the Landau theory has been suggested to describe the PT. For the first time we offer a universal model that is capable to reproduce typical complex microstructures in the domain of the martensite-austenite coexistence. To construct the model we have used the fundamental fact that in general a martensitic structure can be produced from the austenitic one via a specific mutual displacement of the crystal sublattices. As the crystal state is a periodic function of the displacement one has to include the corresponding periodic contribution into the internal energy density. This provides some similarity between our approach to martensitic PT and the conventional theory of the transitions into incommensurate phases. We have found a two-parametric family of the exact solutions of the two-dimensional version of our model. The family describes the evolution of the crystal state in the coexistence domain of martensitic and austenitic phases. The distinguish feature of the solutions Is the spontaneous generation of defects in the initially ideal crystal matrix.

OPTIMIZATION OF BIOMORPHIC VIBRATION CONTROL

Kotov V. V.[1], Arseniev D. G.[2], Polyanskiy V. A.[1], Smirnova N. A.[2]
1 - Institute of Problems of Mechanical Engineering RAS
2 - Saint Petersburg State Polytechnical University
kotov.vitaliy@gmail.com

To mitigate vibrations of distributed elastic mechanical systems the algorithm of biomorphic control was used. By investigating the results, we established that the most accuracy connected with actual amplification of feedback signal, which occurs at the allocation of form module. The method of biomorphic systems optimization was suggested with using the modal decomposition, which allows to solve the connected multidimensional task of amplification factor of feedback, how to solve the selection of sequent one-dimensional tasks. This article describes the results and analysis of regulation errors, which occurs in biomorphic control.

GENERATION OF CIRCULAR PRISMATIC DISLOCATION LOOPS NEAR SPHERICAL VOIDS UNDER ANAXIAL COMPRESION

Gutkin M.Yu.[1,2,3], Kolesnikova A.L.[3], Krasnitckii S.A.[2], Romanov A.E.[4,5,1]
1 - Department of LED Technologies, ITMO UniversitySt. Petersburg, Russia
2 - Department of Mechanics and Control Processes, St. Petersburg State Polytechnical University, St. Petersburg, Russia
3 - Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, St. Petersburg, Russia
4 - Togliatti State University, Togliatti, Russia
5 - Ioffe Physical Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia
m.y.gutkin@gmail.com,
anna.kolesnikova.physics@gmail.com

Nucleation and growth of voids is the primary mechanism of destruction in ductile materials.
Different mechanisms of void growth are known for today, which are vacancy diffusion and emission of prismatic and shear dislocation loops from the void surface [1-5]. Preference for one or another mechanism depends on the strain rate and temperature as well as the initial size of the void. Void growth by emission of dislocation loops was observed in molecular dynamics simulations [1-3] and analyzed in continuum models [4-6]. In particular, Wolfer [4] calculated the energy of elastic interaction between a spherical void and a coaxial circular prismatic dislocation loop and applied it to analyze the loop punching from helium bubbles.
Recently we have revisited the boundary-value problem in the theory of elasticity for a circular prismatic dislocation loop placed coaxially around a spherical void [7]. This has allowed us to consider rigorously the problem of formation of such loops near voids under compression. We have calculated the energy change due to the prismatic loop generation and shown that its appearance is energetically favorable when the remote pressure is larger than a critical value. The critical pressure is a function of the void size and the prismatic loop position with respect to the equatorial plane of the void. In particular, the critical pressure increases with a decrease in the void size. For example, it is about of $0.6G$ and $0.01G$ for the void radius 10 nm and 1 micron, respectively, where G is the shear modulus.

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GENERATION AND EVOLUTION OF LOCAL STRUCTURAL CHANGES PECULIARITIES IN COPPER CRYSTALLITES

Kryzhevich D.S., Korchuganov A.V., Zolnikov K.P., Psakhie S.G.
ISPMS SB RAS
kryzhev@ispms.tsc.ru

The onset and development of plastic deformation in contact zones are important to study both for the accumulation of fundamental knowledge about the nature of plasticity and for the solution of some practical, as well as tribotechnical, problems. Conventionally, structural defects in metals and alloys receive much consideration, though the atomic mechanisms of their generation have not been adequately investigated.
The aim of the present work is connected with the study of the features of plastic deformation onset in a fcc single crystal under complex mechanical loading. The interatomic interaction was described with the potentials calculated in the approximation of the embedded atom method. In this method, the interatomic interaction potentials allow a rather accurate description of elastic characteristics of copper, its surface properties, energies of defect formation, etc.

The study into the generation and development of local structural changes has revealed that at the initial stage of plastic deformation the local structural transformations are generated in the sample. To identify atoms involved in the generation of structural defects the following methods were used. Central symmetry parameter which characterized the deviation of a local lattice configuration from central symmetry. Slip vector which could measure of local plastic deformation. Bond topology parameter of selected atoms and its nearest neighbors. In this method each pair of atoms is assigned a bond topology parameter consisting of four numbers. The first number characterizes the “relationship” between atoms. This number is equal to 1 if the atoms are the nearest neighbors; otherwise it is equal to 2. The second number is the number of common neighbors of a pair of atoms. The third number is the number of bonds between the common neighbors. The fourth number is the number of bonds in the longest continuous chain passing through the common neighbors of a pair of atoms. The bond topology parameter makes it possible to identify the bond topology for each atom and to determine the local type of a crystal lattice.

The interaction between interfaces (grain boundaries and free surfaces) and generating structural defects under complex mechanical loading with different boundary conditions.

HYDRODYNAMIC MODEL OF HYDROTHERMAL SYNTHESIS OF INORGANIC NANOTUBES

Kucher D. A., Chivilikhin S. A.
Saint-Petersburg national research university of information technologies, mechanics and optics
dmitry.a.kucher@gmail.com

Hydrothermal synthesis is one of the methods for synthesis nanotubes. The main characteristics of hydrothermal synthesis are distribution of velocity, temperature and concentrations. Different configuration of these characteristics determines the efficiency of synthesis. Authors have autoclave in his laboratory. This experimental setup allows investigating early step of creation nanotubes. Understanding of these processes can help create configuration of characteristics for more efficient synthesis of nanotubes.

Two-scale model of hydrothermal synthesis of nanotubes in autoclave is proposed for estimation characteristics of process. The macro-scale process includes the thermal convection of liquid, due to heating of autoclave wall, heat transfer and diffusion of chemical components dissolved in the liquid. Distribution of velocity, temperature and concentrations obtained in macro-scale model let us to describe the nano-scale processes - diffusion evolution of nanotube ensemble [1]. The concentrations, calculated in macro-model use in nano-model as boundary conditions on infinity. In the other hand, the summary mass flow on the nanotubes in some small volume is the mass source in diffusion equation of macro-scale model.

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LOCALIZED BUCKLING OF ELASTIC BEAMS ON WEAKENED WINKLER FOUNDATION

Kuklin T., Mochalova Y., Indeitsev D.A.
IPME RAS, Russia
kuklints@gmail.com

We study localization phenomenon in beams of finite and infinite length on a non-homogeneous Winkler foundation. It is shown that discrete spectrum point of the boundary value problem defines the existence of the localized modes. These modes and critical load for a compressed Bernoulli-Euler beam can be found by setting the fundamental frequency to zero. The solution of the problem leads to integral equation analysis. Similarity between buckling and localized modes of oscillations is analyzed. Dependence of the discrete spectrum on the length of inclusion as well as on the length of the beam is obtained. The influence of boundary conditions and position of a foundation defect is investigated.

CONTROLLABILITY OF THE ISHLINSKY SYSTEM

Kuleshov A.S., Rybin V.V.
Department of Mechanics and Mathematics,
Lomonosov Moscow State University
kuleshov@mech.math.msu.su

In 1965 A.Yu. Ishlinsky proposed the example of a low dimensional nonholonomic non-Chaplygin mechanical system. The Ishlinsky system consists of three cylinders. One of them with the radius R rolls without sliding on top of two other identical cylinders of a radius a, which each roll without sliding on a fixed horizontal plane. In this paper we formulate and analyze controllability conditions for the system of cylinders. We prove that the Ishlinsky system is completely controllable by the Chow - Rashevsky theorem. Symbolic computations using MAPLE are employed to obtain up to level four Lie brackets to prove controllability of the system. This example of a non-Chaplygin nonholonomic system clearly illustrates the analytic and control complexity of such systems.

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PKN BASED MULTIFRACTRING MODEL FEATURING FRACTURE INTERACTIONS. NEW APPROACH AND IMPLEMENTATION

Kusmierczyk P., Mishuris G.
Aberystwyth University
pkk8@aber.ac.uk

PKN model of hydraulic fracture propagation has been applied in practice for many years. Despite being relatively simple, its effectiveness and flexibility allows to tackle phenomena which were not considered in the original formulation (e.g. P3D model [1, 2]). Recent improvements introduced to the model, have proved to make substantial impact in computational accuracy, efficiency and stability. These included: speed equation [3, 4], different dependent variable formulations and enriched epsilon-regularization technique [5] utilizing known asymptotic behavior of the solution near the crack tip [6, 7].
Effective single fracture PKN solver [7] built on the modified formulation and exploiting advantages of dynamic system approach is extended to deal with multiple fractures. New challenges arise here from the problem complexity such as: calculation of pressure at segments connections, fracture collisions, building graph representation, and introduction of non-propagating segments. This unavoidably leads to rapidly rising time cost (increase in grid point quantity and graph complexity). Furthermore, two different models of crack interactions are considered. Our numerical multifracturing results are compared to those available in the literature [8].

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ON NUMERICAL SCHEMES IN 2D VORTEX ELEMENT METHOD FOR FLOW SIMULATION AROUND MOVING AND DEFORMABLE AIRFOILS

Kuzmina K.S., Marchevsky I.K.
Bauman Moscow State Technical University
kuz-ksen-serg@yandex.ru

The problem of numerical flow simulation around moving and deformable airfoils using meshless lagrangian vortex methods is considered. The flow assumed to be viscous and incompressible, so the Viscous Vortex Domain method is used for numerical simulation of vortex wake evolution. However the usage of well-known numerical scheme, which often called 'Discrete Vortex Method' on the airfoil surface, can lead to significant errors when calculating intensities for vortex elements. It is shown that qualitatively wrong solution could be obtained not only near the sharp edges and angle points of the airfoil but also on smooth airfoils when there is discrete vortex-type or discrete source-type singularity near the airfoil.
Large number of such vortex-type singularities normally appears near the airfoil in boundary layer while both vortex-type and source-type singularities located on the airfoil surface are used to simulate arbitrary moving or deformable airfoil.
In the present research new approach is developed for computation of vortex layer intensity with high accuracy. It is based on solving of Fredholm-type integral equation for vortex layer intensity determination instead of Hilbert-type singular integral equation which normally appears in 'classical' Discrete Vortex Method. Special discretization formulae for integral equation kernel and its right side are developed and it is shown that only their employment into numerical algorithms of Fredholm-type equation solution allows to raise the accuracy significantly.
It should be noted that the developed approach and appropriate discretization formulae can be implemented into existing numerical procedures and software packages, and their usage doesn't require to change any parameters of design models which used in vortex element methods.
The results of vortex layer intensity computation using mentioned approaches are shown for some test cases in comparison with exact solutions and results obtained with 'classical' algorithm.

INITIATION AND PROPAGATION OF DETONATION WAVES, TAKING INTO ACCOUNT THREE-DIMENSIONAL EFFECTS

Levin V.A., Manuylovich I.S., Markov V.V.
Institute of mechanics, Lomonosov Moscow State University, Russia
levin@imec.msu.ru

Detonation initiation using rotation of the elliptic cylinder enclosed in the circular cylinder, both filled with stoichiometric air-propane mixture, was numerically investigated. The feasibility to form detonation both inside, and outside the elliptic cylinder was stated. Two critical angle velocities of cylinder rotation, which govern the quantitative and qualitative flow pattern, were found. The method to estimate parameters of the 3D spiral channels is proposed based on the plane-sections hypothesis. The comparison with 3D simulation is presented.
The results of numerical simulation of detonation in a flat square chamber with movable walls and detonation in 3D channels of square section, blown by supersonic flows of combustible mixture, are presented. The flows in a contracting square chambers filled with air were studied for different constant values of square sides velocity. Complicated wave patterns of the flows were obtained. In the problem of formation of detonation in a square area with sinusoidally varying side length 200 calculations have been performed for different pairs of values of the amplitude and period of oscillations. The results obtained in a series of calculations have revealed different modes of detonation initiation separated by critical curves in a plane "amplitude-period". As calculations showed, the detonation may occur on the sides, in the corners or at the center after any period of square size oscillations. Comparison with stationary detonation in 3D channels of variable square cross-section has also been performed. It revealed several regimes of stationary 3D detonation corresponding to modes in unsteady 2D problem.
The problems of detonation initiation in supersonic flow of stoichiometric air-propane mixture, which partially or fully fills in the plate channel cross-section, are considered. The flow initiation takes place at the cost of a "bench" or a wall which fully blocks the channel. Critical detonation conditions connected with the inflow velocity and explosion energy were determined. In the discussed processes one can find the unknown detonation propagation mechanism, which is conditioned by formation of complicated wave flow structure, characterized by shock wave penetration in the inert gas to the layer in front of the detonation wave, with the resulting warm-up and combustion. The process is periodic in nature, and differs from standard cellular detonation in the uniform medium. The existence of critical inflow velocities was established upon which qualitative and quantitative flow pattern is dependent. In the uniform flow two different detonation modes were obtained – with stationary wave on the "bench" and with the wave propagating to inlet channel section. In the combustible mixture layer three detonation modes were found – with stationary wave on the "bench", with the wave propagating to the inlet channel section in the form of stationary wave complex or in the mode of galloping layered detonation.
The problem of detonation initiation and stabilization in supersonic flow of stoichiometric air-propane mixture is considered for the curved plane channel of constant width. Three main regimes have been found – without detonation, with detonation leaving the channel through inlet section and with stationary detonation near the channel turning point. Corresponding critical relations between governing parameters have been determined.
Processes observed in experiments of R.I. Soloukhin with the initiation and propagation of divergent detonation in a narrow gap between plates have been simulated. The detonation wave is formed in a tube adjoined at a right angle, propagates to the gap through a circular hole and then transforms to divergent cellular wave. 2D model of the latter process has been considered.
3D cellular detonation in semi-closed channels with fixed square, rectangular, circular and elliptical cross sections has been obtained. Formation of cellular structure was spontaneous due to 1D initial distribution of gas-dynamic parameters in channels. Linear size of computational cells in all cases did not exceed 0.1 mm. In all cases the detonation of a stoichiometric propane-air mixture at rest under normal conditions was studied. It was considered that the channel has a flat closed end, near which in the zone of 3 cm width initiation of detonation occurs due to instantaneous uniform electric discharge. Spin detonation has been obtained numerically in circular channel without any external impact, with strongly 1D initial distribution, and due to instability of 1D flow. Irregular and developed phases of spinning detonation have been observed. The results are illustrated by numerical schlieren diagrams on the surface and inside of the channels.
For the description of a multicomponent gas mixture flows the system of 2D and 3D Euler differential equations is used with one-step combustion kinetics. The study is carried out numerically using the original software package in which modified S.K. Godunov's method for multi-block grids is implemented. This complex has a graphical user interface, allows to perform calculations both on the PC and on a supercomputer "Lomonosov" using up to 10000 CPU cores with computational meshes consisting of up to 10 billions of cells.

SPEED EQUATION, ASYMPTOTIC UMBRELLA AND EXPLICIT LEVEL SET METHOD IN HYDRAULIC FRACTURE MODELING

Linkov A.M.
Rzeszow University ofTechnology, Poland
linkoval@prz.edu.pl

Hydraulic fracturing (HF), being a key means to increase oil, gas and heat production, its numerical modeling is of importance for making proper engineering decisions. To improve the efficiency of numerical simulation of HF, we revisit the fundamentals of the mathematical problem. We reveal those features of the problem formulation, which are of prime significance while not accounted for in conventional approaches. The key role of the particle velocity and the speed equation (SE) is emphasized.

It is shown that when neglecting the lag, the asymptotic behavior of the opening w is uniquely defined by the speed v_* of the fracture propagation. On one hand, this fact makes the HF problem ill-posed and causes computational difficulties, when trying to solve it as a boundary value problem under fixed position of the front. On the other hand, when properly employed, the very fact significantly facilitates finding analytical and numerical solutions. In particular, it provides simple analytical solutions for non-Newtonian fluids, which otherwise hardly can be obtained. It also provides the means for employing explicit, as well as implicit, level set methods for efficient numerical tracing of the fracture propagation.

We derive analytical equations for the asymptotic “umbrella”, which presents the universal dependence $w(v_*)$. They are applicable for arbitrary power-law fluids in a wide range of propagation regimes from the viscosity dominated to leak-off dominated regime. We conclude that the improvements suggested notably extend options for modeling of HF.

CALCULATIVE JUSTIFICATION OF SAFETY OF THE REACTOR BLOCK BREST OD-300 CASE AT SEISMIC LOAD

Lobachev A.M., Lukin A.V., Modestov V.S., Popov I.A.
Saint-Petersburg State Polytechnic University, Institute of Applied Mathematics and Mechanics, Mechanics and Control Processes Department, Saint-Petersburg
lobachev@compmechlab.com

Authors of the present article solved a problem of safety justification of the reactor block BREST OD-300 case in the normal service conditions and at seismic load. In this article the results of research and developmental work are presented, including: development of full-scale FEA model of the reactor block case; development of mathematical model for calculation of a temperature state of the reactor block case in the normal service conditions; development of mathematical model of fluctuations of the lead heat carrier at seismic influence; execution of calculations of durability of the case at seismic influence taking into account temperature state of the case and fluctuations of the lead heat carrier.

The close attention was paid to a problem of taking into account fluctuations of the heat carrier (liquid lead) while analyzing the stress-strain state of the reactor block and to a problem of numerical modeling and calculation of reinforced concrete structures of nuclear power plants under the influence of a wide range of static and dynamic loads taking into account nonlinear mechanical properties of concrete and crack propagation process.

The carried-out calculations using elastic material models allowed to estimate extent of influence of various factors on the stress-strain state of the BREST OD-300 reactor block and to reveal the most loaded points of a design, both in a mode of normal operation, and at seismic influence. By results of nonlinear calculations the conclusion was drawn on ensuring bearing ability of concrete elements and durability of a metalwork of the reactor block according to requirements of industry rules and norms.

METHOD OF THE UNBALANCED ROTOR CRITICAL FREQUENCY OVERCOMING BY MEANS OF THE OPERATED MAGNETIC SPRING

Lukin A.V.[1], Popov I.A.[1], Skubov D.Y.[1,2], Shtukin L.V.[1,2]
St. Petersburg State Polytechnical University, Mechanics and Control Processes Department
Institute of Problems of Mechanical Engineering RAS
lukinalexei@yandex.ru

When passing critical rotational frequency of a rotor at a big imbalance there can be cross fluctuations with big amplitudes. The algorithm of overcoming of critical rotational frequency allowing considerably to reduce these fluctuations is offered. Elastic supports have two rigidity coefficients: working and increased with the corresponding two values of critical frequency. Before dispersal of a rotor the increased rigidity of supports turns on. At the first stage of dispersal the rotor disperses to the frequency exceeding the working critical, but not exceeding critical frequency corresponding to increased rigidity. Then working rigidity joins, and dispersal to the working frequency of rotation proceeds. Thereby throughout all dispersal of a rotor the frequency of rotation isn't close to critical frequency.

It is offered to use a differential magnetic spring as an elastic support with operated rigidity. The magnetic support (spring) is formed by two constant magnets

established with a small air gap which poles are directed oppositely. The elastic characteristic of a magnetic spring has significantly nonlinear character. Change of a magnetic spring rigidity is made by means of an initial gap changing by external influence.
For research of cross fluctuations of an unbalanced rotor the nonlinear non-uniform differential equation with one degree of freedom is considered. The accounting of only one (first) form of fluctuations is supposed. Dimensionless dynamics equation has the following form:
$\ddot{x} + 2\varepsilon n\dot{x} + (\lambda - \delta(1 - e^{-st}))x + \alpha(1 - e^{-st})x^3 = e\Omega^2\cos(\Omega t)$
Feature of this task is, in particular, that the considered equation has acyclicly changing coefficients.
Two cases of transition from the increased rigidity to the working one have been considered.
Upon slow transition (time of transition makes some periods of cross fluctuations) the solution of the equation is searched by a projective method in the form of the sum of harmonicas with slowly changing coefficients.
Upon fast transition (time about one period of cross fluctuations) the problem is solved by a method of instantly changing equation parameters and applying the corresponding initial conditions to the system and by asymptotic methods of big parameter.
In both cases the numerical solution of the initial nonlinear equation was also executed.
Results of the research show that the offered algorithm allows to significantly reduce the amplitude of cross fluctuations of a rotor while reaching the working frequency.

THE NUMERICAL IDEAL MHD MODEL OF THE MAGNETOROTATIONAL INSTABILITY EVOLUTION IN PROTOSTAR SHELL

Lukin V.V., Galanin M.P., Shapovalov K.L.
Keldysh Institute of Applied Mathematics RAS
vvlukin@gmail.com

The parallel algorithm of RKDG method for axissymmetric 2D ideal MHD equations on unstructured triangular grid is developed. The algorithm of divergence-free magnetic field reconstruction in cylindrical geometry leading to physically consistent high order computation result is constructed. A software package using technologies MPI and OpenMP is described. The results of test calculations acceleration obtained through the use of parallel technologies are discussed. High level of the developed parallel code scalability on the multiprocessor systems is shown. The analisys of parallelizing effectivity on KIAM RAS K-100 cluster is given. The results of magnetorotational instability in accreting protostar shell modelling are discussed.

REFINED THEORY OF MICROSTRUCTURE-DEPENDENT BEAMS AND PLATES

Lurie S.A.
Institute of Applied Mechanics, Russian Academy of Sciences, Moscow 125040, Leningradskii pr.7
lurie@ccas.ru

We elaborate the microstructure-dependent theory of beams and plates that can be very interesting and stimulating for both theoretical and engineering applications in the area of the modelling of the micro- and nanoscale components and devices. Here, we use accurate qualitative analysis and show that a non-classical theory of beams can be constructed by using a symmetric gradient theory. It is shown that to construct the consistent model of non-classical theory of structure-dependent beams and plates the boundary conditions at the surfaces for the double stresses must be take into account. Special procedure for the preliminary analysis of the stress state has been proposed to account for these boundary conditions.
In this work, we use the correct variant of the strain gradient elasticity with adhesion effects and show first that the famous strain gradient elasticities must be refined considerably by using an additional, order-of-differentiation symmetry condition. We have shown the need for this clarification and have proven that this necessity has been unnoticed and that as an unwanted consequence, the resulting theories may suffer from spurious solutions.
The new proposed models able to capture the size effect when both bending and axial deformations are considered. However, this effect for very thin structures is due to a greater degree in view of adhesive properties and associated with scale parameter related to surface properties and not with length scale effect. Result, the consistent variational formulation leads to a refined theory of microstructure-dependent beams, which are different from the other theories developed in the works of Ma H.M. (2008), Gao X.L (2010), and Reddy J.N. (2011).
Similar trends are observed for the free vibration problem, where it is shown that the natural frequency predicted by the new model is higher than that by the classical model, with the difference between them being significantly large only for very thin beams. It is worthy to note that this new beam’s theory gives results that are remarkably consistent with the available experimental data for all frequency range with appropriate choice of parameters.

ON NUMERICAL MODELING OF HETEROGENEOUS COMBUSTION IN POROUS MEDIA UNDER FREE CONVECTION WITH ALLOWANCE FOR DEPENDENCE OF PERMEABILITY ON POROSITY

Lutsenko N.A.[1,2]
1 - Far Eastern Federal University
2 - Institute of Automation and Control Processes FEB RAS
NickL@inbox.ru

The present work is devoted to the numerical modeling of one-dimensional unsteady processes of heterogeneous combustion in porous object under free convection in the gravity field. Heterogeneous combustion is caused by the reaction between the combustible substance in the porous solid medium and oxidizer contained in the gas flowing through the porous object. The mathematical model is based on the assumption of interacting interpenetrating continua [1] using the classical approaches of the theory of filtration combustion [2]. The proposed mathematical model is similar to the one used in [3] and allows to describe the processes both of free convection and forced filtration. In [3] the permeability coefficient was assumed to be constant. But typically, the combustion products are more permeable than the initial porous substance, since porosity increases as a result of burning. In present work the dependence of permeability on porosity is taken into account.

There are some expressions describing the changing of permeability due to the changing of porosity. Kozeny (or Kozeny-Carman) equation [4] and Ergun equation [5], which is similar to Kozeny equation, are widely used in the filtration theory. The expression proposed in [6] is also used in the study of some porous media. In present work the mathematical model of combustion process has been proposed using equations for permeability described in [4] and [6]. The numerical method for investigation of one-dimensional unsteady processes of heterogeneous combustion in porous object has been developed which is based on the method described in details in [7]. Various numerical experiments have been carried out. It has been revealed that taking into account the dependence of permeability on porosity can significantly change the solution quantitatively in one-dimensional case; it can also do some qualitative changing in solutions.

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LOADED SOLIDS AND MEDIA AS THE NONLINEAR DYNAMIC SYSTEMS. THE NUMERICAL SIMULATION OF STRES-STRAIN STATE AND FRACTURE EVOLUTION.

Makarov P.V.[1,2], Eremin M.O.[1,2]
1 - Institute of Strength Physics and Material Science SB RAS
2 - Tomsk State University
pvm@ispms.tsc.ru

Loaded solids and media are considered as a multiscale nonlinear dynamic systems. It is shown that taking into account three scale levels is enough for good qualitative and quantitative agreement of simulation with the experiments. These levels are: 1) macroscopic level of averaged description; 2) mesoscopic level where the most important structural elements are taken into account, including interfaces, cracks and other structural elements contained within the representative volume of macroparticle; 3) microscopic level of the integral description of lower scales. Microscopic level is presented with the kinetic equations of damage, non-elastic (plastic) strain accumulation of lower scales than the explicitly accounted cracks and damages of the mesoscopic level [1, 2].

It is also shown that numerical solutions of solid mechanics system of governing equations demonstrates all the features of nonlinear dynamic systems evolution – dynamic chaos, self-organized criticality, blow-up regimes (particularly, fracture), migration of deformation activity if the task of strain-stress state simulation is set as evolutionary [2, 3].

The evolutionary process is regulated by the balance of

positive feedback (destabilizing the deformation process, including the autocatalytic regime of fracture) and negative feedback (stabilizing the deformation process to some metastable state of dynamic equilibrium).
The numerical simulations of brittle and quasibrittle fracture of rock specimens and ceramic somposites, global tectonic flows and seismic process in geomedia are shown as examples.
The simulation of the jerky flow as the typical manifest of the deformation process instability at tensile loading of the aluminum alloys is also shown.

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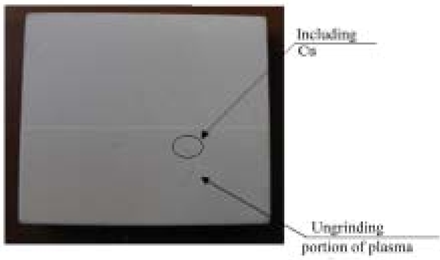
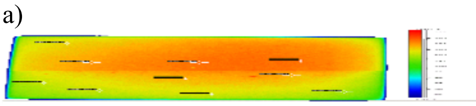
ASSESSMENT OF PERFORMANCE ELECTRICAL INSULATING PLASMA COATINGS ON ELEMENT STRUCTURES WITH ITER BLANKET THERMAL IMAGING SYSTEMS

Maksimov V.A., Zaytzev A.N., Leshukov A.Y., Sviridenko M.N.
JSC NIKIET, Moscow, Russia
v.maksimov@nikiet.ru

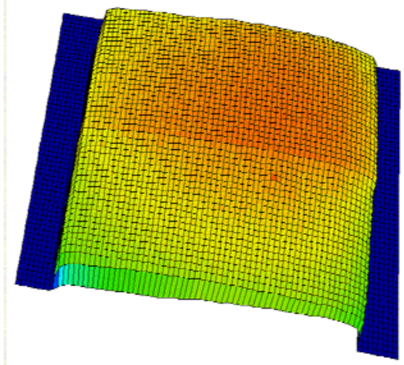
In a fusion reactor ITER attachment system supporting structures of the first wall (NKPS) blanket modules and connectors must be electrically isolated from the walls of the vacuum chamber. For this purpose, structural elements proposed to apply electrically insulating coating .
Performance of coated products depends on many factors. The main factor is the quality of the formed coating, which depends the of defects in it. And the early detection which is an urgent task .
Based on the results of work in an optimal NDT method, which allows to record both surface and internal defects active thermal control method using a thermal imaging system was selected.
The essence of the method is to scan the thermal field from the coating during the thermal effect on the substrate material. If there are defects because of, the difference between defective and defect-free heat transfer zone, a region characterized by the presence of the temperature contrast appears. Amplitude, shape and time variation of the temperature signals are informative parameters that can detect certain defects .
Studies have been conducted of the possibility of active thermal control for the detection of internal (delamination, inclusions) and external (chipped , gage , flows) defects plasma insulation coating on the witness samples, on which the imitation defects was made (Figure).



a)



б)



в)

Drawing - sample of steel 40Cr + Al2O3 (a - a digital picture in the visible spectrum , b, c - digital images in the IR spectrum) .
Contrast plots indicate the presence of defects.
As a result of this work, marked by the ability to detect defects with minimal temperature gradient $\Delta T = 0.7^0$ C.
It is shown that stable defect detection is seen at a temperature of over 500 °C samples.
Assessed the performance of plasma coatings on the full layout details contact pad assembly NKPS ITER blanket before and after the mechanical tests on static loading using the thermal nondestructive testing.

NUMERICAL SIMULATION OF HYDROELASTIC BEAM DYNAMICS IN THE FLOW USING VORTEX ELEMENT METHOD

Marchevsky I.K., Shcheglov G.A.
Bauman Moscow State Technical University
iliamarchevsky@mail.ru

Vortex element method is meshless lagrangian method of computational hydrodynamics. Number of important CFD problems from engineering practice can be effectively solved with it. In the presented research Vortex element method is used for flow-structure interaction simulation. Vortex fragmenton is suggested by authors as new vortex element for 3D incompressible flow simulation around deformable bluff-bodies. Using vortex fragmentons the numerical scheme is developed with the same vortex element used both for flow simulation and vorticity flux computation. It is shown that vortex fragmenton is generalization of well-known Novikov's vorton. Analytical formulae for velocity and vorticity fields of vortex fragmenton are obtained. The program package is developed using MPI technology for parallel computing which allows to run it on different types of multi-processor clusters. Some test problems such as 3D vortex structures dynamics simulation and aerodynamic characteristics of some bodies computation have been solved and the obtained results are in good agreement with experimental data. The phenomenon of vortex rings leapfrogging was simulated and it's shown that the accuracy of the developed numerical scheme with vortex fragmentons is higher than in schemes with other types of vortex elements. The coupled hydroelastic problem of the elastic beam behavior in the flow numerical simulation is considered. Characteristics of the transient mode are computed for this model for different values of the beam elasticity and spring constants of yielding bracings.

NUMERICAL SIMULATION OF STRESS CONCENTRATION IN DEFORMED MATERIAL WITH CURVILINEAR COATING-SUBSTRATE INTERFACE

Martynov S. A, Balokhonov R. R
Institute of strenght physics and material science
Siberian branch of Russian Academy of Sciences
martynov@ispms.tsc.ru

Investigated in the paper are the mechanisms of deformation and fracture of a material with coatings of different thicknesses. Using the finite-difference method the boundary-value problem formulated for the case of plane strain was solved. Microstructure of the composite is taken into account explicitly in calculations. Both the experimentally observed microstructure of a sample with an irregular coating-substrate interface and a model microstructure with an ideal sinusoidal shape of this boundary were considered. The value of stress concentration in the area of the interface is shown to increase with both a decrease in the coating thickness and an increase in the sine amplitude. It is found that these dependences have exponential character.

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

CALCULATION OF THE PERIOD OF TOROIDAL BUBBLE PULSATIONS DURING ELECTRICAL DISCHARGE IN AN ELECTROLYTE IN ADIABATIC APPROXIMATION

Medvedev R.N., Teslenko V.S.
Lavrentyev Institute of Hydrodynamics SB RAS
ruslan@hydro.nsc.ru

The numerical calculation of kinetic energy of liquid during toroidal bubble grows was performed. It was shown that it is possible to use the well known equation for kinetic energy of liquid during toroidal bubble pulsation $K = 2\pi^2 \rho \dot{R}^2 R^2 a \ln \frac{8a}{R}$ (ρ is the density of the liquid, R is the cross-sectional radius, a is the outer radius and $\dot{R}$ is the velocity of the bubble boundary) not only when $R << a$, but at any shape of torus up to closure of torus in the centre ($R \leq a$) with accuracy no worse than 12%.

Based on that result the adiabatic model was used to calculate the period of bubble pulsation depending on its maximal radius. As can be seen the obtained period $\tau \approx 3.3 R_{\max} \sqrt{\rho / p_a}$ (p_a is the pressure in liquid) almost two times more than analogous for spherical bubble.

Electric discharge in electrolyte on current concentrator was used as experimental verification of theoretical result. Three types of current concentrators were used: thin dielectric film with round hole (0.1 mm in radius), thin dielectric film with annular hole (4.3 mm in radius, 0.35 mm width), metal annular electrode (3 mm in radius, 0.3 mm width). As the bubble grows (due to the heating by current and subsequent evaporation) begins from the edge of current concentrator, so all bubbles have the shape of torus.

The comparison showed that for annular concentrators, the bubble oscillation periods are in good agreement with the approximate formula, whereas for round holes, this is not so. This is due to the fact that the adiabatic model of bubble oscillations is not applicable in this case because the bubble growth on a round concentrator is accompanied by heating of the electrolyte by the current in the central part of the hole, which causes evaporation into the bubble during its growth.

The results of this work can be used for underwater shock-waves generation and miniature underwater movers.

THE EFFECT OF STRESS STATE ON THE INTERNAL STRUCTURE OF THE MATERIALS

Mochalova Y. A.[1], Merkushev E. S.[2]
1 - IPME RAS
2 - SPBU
eugenemerkushev@gmail.com

We consider a metal rod with a complex internal structure: the diffusion transfer of impurity in the rod (which can change the structure of the material) depends on the stresses. The dynamics of the rod is described by two-component model of media. The first component is the crystal lattice of the material (in the frame of elastic theory); the second one is the diffusion flux of impurity. The problem is reduces to analysis of a system of nonlinear equations describing the effect of stress state on the diffusion of impurity in the rod. The solutions of the problem are obtained for a number of model examples.

NONLOCAL CONSTITUTIVE LAWS: LATTICE MODEL APPROACHES AND THEIR CONTINUUM LIMITS

Michelitsch T.M., Collet B.A.
Sorbonne Universités, Université Pierre et Marie Curie, Paris 6, Institut Jean le Rond d'Alemebert, CNRS UMR 7190, Paris, France
michel@lmm.jussieu.fr

This contribution aims to establish an analytical approach which provides an interlink between discret and continuous formulations of material systems with non-local interparticle interactions. To this end we analyze cyclically closed linear chains constituted by $N >> 1$ particles in the harmonic approximation. We consider nonlocal interaction patterns which are generated by positive elastic potentials being constructed from quadratic forms of mth -order finite differences ($m = 1, 2, .. \in N$) of the displacement field. The positiveness of the elastic potentials guarantees elastic stability. Application of Hamilton's variational principle leads to descrete "Laplacian operators" ("Laplacian matrices") which are operator functions ($N \times N$ -matrix functions) of the local (weakly non-diagonal) Laplacian generated by next neighbor springs. By construction the obtained nonlocal Laplacians have all required good properties (self adjointness, negative (semi-)definiteness, translational invariance). In the N - dimensional displacement field space these Laplacian matrix functions are non-diagonal, and as a consequence generating non-locality in the constitutive laws. We further deduce continuum limits (long-wave limits) of the Laplacian matrices which yield "Laplacian convolution kernels" and the related elastic modulus kernels of the non-local constitutive law. We establish criteria for "weak" and "strong" nonlocality determined by scaling relations of the material constants in the continuum limit when the interparticle spacing $h \rightarrow 0$. We demonstrate the effect of non-locality on the vibrational dispersion relation by analyzing the elastic potential which corresponds to a Gaussian elastic modulus kernel. The present approach provides a compact method to generate any physically admissible (elastically stable) non-local constitutive law in both, discrete and continuum settings. The approach is useful to model non-locality in cyclically closed (periodic) crystals in $n = 1, 2, 3, ..$ dimensions of the physical space.

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THIN COMPOSITE SANDWICH BEAMS, PLATES AND SHELLS CONTAINING MAGNETORHEOLOGICAL ELASTOMER: VIBRATIONS, WAVES AND THEIR SUPPRESION

Mikhasev G. I.
Belarusian State University, Department of Bio- and Nanomechanics, Minsk, Belarus
mikhasev@bsu.by

Thin multi-layered beams, plates and shells have a wide range of applications in many engineering structures, such as airborne/spaceborne vehicles, underwater objects, and cars. Applying new materials with different physical properties one can design sandwich structures fulfilling up-to-date requirements such as high-specific stiffness, good buckling resistance, safety and noiselessness. The vibroprotection of thin-walled structures experiencing external vibrational loads is of great practical interest for mechanical engineers which develop and model similar structures. The appearance of new multi-functional composite materials with active and adaptive properties (so-called smart materials) opens new possibilities [1, 2]. Some of them are electrorheological (ER) and magnetorheological (MR) composites and, particularly, magnetorheological elastomers (MREs). They belong to the group of active materials which physical properties such as viscosity and shear modulus can vary when subjected to different magnetic field levels [2, 3]. It is expected that MREs embedded between elastic layers will provide for a sandwich a wide range of rheological properties which may be controlled rapidly and reversibly by the application of an external magnetic field.

Laminated beams, plates and cylindrical sandwich shells composed by embedding MREs between elastic layers is the subject of this investigation. Physical properties of the MR layers are assumed to be functions of the magnetic field induction and curvilinear coordinates. A modified system of differential equations with complex variable coefficients depending upon the magnetic field [4] and based on both the assumptions of the generalized kinematic hypothesis for the whole sandwich [5] and experimental data for MREs [6] is used as the governing one.

As the first step, the principle complex parameters of the accepted model (complex coefficients appearing in the governing equations) vs. the homogeneous magnetic field is studied on the example of a three layered adaptive MR cylinder [7]. Variations in the reduced complex stiffness and shear parameters of the sandwich are achieved in response to different levels of applied magnetic field.

Then the natural frequencies and damping ratio for beams, plates and cylindrical shells are calculated for different thicknesses of the MR core under action of the external magnetic field. To analyze damping capabilities of adaptive materials, forced vibrations of a three-layered beams and plates containing the MRE layer are studied at different levels of the magnetic field. In addition, the response of the three layered beam with the MRE core to an impulse action of a magnetic field is studied. As shown in [6], the pulsed signal of an external magnetic field may result in excitation of non-stationary high-frequency vibrations of the adaptive MRE-based beam.

Using the asymptotic approach [8], eigenmodes of free vibrations of a laminated cylindrical shell with variable physical characteristics of MRE are constructed in the form of functions decaying far from the weakest plot on the shell structure. It has been shown [7] that applying constant magnetic field may result in localization of eigenmodes of free vibrations of a three-layered circular thin cylinder with highly polarized MRE core [9]. In particular, the modes corresponding to the lowest frequencies may be localized near some lines where the reduced shear modulus of the sandwich gets its extremum. Dependencies of natural frequencies, damping decrement and parameter characterizing the power of the eigenmode localization on the intensity of applied magnetic field are also analyzed.

Finally, applying the asymptotic method developed in [10], the problem on soft suppression of localized waves (wave packets) running over the adaptive MR shell surface under the effect of the nonstationary magnetic field is studied.

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PREDICTION OF LOCALIZED NATURAL MODES OF SINGLE-WALLED CARBON NANOTUBES EMBEDDED IN NONHOMOGENEOUS ELASTIC MEDIUM

Mikhasev G.I.
Belarusian State University
gimikhasev@rambler.ru

Free vibrations of a single-walled carbon nanotube (SWCNT) embedded in a stiff elastic medium are studied on the base of the nonlocal theory of orthotropic shells. The tube is pre-stressed by external axial forces. The Flügge type shell equations [1], including the initial membrane hoop and axial stresses, are used as the governing ones. The constitutive equations are formulated by considering the small-scale effects [2]. The validity of the governing equations derived in [3] and accepted in this study depends on the correlation between the parameters a, R, h, where a =0.14 nm is the atomic spacing, R is the tube radius, and h is its effective thickness. As shown in [4], an error of the CNT model based on the theory of thin orthotropic shells is a value of the order $O[(a/R)^2]$. So, the error of the SWCNT governing equations applied here may be defined as $\max\{h/R, [(a/R)^2\}$.

The stiff elastic medium is assumed to contain some inclusions which can lead to weakening of the interatomic forces between the SWCNT and the surrounding matrix, and to some dislocations of atoms in the tube structure. It is supposed that this dislocations are sufficiently small so that the tube surface may be considered as the cylindrical one. The effect of the surrounding elastic medium is treated using the Winkler-type spring constant which is variable along the tube axis.

It is assumed that there exists the "weakest" line $x=x_0$ (here, x is the axial co-ordinate at the tube surface), where vibrations of the SWCNT are more intensive. Using the asymptotic approach [5], both axisymmetric and nonaxisymmetric eigenmodes are constructed in the form of functions decreasing rapidly away from the "weakest" line. The dependence of the natural frequencies and the power of the localization of the corresponding modes upon the constant of non-locality, tensile stresses, orthotropy ratio, and the nanotube radius is analyzed. The qualitative analysis of the solutions and examples allowed to conclude:

(i) introducing the internal nanoscale parameter into the tube model permitted to predict the new localized eigenmodes which are not exist for macro-sized cylindrical shell prestressed by tensile axial forces [3];

(ii) an increase in nonlocal nanoscale results in reduced the natural frequencies for the SWCNT and scaled-up the area where the localized oscillations occur.

(iii) growing the tensile axial force leads to growing the natural frequencies and focusing the localized eigenmodes of the SWCNT in the neighborhood of the "weakest" curve.

The results presented in this work show that imperfections in the structure of elastic materials utilized as the matrix for composites should be taken into account when modeling composites on the bases of carbon nanotubes. In particular, it may be concluded that the presence of "soft" inclusions in the elastic matrix containing more rigid CNTs may lead to the strong localization of exited vibrations and, as a result, to the concentration of destructive stresses in a small area of a composite.

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TRANSPORT OF POLAR AND NONPOLAR FLUIDS THROUGH NANOTUBES PLACED INTO LIQUID MEDIUM

Abramyan A.K., Bessonov N.M., Mirantsev L.V., Reynberg N.
Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, St. Petersburg, Russia
miran@mail.ru

Transport of various fluids through nanotubes is of both fundamental and technological importance. For example, as a possible molecular transporters, nanotubes can open a new route for drug delivery that gives rise to a novel mechanism for cancer therapy. In recent years, extensive efforts have been dedicated to both experimental and theoretical investigations of fluid flow through carbon nanotubes (CNTs). These investigations revealed, for example, an extraordinary enhanced transport of water and other fluids through these nanotubes which was attributed to specific interactions between fluid molecules and carbon atoms of the tube walls.

However, using a fluid flow through nanotubes for drug delivery, we should take into account not only interactions between fluid molecules inside the tube and carbon atoms of bounding walls but also interactions between molecules of fluids inside and outside the tube. This is caused by that any nanotube immersed into living organism as adrug transporter is surronded by aqueus medium.

On the basis of the above, we have performed molecular dynamics (MD) simulations of water flow through single wall carbon nanotubes (SWCNTs) of different diameters surrounded by molecules of polarand nonpolar liquids. The nanotube walls were considered to be made of two dimensional graphene sheets. The water molecules were modelled on the basis of TIP3 model which takes into account both Lennard – Jones (LJ) interactions between oxygen atoms and Coulomb interactions between oxygen and hydrogen atoms. The interactions between water molecules and carbon atoms of the walls were modelled by LJ potential. Our simulations revealed a strong difference between properties of modelled water flow and those predicted by classic hydrodynamics. For example, unlike the parabolic profile of the flow velocity predicted by classic hydrodynamics, the flow velocity profile obtained from our simulations is very flat, and the average flow velocity is hundreds times higher than that given by the classic Hagen – Poiseuille equation. We also revealed astrong dependence of the average water flow velocity on a polarity of liquids surrounding the tube. It has been found that the water molecules outside the tube drug the water flow through CNTs much stonger than nonpolar molecules surrounding the nanotube.

ANALYTIC SOLUTION FOR DYNAMICS PROBLEM FOR UNLIMITED ELASTIC GRANULAR MEDIUM

Lalin V., Zdanchuk E., Mishenko O.
Saint petersburg State Polytechnical University
zelizaveta@yandex.ru

Under granular medium one takes to a body consisting of separate contacting solid grains. Rotational degrees of freedom of particles in granular materials are important for modeling of processes in them. We consider that reduced Cosserat model can be applied for description of soils and granular media. In this model translations and rotations are independent, the stress tensor is not symmetric, and the couple stress tensor is zero. In this work we present analytic solution for dynamics problem for reduced Cosserat continuum.

DYNAMIC STRAIN IN GRANULAR CERAMICS PROBED BY REAL-TIME X-RAY DIFFRACTION

Jones M.E.[1], Fearn S.[1], Mishuris G.[1], Winter R.[1], Lennie A.[2], Parker J.[2], Thompson S.[2], Tang Ch.[2]
1 - Dept. of Mathematics and Physics, Aberystwyth University, Aberystwyth SY23 3BZ, Wales
2 - Beamline I11, Diamond Light Source, Didcot OX11 0DE, England
ggm@aber.ac.uk

Generally, shock waves travel at the speed of sound in a homogeneous material. However, in a granular material, the contact points between the grains play an important role: Where two grains impinge on each other, energy is dissipated and the contact points act effectively as a secondary source of strain waves. X-ray diffraction is sensitive to strain because it measures changes of the lattice constants of a strained material. This results in a shift of the Bragg peaks of strained crystallographic orientations. If both strained and un-strained material are present simultaneously, the net result is a peak broadening.
The objective of this experiment is to record x-ray diffractograms with high time resolution to study shock-induced strain in a number of refractory ceramics as well as minerals such as slate. The strain is induced by firing an infra-red laser at the sample while recording x-ray diffractograms a variable distance (up to 8mm) away from the impact point. The strain wave is generated by briefly melting a small volume of sample at the impact site.
Diffractograms are taken with 1ms exposure time following each laser pulse. Individual patterns are added to form rolling averages in order to balance the need for good statistics with maximising the amount of strained material contributing to each composite diffractogram. The composite diffractograms are analysed by Rietveld refinement using the Topas software. This allows to determine strain as a function of distance from the laser impact site, separately for different crystallographic axes.
Early results show that strains of up to 0.35% can be found along the c-axis and 0.25% perpendicular to it in zirconia grains within alumina-zirconia-silicate refractories. The strain maximum is about 1mm distant from the laser impact site, confirming that the lattice expansion is indeed due to mechanical strain rather than thermal expansion as the thermal effect is largest at the impact site itself.
Once the x-ray diffraction data are fully analysed, we intend to use the information about strain distribution in different crystallographic orientations, together with the particle size, to model the mechanism of strain propagation via grain contact points.

UNIVERSAL ALGORITHM FOR HYDRAULIC FRACTURES SIMULATION BASED ON THE PARTICLE VELOCITY

Wrobel M.[1], Mishuris G.[1,2]
1 - Aberystwyth University, UK
2 - Eurotech Sp. z o. o. , Mielec, Poland
ggm@aber.ac.uk

Hydraulic fracturing is a widely used method for stimulation of hydrocarbons reservoirs. This technology has been known and successfully applied for a few decades. Recently it has been revived, due to economical reasons, as a basic technique for exploitation of unconventional deposits of oil and gas.
Together with the development of the fracking technology itself, the need for more efficient and accurate numerical modeling of the problem has emerged. The main computational challenges associated with the modelling of hydraulic fractures are: a) strong nonlinearity resulting from the coupling between the solid and fluid phases, b) singularity of the gradients of the physical fields, c) moving boundaries, d) degeneration of the governing equations, multiscaling and others.
Recent advances in the area of numerical modelling of hydrofracturing have resulted in a formulation of new, more efficient numerical algorithms. Some of the developments include application of various independent and dependent variables together with the so called speed equation and proper regularization techniques.

We present a recently developed universal algorithm and describe its origin and basic concepts. The algorithm directly employs the particle velocity as one of the dependent variables. Its ultimate flexibility enables one to tackle various fracture propagation regimes and elasticity models in frames of the same numerical scheme. Results for the PKN and KGD models (the latter for the fluid and toughness driven regimes) are shown. Comparison with the available literature results is provided. The advantage of proposed approach is illustrated by the accuracy and efficiency analysis.

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ELASTIC CHARACTERISTICS OF GREEN BODIES DETECTED BY ULTRASONIC TESTS

Misseroni D
University of Liverpool
diego.misseroni@unitn.it

We have investigated the evolution of the mechanical properties of ceramic green bodies as function of the forming pressure.
We have shown experimentally, by means of both pressure and shear ultrasonic waves, that at higher compaction pressure correspond higher stiffness in terms of elastic and shear moduli.
This study open new perspective in design of ceramic materials.

S-SHAPE CONSTRAINTS FOR ELASTIC RODS: TENSILE BUCKLING IN TENSION AND MULTIPLE BIFURCATIONS

Misseroni D.[1], Bigoni D.[2], Noselli G.[3]
1 - University of Liverpool
2 - University of Trento
3 - SISSA International School for Advanced Studies
diego.misseroni@unitn.it

The curvature of a constraint against which the end of an elastic rod is prescribed to move deeply influence bifurcation and post-critical behavior.
We show both theoretically and experimentally that an appropriate curvature of the constraint over which the end of a structure has to slide can induce: (i.) tensile buckling; (ii.) decreasing- (softening), increasing- (hardening), or constant-load (null stiffness) postcritical behaviour; (iii.) multiple bifurcations, determining for instance two bifurcation loads (one tensile and one compressive) in a single-degree-of-freedom elastic system.

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NUMERICAL SIMULATION OF THE TRANSVERSE HYDROGEN INJECTION INTO A SUPERSONIC TURBULENT AIRSTREAM

Moisseyeva Ye.[1], Naimanova A.[2]
1 - Al-Farabi Kazakh National University, Almaty, Kazakhstan
2 - Institute of Mathematics and Mathematical Modelling, Almaty, Kazakhstan
k.moisseyeva@gmail.com

Currently, in numerical simulations of supersonic flows the main tool is the essentially non-oscillating schemes: ENO (essentially non-oscillatory) and WENO (weighted essentially non-oscillatory) schemes. These schemes are well adapted for solving the Navier-Stokes equations for a perfect gas. While modeling of multicomponent gas flow is important for practical application, these schemes are less adapted for such problems. The ENO scheme based on the Godunov method was developed and its applicability to the problem of transverse jet injection into a supersonic turbulent multicomponent gas flow in a flat channel was shown by the authors in [1].
As well known, necessary tools for suppressing oscillations in the solutions are limiters. But sometimes limiters reduce accuracy and can give problem with non-physical expansions of mixing layer for multispecies flows.
In this work three-dimensional turbulent steady flowfield generated by transverse hydrogen injection into a supersonic cross-flow was simulated by solving the Reynolds-averaged Navier-Stokes equations using the ENO scheme and closed by the k-ω turbulent model. Additionally, the effective adiabatic parameter of the gas mixture is introduced. It allows one to calculate the derivatives of the pressure with respect to independent variables for determining the Jacobian matrices, and thus to construct an efficient implicit algorithm of solution.
Conditions under which limiters preserve monotonicity

and exactly reproduce linear solution for three-dimensional problem has been numerically performed. Numerical experiments show the need of additional regularization of limiters to exact reproduction of solution.

The mechanism of the formation of vortices in front of the injected jet and behind that is studied. Besides, the influence of the ratio of the pressure in the jet to that in the flow (pressure ratio) on the spatial interaction of the injected jet with the oncoming flow is examined. The research results can be applied for design of the fuel injection method in the combustor of scramjet engine.

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INFLUENCE OF SURFACE ROUGHNESS ON STRESS MEASUREMENTS BY X-RAY DIFFRACTION TECHNIQUE

Monine V.I.[1], Assis J.T.[2], Rodrigues L.D.[1], Freire J.L.F.[1], Paiva V. E. L.[1]

1 - Pontifical Catholic University of Rio de Janeiro, Brazil

2 - Rio de Janeiro State University, Brazil

monvlad@mail.ru

X-ray diffraction technique is well known and well established technique applied for residual stress measurements. It is not destructive method and it is able to perform stress measurements with high accuracy and confidence. Advantages of this method stimulate its widespread use for the control of residual stresses arising in materials after various thermo mechanical treatments, after lamination, stamping and other traditional and modern technologies that are used in the manufacture and production of industrial parts and components. Several factors such as grain size, texture and surface roughness can affect the precision and accuracy of stress measurements by X-ray diffraction method. One of these factors poorly studied in the literature, is the roughness that can modify the stress distribution in the surface layer of the analyzed material, to change the actual stress value measured by X-ray diffraction method.

In this paper it was studied the influence of surface roughness on the stress measurements by X-ray diffraction technique. For this purpose it was used simulation of experimental measurements by composition of diffraction profile by the surface with different parameters of surface roughness. Database for this simulation was obtained by mapping of stress distributions made by finite element method.

MATHEMATICAL MODELLING OF INTERFACIAL CRACKS IN ANISOTROPIC AND PIEZOELECTRIC CERAMIC MATERIALS

Pryce L.[1], Morini L.[2], Mishuris G.[1]

1 - Institute of Mathematics and Physics, Aberystwyth University, Aberystwyth. SY23 3BZ, Wales, UK

2 - Department of Civil, Environmental and Mechanical Engineering, University of Trento, Via Mesiano, 77, 38123, Trento, Italy

lorenzo.morini@unitn.it

We present a number of results concerning the propagation of a crack along an interface in both anisotropic and piezoelectric materials. Firstly, a semi-infinite crack propagating at a constant speed along a perfect interface in an orthotropic bimaterial is considered [1]. The stress intensity factors (SIF) are found and therefore the energy release rate (ERR) is computable. The examples presented here explore the variation of the ERR for different crack speeds and for different configurations of both symmetric and asymmetric loading on the crack faces.

We also present the derivation of singular integral equations for a stationary crack in a piezoelectric bimaterial. These are found by using the extended version of the Betti identity [2, 3], which now incorporates the piezoelectric behaviour of the material, and weight functions for piezoceramic crack problems. Computations for the piezoelectric bimaterial will be shown.

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MODELLING OF INTERFACE CRACKS BETWEEN DISSIMILAR CERAMIC MATERIALS OF INTEREST FOR SOLID OXIDE FUELL CELLS FABRICATION

Morini L., Piccolroaz A.

Department of Civil, Environmental and Mechanical Engineering, University of Trento, Via Mesiano, 77, 38123, Trento, Italy

lorenzo.morini@unitn.it

Solid oxide fuel cells (SOFC) are complete solid-state energetic devices generating electricity through reactions between two reactants, a fuel and an oxidant, triggered in the presence of an electrolyte [1]. The cell components, generally made of ceramic and composite materials, are subjected to extreme environments and severe thermomechanical residual stresses which can allow to structural damages and fracture processes [2]. A general approach for modelling fracture processes at the interface between different components of the cells is developed. In order to account mechanical stresses, thermal stresses and stresses induced by ions diffusion through the interface, the elasticity balance equations are coupled with the linear heat conduction and ions diffusion equations. The original method recently developed by the authors, based on Betti's reciprocal theorem and weight functions theory [3, 4], is applied to formulate the problem in terms of singular integral equations relating the loading applied at the crack faces and the resulting crack opening. The derived integral identities are then used for solving some illustrative examples of crack problems at the interface between cathode and electrolyte or anode and electrolyte in presence of non symmetrical mechanical and thermal loading acting on the crack faces.

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CRACKS PROPAGATION IN CERAMIC MATERIALS: A SINGULAR INTEGRAL FORMULATION

Morini L.[1], Piccolroaz A.[1], Mishuris G.[2]
1 - Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy
2 - Institute of Mathematical and Physical Sciences, Aberystwyth University, UK,
lorenzo.morini@unitn.it

The problem of a crack at the interface between two dissimilar ceramic materials, loaded by a general asymmetrical system of forces distributed along the crack faces is investigated. The proposed original formulation is based on integral transforms and two fundamental notions of linear elasticity: the Betti reciprocal theorem and the weight function approach. The Betti identity has been extensively used in the perturbation analysis of two and three-dimensional cracks [4]. In linear fracture mechanics, the concept of weight function, defined as singular non-trivial solutions of the homogeneous boundary value problem for a solid with a crack, was introduced by Bueckner [1]. Recently, symmetric and skew-symmetric weight function matrices have been derived for interfacial cracks in both isotropic and anisotropic materials [2, 3, 4]. Using these matrices together with the fundamental reciprocal identity (Betti formula), the elastic fracture problem is formulated terms of singular integral equations relating the applied loading and the resulting crack opening.

The derived compact formulation can be used to solve many problems in linear elastic fracture mechanics (for example various classic crack problems in homogeneous and heterogeneous anisotropic media, as piezoceramics or composite materials). This formulation is also fundamental in many multifield theories, where the elastic problem is coupled with other concurrent physical phenomena.

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MODELLING PARAMETERS OF WELDING OF GLASS WITH METAL AT GLASS-AND-METAL COMPOSITE

Lubimova O. N., Morkovin A. V., Druk S. A.
Far Estern Federal University
fly.88@mail.ru

In this work process of production three-layer glass and metal composite with external metal layers identical on thickness is modeled. In case of formation of a three-layer composite (metal-glass-metal) a method of diffusive welding, the temperature mode assumes that at a welding temperature glass gradually comes to a condition of viscous liquid and at certain time of welding processes of volume diffusion of oxides of metal develop in glass. Process of interaction of metals with nonmetals is considered from a position of the theory of topochemical reactions [1] which includes three stages: 1) formation of physical contact – rapprochement of connected surfaces as a result of plastic deformation of one or both connected details before emergence of physical forces of the interaction caused by forces of Van der Waals; 2) activation of the surfaces which, result in formation of the active centers and transition of atoms from a condition of physical adsorption in a condition of chemical adsorption; 3) formations of the active centers as the result of which diffusion processes are developed, which in turn give to connection development volume character. In work [2] it is experimentally shown that physical contact between metal and glass at production glass and metal composite is formed as a result of contacting of a glass in a viscous state with a metal surface.

At mathematical modeling of process of formation of the new material, one of actual tasks is definition of time of the first stage of the topochemical reaction for the purpose of the assessment of formation of one-piece connection, experiment planning by determination of parameters of diffusive process and quality management of a received material.

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ESTIMATION OF THE COEFFICIENT OF FRICTION EPILAM - COATED MATERIALS

Morozov A.V.
A. Ishlinsky Institute for Problems in Mechanics RAS
morozovalexei@mail.ru

One of the techniques of giving anti-friction and wear-resistant properties to the materials used in friction pairs, is the use of methods of processing contacting surfaces with solid lubricants or coatings based on solid lubricants. The modern method of surface treatment of materials with solid lubricants is epilamization technology [1], the essence of which lies in applying fluorinated surface-active agent (Fluorine-SAA) from the solution to the materials' surface. A very thin molecular protective fluorine-SAA (epilam) film with thickness 3-10 nm is formed on the surface after evaporation. The proposed paper presents the results of experimental estimation of the friction coefficients of the materials that are processed with epilamon 6SFK-180-05, and are under operating conditions of friction without lubricant.

The experimental study of friction coefficient was conducted with UMT tribometer using the "pin-plate" contact scheme. The pin is a fixed iron sample with 6 mm diameter, and the plate performs a linear reciprocating motion with a velocity of 1 mm / s with respect to the pin pressed thereto. The friction path was 1 mm. To study the effect of load on the characteristics of materials studied for the static μ_{st} and dynamic μ friction coefficients two values of normal pressure of 0.5 MPa and 5 MPa were chosen.

The analysis of the obtained experimental data shows that the use of materials epilamization technology reduces static and dynamic coefficients of friction; besides, the application technology does not change the geometrical dimensions of the mating parts and does not require bringing in additional modifiers into the friction area. Wear resistance of the sliding friction pair is limited by molecular coating thickness of Fluorine-SAA surfactants. Therefore, for most tribological applications of long term run, the use of the technology will reduce only the static coefficient of friction at the beginning of the friction assembly operation. It should be noted that, after introducing epilam into the lubricant, continuous regenerating of Fluorine-SAA film at the interfacing friction surfaces is expected; in this case, the protective effect of epilam is much higher; the friction surfaces will operate for a long time until Fluorine-SAA active molecules in the lubricant have run out.

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THE SPIN, THE NUTATION AND THE PRECESSION OF THE EARTH'S AXIS REVISITED: A (NUMERICAL) MECHANICS PERSPECTIVE

Mueller W.H.
Technical University of Berlin, Institut fur Mechanik, LKM, Einsteinufer 5, 13591 Berlin, Germany
wolfgang.h.mueller@tu-berlin.de

Mechanical models describing the motion of the Earth's axis, i.e., its spin, nutation and its precession, have been presented for more than 400 years. Newton himself treated the problem of the precession of the Earth, a.k.a. the precession of the equinoxes, in Liber III, Propositio XXXIX of his Principia [1]. He decomposes the duration of the full precession into a part due to the Sun and another part due to the Moon, to predict a total duration of ca. 26000 years. This agrees fairly well with the experimentally observed value. However, Newton does not really provide a concise rational derivation of his result. This task was left to Chandrasekhar in Chapter 26 of his annotations to Newton's book [2]. He follows an approach suggested by Scarborough [3] starting from Euler's equations for the gyroscope and calculating the torques due to the Sun and to the Moon on a tilted spheroidal Earth. These differential equations can be solved approximately in an analytic fashion, yielding Newton's result. However, they can also be treated numerically using a Runge-Kutta approach allowing for a study of their general non-linear behavior. This paper will show how and explore the intricacies of the numerical solution. A comparison the actual to actual measurements will also be attempted.

When solving the Euler equations for the aforementioned case numerically it turns out that besides the precessional movement of the Earth's axis there is also a nutation present. However, the period of this nutation turns out to be roughly half a year with a very small amplitude whereas the observed (main) nutational period is much longer, namely roughly nineteen years, and much more intense amplitude-wise. The reason for this discrepancy is based on the assumption that the torques of both the Sun and the Moon are due to gravitational actions within the equinoctial plane. Whilst this is true for the Sue, the revolution of the Moon around the Earth occurs in a plane which is inclined by roughly 5° w.r.t. the equinoctial. If this is taken into account the predicted nutation period will be of the order of the observed value [4], [5]. As in the case of the precession we will provide a stringent analysis based on a numerical solution of the Euler equations, which is in contrast to Section 12.10 of [5].

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EQUILIBRIUM OF A DUST AND GAS CLOUD

Murachev A.S.[1,2], Krivtsov A.M.[1,2]
1 - St. Petersburg State Polytechnical University, Saint Petersburg, Russia
2 - IPME RAS, Saint Petersburg, Russia
andrey.murachev@gmail.com

The problem of the planets and planetary systems formation is one of the challenges for the modern astrophysics. According to the hypothesis which is developed by academician Galimov the Earth-Moon system was formed as a result of the rotary collapse of a gas and dust cloud. We have considered the equilibrium state of a spherical cloud under the action of three forces: gravity, gas pressure forces and interparticle repulsive force caused by the evaporation of the particles ice. Term which is responsible for the repulsive force is derived from the radiative transfer theory. We have used a modified equation of the hydrostatic equilibrium to find the distribution of the dust and gas concentrations. It is shown that the considered model demonstrates a maximum concentration of the particles at some distance from the center in the equilibrium state of the cloud.

CRITICAL BEHAVIOR IN HIGH - VELOCITY IMPACT FRAGMENTATION

Myagkov N.N., Silant'ev M.V.
Institute of Applied Mechanics, Russian Academy of Sciences, Moscow
nn_myagkov@mail.ru

Experiments on the high-velocity impact fragmentation for the projectile-bumper system show: (i) the threshold nature of fragmentation [1]; (ii) the similarity of the debris cloud structure [2]. However the current experimental resources cannot give a more detailed picture of the critical and scaling effects of the fragments distribution in a cloud and investigate the fragments structure "in-situ". These gaps may be filled up by computer simulation. *Previously*, *we studied* the high-velocity impact fragmentation for the projectile-bumper system using 2D particle-based simulations with interparticle interaction by the pair Lennard-Jones potential to obtain a statistically considerable number of fragments as well as to avoid huge amount of calculations [3]. Currently, modern computers allow us to study this problem using 3D simulation based on the equations of deformable solid mechanics (DSM).

In the present work we consider the problem of the fragmentation of aluminum projectile on a thin mesh bumper at high speeds impact. The numerical simulation was carried out by a gridless smoothed-particle-hydrodynamics (SPH) method in the program LS-DYNA. The absence of the grid in the SPH method allows us to model the processes of the intense fragmentation and the motion of a cloud of fragments. We performed series of 3D simulations of the problem at different impact velocities. The behavior of the materials was described by the Mie–Gruneisen equation of state and Johnson-Cook model of plasticity.

We give a quantitative characterization of destruction of the projectile expressed in statistics of cloud fragments, and study the nature of the transition from the state of damage to fragmentation of the projectile at variation of the impact velocity (the control parameter). We obtained the distributions of the fragments by mass, maximum and average masses of fragments depending on the impact velocity and the two pairs of values of stress limits in fracture criteria for materials

Simulation of fragmentation based on the DMS equations allows at least to check the conclusions drawn on the basis of simplified models, and to identify the influence of the destruction criterion on the results obtained.

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COMPUTATIONAL TECHNIQUES FOR TIRES IN ROLLING CONTACT

Nackenhorst U.
Leibniz Universitaet Hannover, Germany
nackenhorst@ibnm.uni-hannover.de

A general framework for the computation of rubber tires in rolling contact will be presented. Key for the efficient treatment is a relative kinematics formulation, which is based on a Arbitrary Lagrangian Eulerian (ALE) description. This enables for a time independent formulation of stationary rolling and local spatial mesh refinement. On the other hand special techniques for the efficient treatment of frictional contact as well as inelastic material behavior are needed. Besides these techniques sophisticated constitutive models for the thermo-mechanical behavior of rubber materials as well as velocity and pressure dependent friction laws will be introduced. Numerical examples of detailed tire models will demonstrate the practicability of this approach.

INVERSE PROBLEMS FOR THE PRODUCTIVE STRATUM GEOMECHANICS

Nazarova L.A.[1,2], Nazarov L.A.[1,3], Karchevsky A.L.[4], Panov A.V.[1]
1 - Institute of Mining Siberian Branch of RAS
2 - Novosibirsk State University
3 - Novosibirsk State Agrarian University
4 - Institute of Mathematics Siberian Branch of RAS
lanazarova@ngs.ru

The remote sensing data, together with the data on output of production wells or degassing holes, give the source information for inverse problems on diagnostics of the condition and for estimation of the parameters of oil- and gas-bearing strata, coal beds and aquifers. The absolute precision of modern methods of space geodesy (GPS, InSAR - up to 1 mm) as well as tacheometric survey and laser scanning (0.25 mm) makes it possible to use recorded displacements and/or strains as input data for these purposes.

The porous elasticity model of deformation of a rock mass under hydrocarbon recovery assists in the analysis of resolvability of the inverse problem on spatial distribution of pressure in a gently dipping productive stratum by increments of the daylight surface displacements. The structure of the cost function is validated, and the inverse problem solution algorithm is developed. The cost function mininum search was carried out using the original modification of conjugate gradient method. Numerical experiments based on the synthetic data have shown that for the unique resolvability of the inverse problem, both the vertical and horizontal displacements of the daylight surface are to be recorded.

The geomechanical model of the block-structure coal bed methane emission (taking into account mass transfer at the block interfaces as well as diffusion and desorption processes) was developed. Using the designed model as the base the inverse problem has been formulated for finding diffusion and capacity characteristics of a coal bed (initial gas content, diffusion and mass transfer coefficients) by measurements of borehole pressure. The numerical experiments show that gaining the unique solution of the problem requires additional data on gas-kinetic characteristics of the test coal bed.

The investigation was partially supported by the Russian Foundation for Basic Researches, project no. 13-05-00782 and the Siberian Branch of the Russian Academy of Sciences, Integration project no. 14.

DETERMINATION OF UNDERGROUND VOID GEOMETRICS BY THE SUBSIDENCE TROUGH CONFIGURATION ON THE BASIS OF INVERSE PROBLEM SOLUTION

Nazarov L.A.[1,2], Nazarova L.A.[1,3], Khan G.N.[1]
1 - Institute of Mining Siberian Branch of RAS
2 - Novosibirsk State Agrarian University
3 - Novosibirsk State University
mining1957@mail.ru

Hydrocarbon recovery, karst cavities formation, mineral mining, subsurface blasting and other technogenic and natural influences upset the current equilibrium state of the Earth crust upper part. The disbalance response of rock massive recorded on the daylight surface contains information about underground processes and objects and can serve as input data for finding their parameters.

The geomechanical model of soil mass behavior under instantaneous origination and slow collapse of a cavity with length L and height H at a certain depth D was developed. In course of soil irreversible deformation (described using the distinct element method, the initial packing is generated by the method of particle sedimentation under the action of gravity), a subsidence trough emerges. The trough shape S depends on the soil

strength properties (internal friction angle and cohesion) as well as on the parameters L, H and D. The inverse problem was formulated: to determine the geometry of the cavity and its occurrence depth by the S at known soil strength properties.
The direct problem is a computational resource-intensive; so it is unacceptable to use the traditional approach to the inverse problem solution, when the corresponding algorithm is built-in to procedure of the objective function minimum search. Let for a discrete sets of values of L_i, H_m, D_n a series of forward problems is solved and the three dimensional array S_{imn} are found. Based on these data, we approximate the shape of the trough by a function $F = F(L,H,D,P_k)$, where parameters of the approximation P_k depend on elements of introduced sets. The function F is assumed the solution of the forward problem. This approach allows solving classically formulated inverse problems. The numerical experiments have shown that the problem on finding the geometrical parameters of cavity and its depth the known trough shape is uniquely resolvable if the input data relative error is less than 0.1.
The investigation is supported by the Russian Foundation for Basic Researches (project no. 12-05-00843).

CONTINUUM MODELS WITH CONSTITUTIVE LAWS FOR BODY FORCES AND MOMENTS

Neygebauer I.
The University of Dodoma, Russia
newigor52r@yahoo.com

There exist the continuum models without any constitutive law, for example: elastic string and membrane, ideal incompressible fluid.
There exist also the models with constitutive law for stresses or for internal surface interactions, for example: elasticity, ideal compressible and viscous fluids, heat conduction.
There exist continuum models with constitutive laws for body forces and body moments, for example: elastic string, beam, membrane, plate, elasticity, hydro- and fluid dynamics, heat conduction where the constitutive laws of the body interactions are added. These models allow to consider the real finite point boundary conditions applied to continuum. That point boundary conditions could be given at any finite point of a continuum or at infinity for unbounded continuum. Some of these models will be presented in the paper. The local and non-local internal body interactions are considered. The boundary conditions are considered in more details because the order of the partial differential equations in the given models is usually higher as in the classical case.
The Galerkin type displacement potential is introduced in case of linear isotropic elasticity with local and non-local internal body forces.

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MOLECULAR-DYNAMICS STUDY OF BEHAVIOR OF SYMMETRICAL TILT GRAIN BOUNDARIES IN BCC AND FCC METALS UNDER SHEAR LOADING

Nikonov A. Yu.[1], Dmitriev A. I.[1,2]
1 - Institute of Strength Physics and Materials Science SB RAS
2 - National Research Tomsk State University
nikonov@usgroups.com

Behavior of symmetrical tilt grain boundaries under shear loading was studied in the framework of classical molecular dynamics. Grain boundaries Σ5, Σ9 and Σ11 in Cu and α-Fe were modelled. It was found that behavior of defect depends not only on the structure boundaries, but also on the type of crystal lattice. It is shown that under external stress grain boundary behaves differently in the BCC and FCC metal. Initially in the sample with GB Σ5 an elastic deformation of grains was observed in the condition of shear loading. That led to the formation near the defect structure different from BCC. With further loading, this structure is destroyed, which led to structural failure near the grain boundary. After that the defect is starting to move in a direction perpendicular to the applied loading. It was shown that grain boundary Σ9 behavior in α-Fe similar to the behavior of GB Σ5 in Cu: under an external influence defect begins to move without any changes in structure of GB. Grain boundary Σ11 also moves under shear loading, but structure analysis shown that there are disturbance of the order of atomic lines near the defect. A comparison of the amount of displacement of GB with the amount of grain boundary slip due to shear deformation was performed. These results can help to understand the features of development of plastic deformation in polycrystals under shear loading.

MODELING OF BEHAVIOR OF CRYSTALLITE WITH INTERFACE UNDER LOCAL FRICTIONAL CONTACT

Nikonov A. Yu.[1], Dmitriev A. I.[1,2], Kuznetsov V. P.[3]
1 - Institute of Strength Physics and Materials Science SB RAS
2 - National Research Tomsk State University
3 - Kurgan State University
nikonov@usgroups.com

In the paper simulation of the behavior of copper crystallite under local frictional contact was carried out using the method of molecular dynamics. Loading was realized by the movement of hard indenter along the surface of the sample. Following configurations were considered: initially defect-free crystallite, structure with a symmetrical tilt grain boundary Σ5 (oriented along and perpendicular to the loading direction) and with interface between different materials. Influence of the initial structure on the behavior of the crystallite under loading was analyzed. Nucleation of nanofragmentation of the surface layer was displayed. Atomic mechanisms of a process of nanofragmentation were investigated. It was shown that the presence of grain boundary prevents extension of defects in sample. In case of modelling of interface between Cu and Fe processes are taken place near the interface were analyzed.

ON FINDING THE EXPRESSION FOR THE ELASTICITY TENSOR LINKING TENSION AND TORSION

Osokina A.E., Vilchevskaya E.N.
Saint Petersburg State Polytechnical University, Russia
aeosokina@gmail.com

The deformation of thin rods is investigated in this work.
There are several elasticity tensors describing deformation of thin rods, one of which is responsible for the rod tension and laminated shift, the second one determines the modules of elasticity in the case of the rod bending and torsion.
Because of the independence of the above-described tensors on the strain , they can be found according to the linear theory. In these cases, all modules of elasticity can be found on experiments with straight rods.
The research is devoted to the problem of finding the expression for the third elasticity tensor, which components represent the modules of elasticity, evaluating the connection between tension and torsion.
Neglect of this tensor in simple cases can be justified as follows: mass density of the internal energy is a rod's local characteristic. Locally not too strongly curved rods can be considered as straight rods. Therefore, it is reasonable to assume that mass density of the rod's inner energy isn't dependent on the curvature.
On the other hand, in comparison with some of the accurate three-dimensional elasticity solutions, it became obvious that one cannot further ignore this tensor, especially when determining the displacements. Some of the modules can be determined by experiments with flat curved rods, the rest of them can be found only on experiments with spatially curved rods. Main difficulty in determining the elastic modulus connected with the fact that they depend on the cross sectional shape of the rod.

ANALYTICAL AND NUMERICAL INVESTIGATION OF STATIONARY CORRELATIONS IN IDEAL CRYSTAL LATTICES

Panchenko A.Yu.[1,2], Loboda O.S.[1,2], Krivtsov A.M.[1,2]
1 - Institute for Problems in Mechanical Engineering RAS, St. Petersburg, Russia
2 - St. Petersburg State Polytechnical University, St. Petersburg, Russia
artemqt@yandex.ru

Recent advance in nanotechnology has lead to the necessity of determining mechanical properties of solids with microstructure in a sufficiently wide range of thermal actions and mechanical loads. Basing on analytically derived Mie-Grüneisen equations of state for crystalline solids using widespread interaction potentials, we can broaden the class of problems allowing approximate solutions without molecular dynamics simulation, and also simplify the solution of inverse problems.

In the present work we considered ideal infinite (in analytical part) and periodic (in MD part) crystal lattice as set of interacting particles moving according to the laws of classical mechanics and interacting with pair potential.

In the work of V.A. Kuzkin [1] the expression were obtained for thermal components of stress tensor and internal energy in terms of derivatives of the potential, average particles positions and an additional tensor, responsible for thermal motion. In this work analytical and numerical investigation of the correlation tensor of particle displacements is carried out for thermodynamic equilibrium.

Equilibrium distribution of correlations tensor was obtained analytically and numerically for square and triangular lattices. The results of the investigation have given the possibility to determine the dependence of thermal expansion coefficient on the type of interaction potential, the number of coordinational spheres taken into account and external stress.

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SYNCHRONOUS CHAOS IN A SYSTEM OF IDENTICAL SELF-SUSTAINED ELECTROMECHANICAL OSCILLATORS MOUNTED ON A MOVABLE PLATFORM

Pankratova E.V., Belykh V.N.
Volga State Academy of Water Transportation
pankratova_e.v@mail.ru

In this report we consider a system of *n* identical self-sustained electromechanical oscillators connected (via springs) to a platform that is attached to the wall via a spring and a damper [1]. We assume that the oscillators are driven by a force *f*(*x, dx/dt*) introduced to sustain self-oscillating behavior of subsystems (with a limit cycle in phase space of each individual uncoupled subsystem). The meaning of this control force is that without changing the setup, we can individually specify an arbitrary form of individual oscillations. In reality, this oscillation control can be provided on the basis of combined hardware/software method [2].
Let the platform be constrained to move in one dimension only. This motion of the platform can change the dynamics of indirectly coupled oscillators and can lead to emergence of their complicated (chaotic) oscillations. We show that in the case of synchronous subsystems' oscillations the considered (2*n*+2)-dimensional system can be reduced and be considered on 4-dimensional synchronous manifold. For this reduced system we obtain the conditions for emergence of chaotic oscillations. We show that this synchronous regime in (2*n*+2)-dimensional system is stable and its basin of attraction has very complicated structure. We reveal that the nature of this chaotic behavior is closely related to the Shilnikov chaos, and defined by complicated intersections of stable and unstable manifolds via homoclinic and heteroclinic orbits.

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NUMERICAL INVESTIGATION DIRECTIONAL SOLIDIFICATION OF BINARY ALLOYS UNDER THE ACTION OF ROTATIONAL VIBRATIONS

Parshakova Ya.N., Lyubimova T.P.
Institute of Continuous Media Mechanics UB RAS
parshakova@icmm.ru

Numerical simulation of the influence of high-frequency rotational vibrations on the flows and heat and mass transfer at vertical Bridgman crystal growth from alloys was conducted. We carried out numerical simulation of flows and heat-and-mass transfer at direct crystallization subject to rotational vibrations of finite amplitude and frequency, on the base of full non-stationary non-averaged equations and boundary conditions. Mesh refinement of front crystallization was used to better resolved convection flow. The numerical solution of the given problem is conducted applying finite volume method. The study takes into account the processes of inhomogeneous heat-exchange on the lateral wall, the deformation of crystallization front, two-phase zone between the melt and crystal, and dependence of solidus and liquidus temperatures on admixture concentration. Data on time-evolution of velocity, temperature and admixture concentration fields in the melt during crystallization process; and data on admixture distribution in the grown crystal with and without vibrations were obtained. The vibrations were shown to lead to considerable decrease of radial admixture segregation and increase of homogeneity of admixture distribution in the grown crystal; the formation of the paraxial depression isn't observed.

The work was made under financial support of the Russian Foundation for Basic Research (Grant 13-01-96021).

BEATING OF MODES IN DISSIPATIVE SYSTEMS, WITH APPLICATIONS TO SEISMO-GRAVITATOPONAL OSCILLATION OF TECTONIC PLATES

Martin G.[1], Mikhailova A.[2], Pavlov B.[1,2]
1 - New Zealand Institute of Advanced Study
2 - Department of Physics of St. Petersburg University, Russia
pavlovenator@gmail.com

Analytic perturbation procedure allows to interpret mathematically typical features of conservative dynamics of coupled oscillators systems with simple discrete spectrum. Similar machinery for unperturbed systems with multiple eigen-frequencies allows to construct the eigenmodes, but fails when attempting to interpret beating of modes, clearly observed for the Wilberforce pendulum and others coupled oscillators systems in classical and quantum mechanics. Instability of eigenfrequencies of a thin plate under a localized contracting pressure suggests a hypothesis concerning interpretation of some typical dynamical patterns [1] of seismo-gravitational oscillation of tectinic plates as resonance interaction of the corresponding eigenmodes, see [3]. For a tectonic plate with localized active zones, formed due to localized contraction pressure we suggest a zero-range model, choosing an analog of the Saint-Venant parameters for characterization of the corresponding operator extension [2,3] of a dissipative generator of the wave dynamics. Assuming that the eigenfrequencies of some active zones of the tectonic plate coincide with each other and are equal to some eigenfrequency of the complement, we observe the alternation process as migration of energy between the corresponding modes. While the frequency of the alternation - the beating - is strongly dominated by the mean frequency of the alternating modes, we prove that the total migrating energy is approximately conserved. In particular, this implies alternation of maximal energy periods on the active zone and on the complement, in the case of a single active zone on the plate. Comparison of the periodic pattern of alternation with the observation data presented by the Spectral-Time cards may provide an alternative data which can be used for short-time prediction of eatrhquakes. We are grateful to Doctor Petrova for supplying us an interesting set of Spectral-Time cards and a relevant discussion.

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PERMANENT MAGNETIC LEVIATION OF LEVITRONS USING PERIODIC MAGNETIC FORCING

Perez A.T., Garcia-Sanchez P.
Universidad de Sevilla
alberto@us.es

Levitron is a toy that consists in a spinning top that levitates over a magnetic base. In the original toy the air drag decreases the spin rate until, after two or three minutes, the top destabilizes and falls. It is possible to achieve levitation during long periods of time driving the top with an alternating magnetic field. We report measurements of stable levitation for the latter case and analyze theoretical and experimentally the top dynamics. It is demonstrated that the magnetic torque that drives the top is due to a misalignment between the magnetic dipolar moment and the mechanical axis of the top.

NUMERICAL SIMULATION OF PKN MODEL OF HYDROFRACTURING FOR SHEAR-THINNING FLUIDS

Perkowska M., Mishuris G., Wrobel M.
Aberystwyth University
mop9@aber.ac.uk

The notion of hydraulic fracturing, in its broadest definition, can be attributed to a problem of a hydraulically induced fracture propagating in a brittle material. Although the phenomenon can be observed naturally it is now mainly associated with the technological process used for stimulation of hydrocarbon reservoirs, especially unconventional ones. In the last decade, this very complex technology has been given much attention for economical reasons.

Alongside the development of modern stimulation techniques, the need for more efficient and accurate numerical modeling of the problem has emerged. Regardless of how advanced the particular mathematical model of hydrofracturing is, the greatest computational challenges result from the nonlinearity and singularities of the physical fields, moving boundaries, degeneration of the governing equations, multiscaling and other such conditions.

Although a number of dedicated software packages are available on the market, there is still a great need to improve their performance.

Recent advances in the area have led to the formulation of new, more efficient, numerical algorithms. Some of the developments include application of various independent and dependent variables together with the so called speed equation and proper regularisation techniques.

In the presentation, we analyse the performance of a universal algorithm for hydrofracturing proposed by the authors. It directly employs the particle velocity as one of the dependent variables. Results for the PKN model are shown for a variety of shear-thinning fluids. Possible extensions of the numerical scheme to various elasticity models are discussed.

We also suggest an optimal strategy for the implementation of the algorithm and compare the accuracy achieved with other available results.

MODELING OF FATIGUE PROCESS BY COMBINING THE CRACK INITIATION AND GROWTH

Petinov S.V.[1,2], Letova T.I.[2], Guchinsky R.V.[1]
1 - IPME RAS, St.Petersburg, Russia
2 - St.Petersburg Polytechnic University, St.Petersburg, Russia
spetinov@mail.ru

The present codes for fatigue design of structures and rules for assessment of residual fatigue life of existing structures are based on considering the fatigue process composed of the two phases: the crack initiation and crack propagation until a specified critical condition would be attained. Respectively, different approaches are applied in fatigue analysis within these phases. However, uncertainties inherent into the data base of the approaches, especially of the Stress-Life criteria-based approaches, do not provide the continuity of fatigue assessment of structures.
Versions of combined model of fatigue are suggested providing continuous analysis of fatigue damage of structures starting from initiation of service until a prescribed crack size would be attained. The problems of application and the prospects of practical implementation of models are discussed.

MATHEMATICAL MODELING OF FORCED QUASI 2D TURBULENCE WITH GLOBAL REACTION

Petrov V. E.
Kutateladze institute of thermophysics SB RAS
ALLUSR@itp.nsc.ru

The paper presents the results of mathematical modeling of forced quasi 2D turbulence with global reaction. This model leads to a new phenomenons in comparison without the global reaction. The KLB (Kraichnan-Leith-Batchelor) theory 2D turbulence predicts the existence of two inertial ranges. The influence of global reaction both on forward enstrophy and inverse cascades is investigated. The characteristics of cascades for various parameters were obtained. The physical mechanism is corrected via data generated numerical-analytical simulations.

DISPERSION AND LOCALIZATION IN STRUCTURED RAYLEIGH BEAMS

Piccolroaz A.[1], Movchan A.[2]
1 - University of Trento
2 - University of Liverpool
roaz@ing.unitn.it

This paper concerns the analysis of dispersive properties, band-gaps and localization modes in structured Rayleigh beams. The Rayleigh beam theory is a refinement of the Euler-Bernoulli beam theory, to account for the rotary motion of beam elements. It is known that the Euler-Bernoulli beam model fails to properly describe flexural waves at high frequency, in that it predicts that waves of infinitely short wavelength travel with unlimited speed. This fact, contradicting the physical evidence, constitutes the basis for the adoption of the Rayleigh beam theory for the description of flexural waves at all frequency ranges. Dispersion and localization properties of structured Rayleigh beams are derived on the basis of the Green's function approach.

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant agreement n° PCIG13-GA-2013-618375.

INCORPORATING INTRINSIC LENGTH-SCALES IN FRACTURE TOUGHNESS OF MICROSTRUCTURED CERAMICS

Piccolroaz A., Morini L., Gourgiotis P.
University of Trento
roaz@ing.unitn.it

Nowadays artificial composite ceramics may be micro-tailored with a hierarchical structure, or may be produced with sculptured chiral structures, or with stabilized negative-stiffness inclusions. The result is that these new materials can achieve surprisingly excellent mechanical properties. For instance: composite materials produced with inclusions of barium titanate in a tin matrix may exhibit a viscoelastic modulus far higher than that of either constituent, reaching a stiffness substantially greater than that of diamond [1]; these materials are proved to be stable even with negative-stiffness constituents [2]. Moreover, a hierarchical heterogeneous microstructure can give extremal values of material properties such as negative Poisson's ratio [3]. This is very important in the case of synthetic biomaterials, such as bone replacements and scaffolds for bone regeneration [4]. This poses a new challenge for the analytical modelling of fracture properties and fracture toughness of such microstructured materials, since the classical theory of fracture mechanics is unable to describe the microstructural characteristics of the material. We propose a model to incorporate intrinsic length-scales in the fracture toughness of microstructured ceramics, based on the couple-stress elastic theory [5,6,7,8].

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant *agreement n° PCIG13-GA-2013-618375.*

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INTEGRATION ALGORITHMS OF ELASTOPLASTICITY FOR CERAMIC POWDER COMPACTION

Penasa M., Piccolroaz A., Argani L., Bigoni D.
University of Trento
roaz@ing.unitn.it

Inelastic deformation of ceramic powders (and of a broad class of rock-like and granular materials), can be described with the yield function proposed by Bigoni and Piccolroaz (2004, Yield criteria for quasibrittle and frictional materials. Int. J. Solids and Structures, 41, 2855-2878). This yield function is not defined outside the yield locus, so that 'gradient-based' integration algorithms of elastoplasticity cannot be directly employed. Therefore, we propose two ad hoc algorithms: (i.) an explicit integration scheme based on a forward Euler technique with a 'centre-of-mass' return correction and (ii.) an implicit integration scheme based on a 'cutoff-substepping' return algorithm. Iso-error maps and comparisons of the results provided by the two algorithms with two exact solutions (the compaction of a ceramic powder against a rigid spherical cup and the expansion of a thick spherical shell made up of a green body), show that both the proposed algorithms perform correctly and accurately.

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TWO-TEMPERATURE ATOMISTIC MODEL FOR ION TRACKS IN UO_2

Pisarev V. V.[1,2], Starikov S. V.[1,2]
1 - Joint Institute for High Temperatures of RAS
2 - Moscow Institute of Physics and Technology (State University)
pisarevvv@gmail.com

A two-temperature atomistic model for ion tracks in uranium dioxide is developed. Atoms are treated via molecular dynamics (MD) equations, and excited electrons are treated via continuous medium model. The electron-lattice energy transfer is included is implemented using electron-temperature dependent Langevin thermostat for atomic subsystem, and electronic pressure effects are included into the model.
Swift heavy ion impact is modeled by creating initial electron temperature profile, and the effects of its relaxation are studied in MD simulations. In the bulk uranium dioxide tracks are formed through melting and recrystallization of material along the ion trajectory. The track itself is a region around ion trajectory with high defect concentration. When the ion trajectory comes close to the surface, the track formation mechanism changes. The track is seen as a deformation of the surface on the nanoscale and the electronic pressure effects play a crucial role in its formation.
It is shown that the energetic threshold of surface track formation in the new model is lower than the threshold for bulk tracks, in agreement with the experimental observations [1].

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CALCULATION OF INSTABILITY DEVELOPMENT OF NON-SYMMETRICAL PERTURBATIONS OF NANORPATICLE SURFACE SHAPE

Pogosian T.N., Chivilikhin S.A.
Saint Petersburg National Research University Information Technologies, Mechanics and Optics
edo-chan@mail.ru

Mathematical model approach is used in this work to investigate the influence of a mass diffusion flux on nanoparticle growth. If there is a local eminence on the surface it can lead to perturbation of surface shape. Stability and instability of perturbation depends on factors which will prevail. Diffusion causes distortion of

surface shape and dominance of capillary forces achieves the opposite effect.
We take into consideration both axially symmetrical and non-symmetrical perturbations, that's why perturbation of surface is expanded in series of Legendre associated polynomials. As a result the coefficients of expansion have complicated dependence on polynomials indexes. We investigated various modes at which the surface of nanoparticle loses stability and made conclusions about dynamics of instability development.

A VORTEX FLOW, THAT IS LIKE A TROPICAL CYCLONE (A COMPUTATIONAL EXPERIMENT)

Tarunin E. L., Poliakov A. V.
Perm State University, Russia
tarunin@psu.ru, specpsu@gmail.com

In the Institute of Continuum Mechanics of the Ural Branch of Russian Academy of Sciences at the end of the last century Bogatyrev G. P. and his colleges were performed the laboratory experiments to study a thermal convection in the rotating cylindrical cavity [1]. These experiments, according to the author [2], gave "...циклонический вихрь большой интенсивности, очень схожий с вихрем тропического циклона." (...high intensity cyclonic vortex that is very similar to a tropical cyclone vortex.). After these experiments there were performed some computational experiments with attempts to obtain accordance with- and verification of laboratory studies. Computational experiments [3] shown good agreement with results of laboratory experiments and, moreover, allowed to find out some additional dependencies for flow characteristics. In particular, there were shown conditions for the emergence of a vortex with a phenomenon that is called "eye of the typhoon".
In our activities, it is expected to continue the numerical study [3] to clarify and obtain various integral characteristics, and also for deciding on the applicability of the ideal gas model, proposed in [4], to the description of cyclonic vortexes.
At the first stage equations of the Navier-Stokes mathematical model of a thermal convection were solved in the Boussinesq approximation. The geometry of the region corresponded to laboratory experiments [1, 2]. To solve the corresponded equations of convection we used the two-field method in the assumption of axial symmetry of the convection. Finding a vorticity, a temperature and an axial velocity component was carried out by an explicit scheme. To find a streamfunction we used the successive over-relaxation method to solve the corresponded Dirichlet problem. As an integral characteristics of the convective flow we used a kinetic energy, a Nusselt number (a dimensionless heat flux) and an extreme values of the streamfunction and a velocity components.
Computational experiments yielded results clarified previous calculations [3].

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THE DIFFERENT TYPES TRANSVERSE OSCILLATIONS OF THIN HELICAL BEAM

Polishchuk A.D.
Izhevsk State Technical University, Russia
apolischuk@mail.ru

The non-self-conjugated problem of interconnected spatial oscillation thin helical beam is investigated. There are two branches of characteristic equation. Pairs classical fundamental transverse modes are located near characteristic equation local minimum. But there are pairs of modes, which mode shapes are looks like a spatial fundamental transverse modes, near characteristic equation local maximums.

MICROMECHANICAL MODELLING OF THE THERMO-MECHANICAL BEHAVIOUR OF ORIENTED SEMICRYSTALLINE POLYMER FOILS

Poluektov M., Van Dommelen J.A.W., Govaert L.E., Geers M.G.D.
Eindhoven University of Technology
J.A.W.v.Dommelen@tue.nl

In flexible electronics, polymeric materials may replace conventional substrate materials as silicon, providing flexibility, and potentially enabling roll-to-roll manufacturing. Polymeric foils that are used as a substrate for flexible electronics and which usually have a strongly oriented semicrystalline microstructure, need to satisfy a number of requirements, among which good dimensional stability, also at elevated temperature. This dimensional stability is highly dependent on the internal macromolecular orientation.

This work aims at understanding and predicting the effects of the microstructure, as well as loading conditions as time, stress, temperature and humidity on the mechanical response of thin semicrystalline polymer foils. For this purpose, a micromechanical thermo-elasto-viscoplastic model is developed to predict the dimensional stability of foils when exposed to these loads. The model considers the material to consist of an aggregate of two-phase layered domains, where different constitutive laws are used for the phases [1,2]. The crystalline phase is modelled with crystal viscoplasticity and the amorphous phase is described as an elasto-viscoplastic glassy polymer, taking account material ageing [3].

The micromechanically-based model is used to describe the mechanical behaviour of amorphous and semicrystalline polyethylene terephthalate (PET) under uniaxial compression and uniaxial tension up to large strains and at different temperatures. The model is used to describe the anisotropic elastic and viscoplastic response of oriented PET foils, that is experimentally observed, based on their microstructure. The presence of internal stresses in the material, resulting from material prestretching and heat treatment, is measured and modelled. Using information about the orientation distribution of the crystalline phase, the local thermo-mechanical behaviour is predicted. To demonstrate the applicability of the model to describe the long-term response, the creep behaviour is simulated and compared to experimental data.

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SECONDARY CONVECTIVE STRUCTURES OF MIXTURE CONCENTRATION IN A COUNTER PROPAGATING FLUXES

Demin V.A.[1], Kostarev K.G.[2], Mizev A.I.[2], Mosheva E.A.[2], Popov E.A.[1]
1 - Perm State National Research University
2 - Institute of Continuous Media Mechanics UB RAS
evjeniy.p@gmail.com

Theoretical investigation of the displacement process of a light liquid by a heavy one in a thin isothermal horizontal layer of finite length has been carried out. Initial non-equilibrium step distribution of liquids density generates dissipative spiral convective structures in this inhomogeneous system. Direct numerical three dimensional modeling has been executed with the help of package OpenFOAM which is intended for solution of different problems in the field of fluid mechanics. The effect of liquids miscibility is taken into account over the calculation. The conditions of convection excitation in the regions with unstable stratification near the interface between counter propagating fluxes of liquids have been analyzed. The calculation results of concentration fronts velocity in dependence on densities difference are received in the presence and in the absence of the secondary spiral rollers in a flow. The evolution of secondary convective structures has been simulated in details at various stages of the process. The results of numerical modeling confirm previous experimental data.

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SUSPENDED CONDUCTIVE PLATE OSCILLATIONS IN THE MAGNETIC FIELD OF THE CONDUCTOR WITH ALTERNATING CURRENT

Popov I.A.[1,2], Lukin A.V.[1,2], Skubov D.U.[1,2], Shtukin L.V.[1,2]
St. Petersburg State Polytechnical University, Mechanics and Control Processes Department
IPME RAS
vanwork@yandex.ru

The purpose of this work is research of the autonomous cooling system of the high-ampere conductor with an alternating electric current. The system is supposed to be autonomous in the sense that neither initiation of oscillations, nor circulation of air shouldn't demand additional expenses in the form of power supplies or motive devices.

The cooling system consists of the plate suspended on vertical elastic threads, attached to the middle top and bottom (or left and right) the plate parties, over the

high-ampere conductor with an alternating electric current.
The conductor is presented in the form of infinitely long copper cylinder which magnetic field is supposed to be known. The suspended plate is considered as conductive frame with an electric current.
At interaction of currents induced in a frame and an induction of an external field there is a torque of ponderomotive forces. Magnetic flux through a frame and currents inducting in it depend not only directly on time, but also on an angle of rotation. Thereby, problems of finding of mechanical and electric fluctuations of the suspended frame are interconnected and are described by system of two nonlinear differential equations with periodically changing coefficients:

$$\begin{cases} \varphi''+2\pi\varphi+\dfrac{\lambda^2}{\nu^2}\varphi=-\gamma\tilde{\imath}\sin\tau\dfrac{a\cos\varphi}{1-\alpha^2\sin^2\varphi} \\ \tilde{\imath}+r\tilde{\imath}=-\chi\left[\cos\tau\ln\left(1+\dfrac{2\alpha\sin\varphi}{1-\alpha\sin\varphi}\right)+\sin\tau\cos\varphi\dfrac{\alpha}{\sqrt{1-\alpha^2\sin^2\varphi}}\varphi'\right] \end{cases}$$

Where φ – frame rotation angle, ĩ – dimensionless inducting frame current, n, γ, λ, ν, α, r, χ – system parameters defined from the geometry characteristics and physical parameters of the elastic threads and environment.
As a result of the compelled oscillations calculation, periodic rotary oscillations of the suspended plate with a frequency of alternating current are received. By the analysis of linearized system (1) near equilibrium the stability region was defined using direct numerical and asymptotic methods.

LONGITUDINAL PLANE WAVES IN MEDIA WITH HEXAGONAL STRUCTURE

Porubov A.V.[1,2,3], Berinskii I.E.[3,4]
1 - Saint Petersburg Polytechnical University
2 - Saint Petersburg State University
3 - IPME RAS
4 - Saint Petersburg State Polytechnical University
alexey.porubov@gmail.com

It is known, that internal or microstructure of a material seriously affects dynamic processes in it, in particular, localization of strain waves. A modification of classic description may be done by adding so-called gradient terms in the continuum relationship for the strain energy. Another approach is based on the use of the continuum limit of the model of the crystalline lattice of the material
In this paper it is suggested nonlinear generalization of the two-dimensional model of the hexagonal lattice. An analysis of its linearized version reveals new optical branches for longitudinal strain waves. It allows us to perform a continuum limit in three different ways. First of them gives rise to the single governing nonlinear partial differential equation for the strain waves belonging to the acoustical branch. Two other continualizatoins result in new coupled governing equations describing interaction between long acoustic and short optical modes.
Generation and propagation of plane localized nonlinear strain waves is studied as well as its transverse instability.

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MATHEMATICAL MODELLING OF THE ALUMINOTHERMIC IRON REDUCTION PROCESS

Potianikhin D.A.[1], Komarov O.N.[2]
1 - Amur State University of Humanities and Pedagogy
2 - Institute of machinery and metallurgy of Far Eastern Branch of Russian Academy of Sciences
potyanikhin@mail.ru

Application of thermite mixtures to foundry engineering leads to cost saving of cast products. Aluminum shavings and iron dross are main components of thermite mixtures. Their interaction result in formation of reduced iron and slag. Shavings of aluminum, steel and cast iron are the machining waste, and iron dross is rolling mill scrap. Thermite mixtures combustion is self-propagating process; therefore it doesn’t require makeup heating.
The mathematical model of thermite steel melting of metallurgical and machinery works waste is proposed and investigated. Exothermal oxidation-reduction aluminothermic reaction is the basis of this process. This model takes into account heat-mass exchange, phase transformation and hydrodynamical flow of liquid melt as well as inhibition of chemical reaction by products and volume change effect. Mechanical properties are specified by Maxwell rheological model. Finite-difference technique for solving of connected one-dimensional boundary problems within the bounds of proposed model has been developed. Investigations of moulding conditions are conducted as computing experiments series with different initial parameters of technological process, such as proportion of batch materials, preheating etc. According to proposed technique the dependence between proportion of batch materials and chemical composition of generated melt was determined.

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INFLUENCE OF THE DISCRETE ON MATHEMATICAL MODELS FOR CONTINUOUS MECHANICS AND RAREFIED GAS FOR GREAT GRADIENTS

Prozorova E.V.
Mathematics & Mechanics Faculty, St. Peterburg State University, University av. 28 , Peterhof, 198504, Russia
prozorova@niimm.spbu.ru

A problem of building the more full mathematical theory for continuous mechanics and rarefied gas is considered. There are influence an angular momentum in classical and quantum cases. Non-local and non-space mechanics, the conditions of their application. Influence of an angular momentum received from Boltzmann equation and phenomenological, for solid is from another interpretation of classical theory. The non-local effects are investigated by the distribution function in classical case and one-particle matrix of density in quantum case. Peculiarities of these processes were analysed for gas and solids.

SIMULATION OF THERMAL STRESSES DURING ANNEALING UNCOORDINATED SOLDERED JOINTS FROM GLASS AND METALS

Putyrin N.E., Lyubimova O.N.
DVFU
nikitahome@yandex.ru

Welding glass with metals is widely used in various fields of engineering and construction. Mathematical modeling of the kinetics and temporary thermal stresses has allowed to execute more qualitatively heat treatment and to control residual stresses. The processes, which take place in glass and metal during welding, complicate the mathematical modeling. They are: changes in the state of aggregation of glass from solid to viscous and back: diffusion in the weld zone and relaxation during annealing. O.V. Mazurin, in his paper [1], suggested the method of calculation of stresses for soldered joints from glass and metals. In most cases, this method is used for a quarter century chemists and technologists to determine the residual stresses not only for soldered joints from glass and metals, but in amorphous coatings on metallic substrates [2,3]. The simplicity of this method, due to a number rather crude approximations, which in some cases gives the corresponding calculation with experiment, while others include estimates for residual stresses in the coating or group of existing the soldered joints, however in practice they does not exist or contrary [3]. When forming the laminated composite in which the layers may be of the same order, for example, in glass-and-metal-composite [4], there is a need to monitor the stress-strain state, not only glass but also metal. Furthermore, the welding glass and metal diffusion zone may be present, which, as shown in [5], also affects the stress-strain state in the composite. The object of this work is to develop a more rigorous model allows to analyze the technological stresses in junction glass with metal, taking into account the relaxation processes in the glass at certain stages of the process. To achieve this goal considered the problem of strain of a cylinder composed of two different materials are viscoelastic (for glass) and elastic (for metal) under the action of an unsteady temperature field. The problem was solved in a cylindrical coordinate system with the acceptance of the hypothesis of plane strain and axial symmetry. Equations of state for glass written in integral form as the ratio of the Boltzmann-Volterra, in same time in metal bond stress with strains adopted into law Duhamel-Neumann. Analytical formulas for the stresses, strains and displacements in a two-layer composite with consideration of relaxation processes in materials, using the obtained dependence can be investigated thermo-stressed state in layered composites.

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EXTENSION OF THE LS-STAG CUT-CELL IMMERSED BOUNDARY METHOD FOR RANS-BASED TURBULENCE MODELS

Puzikova V.V., Marchevsky I.K.
Bauman Moscow State Technical University
valeria.puzikova@gmail.com

The LS-STAG method for viscous incompressible flows simulation combines the advantages of the MAC-method, immersed boundary methods and level-set method. This method allows to solve on the Cartesian meshes problems when domain shape is irregular or it changes in the simulation process due to hydroelastic body motion. For these reasons, the LS-STAG method is very useful for solving such complicated computational mechanics problems as coupled hydroelastic problems, biomechanic problems, problems of solid mechanics with deformable bodies. However, the LS-STAG method, as all mesh methods has a significant limitation when simulating flows with high Reynolds number: it requires extremely small space and time steps. It leads to significant increase in computational cost. The traditional method of solving this problem is RANS, LES, DES etc. turbulence models usage.

In this research, the general approach to the application of the LS-STAG method for the numerical solution of RANS equations is suggested by constructing the LS-STAG method extension with the Spalart – Allmaras turbulent model. According to the concept of the LS-STAG method normal Reynolds stress components are sampled on the base mesh (similar to pressure discretization) and tangential once - in the upper right corners of the base mesh cells. Thus, for the tangential Reynolds stresses an additional mesh (*xy*-mesh) is introduced. In case of Reynolds Stress (RSM) RANS models, these meshes are used for transport equation solving for Reynolds stresses. The result then is taken into account in the Helmholtz equation for the velocity. In case of Eddy Viscosity (EVM) RANS models eddy viscosity is sampled on the *xy*-mesh. It is very suitable that the eddy viscosity at solid boundaries vanishes, so the cut-cells discretization of the eddy viscosity equations and computation of Reynolds stresses become simple. In this research the LS-STAG-discretization for convective and diffusive fluxes on the additional *xy*-mesh is developed.

FULL FIELD SOLUTION FOR A RECTILINEAR CRACK IN AN INFINITE KIRCHHOFF PLATE SUPPORTED BY A PASTERNAKELASTIC FOUNDATION

Nobili A., Radi E., Lanzoni L.
University of Modena and Reggio Emilia
eradi@unimore.it

The failure of cracked ceramic components is governed by the stresses in the neighbouring of the crack tip, which is described by the stress intensity factor (SIF). Despite the availability of several handbooks for SIFs, very few full-field solutions are available for cracked plates resting on an elastic foundation. This lack of results is problematic, since this situation often occur in practice (e.g. roadways, pavements, floorings, etc.). Furthermore, when some results are available, they never involve the foundation's mechanical properties alone. For instance, the problem of a finite crack in an infinite Kirchhoff plate supported by a Winkler foundation is considered in [1] and it is reduced to a singular integral equation. However, since two length scales exist in the problem (the crack length and the foundation relative Winkler modulus), the SIF may be related to some dimensionless ratio of them and not directly to the foundation's mechanical property. In actual facts, this outcome stems from the Winkler approximation to the foundation and not from the physical feature of the problem. The full-field solution for a semi-infinite rectilinear crack in an infinite Kirchhoff plate resting on a Winkler foundation is found in [2]. Since this is a self-similar problem, no characteristic length scale exists. Application of the above results to road and airport pavements is given in [3]. As a result, the influence of the pavement foundation on the SIF cannot be properly assessed. Several papers address crack problems in plate theory and a literature review of the stress field at the crack tip in thin plates and shells is given in [4] along with comparison with the available experimental results.

The present work deals with the elastostatic problem of a semi-infinite rectilinear crack in an infinite Kirchhoff plate resting on a two-parameter elastic foundation under very general loading conditions. The foundation, also termed Pasternak-type, is weakly non-local, as it accommodates for coupling among the independent springs of a purely local model (i.e. the Winkler model). The same model governs the problem of a Kirchhoff plate equi-biaxially loaded in its mid-plane. The Pasternak foundation accounts for two length scales such that the whole problem is governed by a parameter η expressing the soil to plate relative stiffness. The discussion was addressed in a previous paper [5] but therein limited to the range $0 < \eta < 1$, where the limiting case as $\eta \rightarrow 0$ recovers the non-local Winkler model. In the present work the analysis has been extended to the full range of values for the paremeter η. The problem is formulated in terms of a pair of dual integral equations solved through the Wiener–Hopf technique. Numerical results are given for the full field bending and shear stress field within the plate, the corresponding SIFs are obtained and some conclusions drawn.

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FULL FIELD SOLUTION FOR A RECTILINEAR CRACK IN AN INFINITE KIRCHHOFF PLATE SUPPORTED BY A PASTERNAKELASTIC FOUNDATION

Nobili A., Radi E., Lanzoni L.
University of Modena and Reggio Emilia
eradi@unimore.it

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The present work deals with the elastostatic problem of a semi-infinite rectilinear crack in an infinite Kirchhoff plate resting on a two-parameter elastic foundation under very general loading conditions. The foundation, also termed Pasternak-type, is weakly non-local, as it accommodates for coupling among the independent springs of a purely local model (i.e. the Winkler model). The same model governs the problem of a Kirchhoff plate equi-biaxially loaded in its mid-plane. The Pasternak foundation accounts for two length scales such that the whole problem is governed by a parameter η expressing the soil to plate relative stiffness. The discussion was addressed in a previous paper [5] but therein limited to the range $0 < \eta < 1$, where the limiting case as $\eta \to 0$ recovers the non-local Winkler model. In the present work the analysis has been extended to the full range of values for the paremeter η. The problem is formulated in terms of a pair of dual integral equations solved through the Wiener–Hopf technique. Numerical results are given for the full field bending and shear stress field within the plate, the corresponding SIFs are obtained and some conclusions drawn.

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INFLUENCE OF CARBON NANOTUBE WALLS ON FLUID FLOW

Mirantsev L.V., Abramyan A.K., Bessonov N.M., Reynberg N.A.
Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, St. Petersburg, Russia
natashareynberg@gmail.com

Transport of various fluids through carbon nanotubes (CNTs) is a very interesting phenomenon from both fundamental and technological point of view. Therefore, in recent years, this phenomenob is an object of extensive efforts of experimental and theoretical investigations. These investigations demonstrated that the behavior of fluids confined in nanoscopic channels differs strongly from that of the bulk liquid phase. For example, a number of experiments and computer simulations revealed an extraordinarly enhanced flow of water and other fluids through CNTs which is attributed to specific interactions between fluid molecules and carbon atoms of the bounding walls.
However, an influence of the wall atoms on the behavior of fluid molecules should depend not only on individual intermolecular and interatomic interactions but also on the structure of bounding walls, their number, and orientations of these walls relative to each other. Therefore, we have performed molecular dynamics (MD) simulations of a flow of various fluids through single- and multy - wall carbon nanotubes with walls made of both regular two dimensional graphene sheets and two dimensional amorphous sheets composed of randomly distributed carbon atoms. Intermolecular liquid – liquid interactions were modelled as Lennard – Jones (LJ) interactions + Coulomb interactions (in the case of polar liquids), and interactions between fluid molecules and carbon atoms of the walls were assumed to be LJ ones. The CNTs were considered to be

immersed into either polar (water) or nonpolar fluid. For multy wall CNTs, the bounding wealls were assumed to be rotated relative to each other by different angles.
Our simulations revealed properties of the fluid flow through CNTs strongly different frome those predicted by classic hydrodynamics. For example, we found up that dependence of the fluid flow on the driving external force exhibits a threshold character. It means that there is a certain threshold value of the driving force below which the fluid does not flow tgrough the CNT and this value depends on the structure , number, and mutual orientation of the tube walls. For single wall CNT, a regular graphene structure of the wall provides a smaller threshold value of the driving force than that for CNT with the amorphous single wall. In addition, for CNTs surrounded by molecules of of polar liquid, the fluid flow through CNTs with two, three or four bounding walls is significantly higher than fluid flow through single - wall CNT.

MAGNETO- AND ELECTROACTIVE DEFORMABLE COMPOSITES

Rudykh S.[1,2]
1 - Department of Mechanical Engineering, Massachusetts Institute of Technology, USA
2 - Department of Aerospace Engineering, Technion – Israel Institute of Technology, Israel
rudykh@mit.edu

We investigate the coupled behavior of dielectric elastomer composites (DEC) and, mathematically analogous, magnetoactive elastomers (MAE) under electro- and magneto-mechanical loadings. We focus on the role of microstructures in the coupled response of these active materials. To this end we analyze the composites with (i) *periodically* [1] and (ii) *randomly* distributed active particles embedded in soft matrix [2], as well as (iii) layered composites [3,4] and similar anisotropically structured composites [5]. Through the theoretical analysis and through finite element simulations we identify the key parameters that govern the electro- and magneto- mechanical coupling. Furthermore, we investigate the stability of DEC and MAE. We study the role of the externalfield (electric or magnetic), microstructure parameters, and material properties on the onset of both microscopic and macroscopic instabilities. To determine the response of the multilayered structure to an external excitation and mechanical loadings, an analytical solution is derived. The determined from the exact solution local fields are used in the Bloch-Floquet analysis to predict the onset of microscopic instabilities [4]. The onset of macroscopic instabilities is identifed by analyzing the homogenized tensor of electro- or magneto-elastic moduli [3-5]. The results for global bifurcation modes agree with these of the limit of infinite wavelengths in the microscopic instability analysis [4].

The results are based on joint work with K. Bhattacharaya, K. Bertoldi, E. Galipeau, A. Lewinstein, G. Uner, P. Ponte-Castañeda, G. deBotton.

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AVERAGE CONVECTION IN ROTATING TILTED PLANE LAYER

Rysin K.Y., Kozlov V.G.
Laboratory of Vibrational Hydromechanics, Perm State Humanitarian Pedagogical University
8pspu@mail.ru

Thermal convection in an inclined plane layer rotating about an axis oriented perpendicular to the plane is studied experimentally. The threshold of convection excitation and the structure of supercritical flows depending on the angle of inclination, the temperature difference and the rotational speed are studied. The results are compared with the limiting cases of the rotational axis orientation.
The layer of thickness *h* with cylindrical lateral boundary is located on a table rotating at a predetermined speed around an inclined axis. Hydraulic distributor provides the circulation of liquid from the thermostats in the heat exchangers. Experiments are carried out on water and glycerol-water solutions.
In the experiments there are two limiting cases of the layer orientation: the horizontal ($\alpha=90^o$) and vertical ($\alpha=0^o$). For the horizontal orientation (the classical case) the results obtained are in good agreement with the theory [1] and experiments [2]. The increase of the dimensionless rotation velocity (Taylor number) leads to growth of stability threshold. In case of vertical layer orientation the convection is excited in a threshold way by the action of thermovibrational mechanism [3].
It is found that the change of the mechanisms of convection accompanied by changes of convective

structure and heat transfer takes place at *α~30º*. At lower angles of the layer inclination the thermovibrational mechanism [4] comes to replace the Rayleigh convective mechanism. In this case the gravity causes fluctuations of nonisothermal fluid in the cavity frame and generates the average vibroconvective flows.

The results of investigation of the quasi-equilibrium stability and heat transfer in the supercritical region are plotted against the dimensionless parameters: gravitational Rayleigh number, vibrational parameter and dimensionless rotation velocity. It is found that the excitation of average thermovibrational convection is possible at *α~0º* (heating of layer from the top).

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

Rzhavtsev E. A.[1], Gutkin M. U.[2,3,1]
1 - Department of Mechanics and Control Processes, St. Petersburg State Polytechnical University, Polytekhnicheskaya 29, St. Petersburg, 195251, Russia
2 - Department of LED Technologies, ITMO University, Kronverkskiy pr. 49, St. Petersburg, 197101, Russia
3 - Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, Bolshoj 61, Vasil. Ostrov, St. Petersburg, 199178, Russia
egor.rzhavtsev@gmail.com

The physical processes of grain refinement in polycrystalline metals and alloys under severe plastic deformation are now in focus of many experimental, theoretical and computer-simulation studies [1-4]. An effective way for theoretical description of these processes is the coupled two-dimensional dislocation-disclination dynamics which was used in past under conditions of quasistatic loading [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]. 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 create elastic fields which strongly affect upon edge dislocations being generated and gliding within the simulation box under a shear stress. We modeled the process of nucleation of subrains in the simulation box formed by these dislocations. If in the process of modeling the distance between the two dislocations becomes less than a critical distance, it is considered that the dislocations are annihilated. The main result of this modeling is that regardless of the disclination configuration, the dislocations form a number of stable subgrains (fragments) and the final structure obtained by the computer simulation (final size and type of grain) is visually similar to the structure observed in experiments [9, 10]. The shear stress ($\tau = 0.5$ GPa) at which dislocation structures formed also agrees with the experimental. This paper represents our further results in this field. We are working on to take into account 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 are expected to strongly affect the dynamics of all dislocations in the simulation box. We assume that this modification of the boundary conditions will make a significant impact on the final result in the case of finer initial subgrains, and will elucidate the model in the case of coarser initial subgrains.

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CONVECTION OF HEAT-GENERATING FLUID IN A ROTATING CYLINDER SUBJECTED TO TRANSVERSAL VIBRATIONS

Vjatkin A.A., Sabirov R.R., Kozlov V.G.
The Laboratory of Vibrational Hydromechanics, Perm State Humanitarian Pedagogical University
sabirov_r_85@mail.ru

The impact of translational vibration on the flow structure and heat transfer in a rotating fluid with internal heat sources is investigated experimentally [1]. In experiments, the parameters of rotation and vibrations, cavity dimensions and characteristics of the liquids are varied. The study is carried for the case of rapid rotation, which, in the absence of vibrations, causes the liquid in a state of stable mechanical equilibrium. Under the action of the centrifugal force the axisymmetric temperature distribution appears. Liquid on the axis of rotation becomes the most heated.
The experiments show that the vibration perpendicular to the axis of rotation can disturb the liquid in a quasi-equilibrium state if the frequencies of rotation and the vibrations coincide. At this condition the temperature at the center of the cavity decreases indicating the occurrence of the flows which carry the heat away from the center. The increasing of the heat sink depends on both the intensity of vibration and the speed of rotation. In experiments with visualization the plastic particles having a density less than the density of the liquid are used. At significantly different frequencies of rotation and vibrations under the action of centrifugal inertia force the visualizing particles are clustered near the cavity axis. As the frequencies coincide the particles are addicted by the intense convective currents and arranged in the form of the column along the entire length of the cavity at a certain distance from the axis. The distance between the axis and the particles increases with the amplitude of vibration.
The heat transfer in the convective region strongly depends on the difference between the frequencies of vibration and rotation. Although the width of this area is quite small, the heat transfer curve has a complicated form.
It is demonstrated that transversal vibration of rotating cavity with frequency coinciding with the frequency of rotation results in production of an effective average force field in the cavity frame [2]. This field is analogous to the gravity. It is shown that in the development of the convection a key role belongs to the centrifugal and this novel vibrational mechanism. The results of the research are generalized in the plane of the control parameters – vibrational and centrifugal Rayleigh numbers.

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FINITE ELEMENT METHOD FOR SOLVING BOUNDARY VALUE PROBLEMS OF BENDING OF MICROPOLAR ELASTIC THIN BARS

Sargsyan S.H., Zhamakochyan K.A.
Gyumri State Pedagogical Institute
s_sargsyan@yahoo.com

Currently finite element method (FEM) is widely used to solve problems of continuous media mechanics. This is explained by wide versatility of the FEM and possibility of representing the most complex structures by finite elements of a simple configuration. The method is very useful when computer is used, as all of its algorithms are written in matrix form.
Mathematical model with functional of potential energy of deformation of micropolar elastic thin bars is constructed in papers [1-2].
In the present paper the finite element method is developed to solve specific problems of determination the stress-strain state of bending deformation of micropolar elastic thin bars with different boundary conditions, which is implemented on personal computer. On the basis of the numerical results effective manifestations of micropolar materials in terms of strength and rigidity characteristics are discussed.

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ROUGHNESS AND WEAR OF SINTERED NANOMATERIALS PRODUCED BY HOT ISOSTATIC PRESSING (HIP)

Sayah T.
Faculty of Mechanical Engineering and Process Engineering, BP 32 El-Alia, Bab Ezzouar, Algiers 16111, Algeria
sayahtahardz@yahoo.fr

We propose an experimental study of the surface to dry and analysis of the evolution parameters roughness. The simplified model was proposed to predict the metrological parameters in the contact area of the deformed surface. The model is based on the analysis of the topography 3D of the deformed surface.
The hot isostatic pressing (HIP) is the only process that will develop fully dense samples, From Fe,Cr,Mo,Ni,Ti,W powder. This sample is hot pressed at 1500°C under 150Mpa of argon pressure. Moreover, the grain size of the consolidated samples was analyzed by SEM, ABSD and optical microscopy.
Study aims to characterize the topography of sintered materials obtained by wear tests. Therefore it is interesting initially in the evolution of wear for the loads applied and to characterize the different roughness emerging from 3D AFM observations.
Experimental and theoretical research on the topography changes during dry contact deformation was carried out, providing results that demonstrate the persistent nature of roughness asperities even under high loading when bulk plastic deformation appears. Most theoretical investigations of the problem have been based on a simplified model neglecting the statistical distribution of asperities on the real surface. Used test and 3D measurement of surface topography in order to investigate its frictional behaviour. The mechanism of contact of a rigid plane with a rough surface in the presence of a lubricant is different than in the case of dry contact. The topography of the samples was measured both in initial undeformed and in the deformed state after removal of the load. In these states, however, a change of the shape of the samples when compared to the initial state was observed. Thus, prior to the determination of roughness parameters of the deformed surfaces, their curvature was removed using a filtration procedure.
The essential differences in surface topography of samples loaded in dry condition are confirmed in the analysis of roughness parameter evolution. The following 3D parameters were considered:
In the unloaded state, flattened asperities can be observed on the deformed surface. The real contact area corresponding to the maximal load attained in the surface compression experiment can be identified from measurement of the deformed roughness after unloading.
The identification of the real contact area was carried out using a special algorithm based on single profile analysis, were extracted from the measured topography of the deformed surface. It should be noted that the profiles obtained in this way have a common reference level. The selected profiles also have the same direction, which, in the case of anisotropic surfaces (turning, grinding) should be perpendicular to the direction of the movement of the machining tool.
The wear and surface roughness based on the parameters of dry friction tests were measured. This study suggested the optimal parameters of chemical composition, and analysis of the effects of alloying elements on surface roughness and wear in the process dry friction tests. The proposed model was applied to analyze a wear of four kinds of rough surfaces. The predicted values were compared with experimental results.

BEHAVIOR OF NEUTRAL BUOYANCY SOLID IN CAVITY WITH LIQUID UNDER ROTATIONAL VIBRATION

Kozlov V.G., Schipitsyn V.D.
The laboratory of vibrational hydromechanics, Perm State Humanitarian Pedagogical University, Perm
schipitsyn@mail.ru

The hydrodynamic interaction of a solid cylindrical body of circular cross section with the cavity walls, which is the annulus with a barrier under high-frequency rotational vibrations around its axis are experimentally studied.Technique and experimental setup as described in [1]. The difference between the body and liquid densities is small and varies: the experiments are carried with both «light» and «heavy» cylinders. During the experiments, the non-dimensional frequency and amplitude of vibration are varied.
It was found that with the increase in the intensity of vibration the bodies are repelled from the borders of the cavity in a threshold way (the light – from the ceiling, the heavy – from the bottom).It is shown that the effect of the body levitation is connected to the excitation of the repulsive force acting at a distance comparable with the thickness of the Stokes layer and monotonically decreasing with distance. Further intensification of the vibrations leads to a heavy cylinder transition to the ceiling of the cavity. Similar transition of the light solid to the bottom of the cavity does not take place in the entire investigated range of non-dimensional frequency of vibrations. Reverse transitions of the body occur in a threshold manner with decreasing frequency of cavity vibrations.
It is shown that the transitions of solid obtained for different values of the angular amplitude of the oscillations of the cavity are in a good agreement on the plane of the non-dimensional parameters. However, value of the vibrational lift force in thresholds of the body repulsion is higher, than in the experiments with more densely bodies under rotational vibrations [2], where the effect of levitation has been associated with inertial oscillations of the body relative to the fluid. It is concluded that the shear fluid oscillations, related to the nonlinear character of oscillations of the cavity play important role in the generating of the averaged lift force acting on the solid of neutral buoyancy near the walls.
The study of the nature of translational and rotational oscillations of the body, as well as its interaction with the boundaries of the cavity performed using high-speed videorecording.

The considered effects are of great interests to vibrational control of solid inclusions in viscous liquids and in vibrational methods of liquid cleaning.

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IMPACT OF PLASMA JET ON TUNGSTEN BARRIER. EXPERIMENT AND SIMULATION

Semenov B.N.[1], Sudenkov Yu.V.[1], Voronin A.V.[2]
1 - Saint Petersburg State University, Saint Petersburg 199034, Russia
2 - Ioffe Physical Technical Institute, , Saint Petersburg 194021, Russia
semenov@bs1892.spb.eu

There are presented the results of investigations of the destruction in the vicinity of the surface of tungsten barriers as a result of exposure to it pulsed plasma jet.
The results of experimental studies show that the degradation of tungsten barrier when exposed to the plasma jet energy flux density 0,25 ÷ 1 MJ/m2 accompanied not only by evaporation and surface melting , but the destruction of the surface layers on the scale of the order 150-250 μ m. In this case the process of degradation of tungsten at exposure of plasma jet occurs almost continuously from the moment of impact (evaporation, melting) until the time by more than three orders of magnitude greater than the duration of exposure , and this is due to thermo-mechanical processes in the target.
For the analysis of thermomechanical processes occurring in solid samples as result of fast plasma jet exposure is proposed a finite element model and the results of numerical modeling of thermomechanical processes in the tungsten barrier during pulsed plasma jet exposure are given. The dependence of stress-strain state in the barrier on time and influence of the shape of the heat pulse on the distribution and level of residual stresses are investigated. An estimate of the depth of degradation of the surface layer is obtained. Results of the finite element analysis are compared with experimental results.

NUMERICAL SIMULATION OF AIR FLOW IN MINE WORKINGS USING WALL ROUGHNESS FUNCTIONS

Levin L. Yu., Semin M. A., Zaitsev A. V.
Perm Mining Institute, Aerology and Thermal Physics Department
mishkasemin@gmail.com

In recent years, computer modeling became a substantial part in process of mine ventilation system design. Many composite elements of mine ventilation systems require computer modeling in order to determine complex airflow distribution in fan drifts in mine shafts, in mine workings coupling, conditioning air circuits etc. Due to complexity of today's mine ventilation networks and strict safety requirements numerical simulation became the best way to predict fields of air velocity, temperature and gas concentration in ventilation networks.
Mine ventilations problems have an essential peculiarity – the wall roughness effects are considered to be predominating. For this reason it is necessary to take into account the wall roughness effects. Existent turbulence models are usually applied for smooth walls and give only one law-of-the-wall function modified for roughness.
This research is about determination of applicability of existent law-of-the-wall function for problems of mine ventilation. A turbulent flow through the rectangular conduit is considered. Navier-Stokes equations combined with standard K-Epsilon turbulence model were used. A set of numerical calculation in ANSYS Fluent package is presented. As a result we give a comparison with experimental measurements in "Norilsk nikel" mines and results of other numerical models of mine air distribution determination.

INVESTIGATION OF THERMOPLASTIC MATERIALS ELASTIC-VISCOUS-PLASTIC BEHAVIOR. EXPERIMENT AND SIMULATION

Garishin O.K., Shadrin V.V., Korlyakov A.S.
Institute of Continuous Media Mechanics UB RAS
shadrin@icmm.ru

Polymer materials capable of reversibly pass when heated into highly elastic and further the viscous state that enables the molding of a large variety of products called thermoplastics. These transitions are reversible and can be repeated, which allows, in particular, to process its domestic and industrial waste from thermoplastics in new products. Polyethylene is a main industrial product of this class of materials, both in pure form and with the various grades of fillers. This is partially crystallized polymer, that is, it even pure is structurally heterogeneous at the nano and micro level. Polyethylene has a complex mechanical behavior, demonstrating well-defined elastoplastic and viscoelastic properties. This work is devoted to experimental and theoretical study of these properties.

In order to obtain in a single experiment all necessary experimental data on the elastic-visco-plastic behavior of the polymer the appropriate methodology based on the sample cyclic deformation was developed: 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 parameters for a phenomenological model.

The model is based on a differential approach to the construction of constitutive equations of material mechanical behavior with the help of symbolic schemes and uses mathematical apparatus of mechanics of nonlinear finite deformations. The symbolic model schema consists of two parallel branches containing two serially connected elements: a) the elastic (1) and plastic (3), b) the elastic (2) and viscous (4). Elastoplastic branch simulates the behavior of agglomerates of more rigid crystallites, their displacement and destruction during the deformation. Viscoelastic branch describes the flow of the amorphous polymer between the lamellae inside the crystallites and in the space around the crystallites and particles. As shown by known experiments, these processes occur almost independently, and that was the rationale for the choice of the scheme.

Experimental data obtained for grade polyethylene PE 107-02K, were theoretically treated using this model. Calculations showed that the rigidity of the elastic element ("plastic" branch) first sharply decreased and then began to grow again (but with less intensity). Initial fall can be explained by the destruction and re-orientation of crystallites in the structure of PE, and after a slight increase was due to the development of plastic orientation processes, and possibly the formation of new crystallites. The stiffness of the second elastic element ("viscous" branch) was constant. Upon loading up to $\lambda < 1.2$ (λ stands for elongation ratio) polymer material deforms elastically. Further plastic flow begins, and at values approximately $\lambda = 1.8$ deformation of the sample became purely plastic. As for viscosity versus strain, it increased monotonically over the entire range of loading.

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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NEW CASES OF INTEGRABILITY IN MULTIDIMENSIONAL DYNAMICS IN A NONCONSERVATIVE FIELD

Shamolin M. V.[1,2]
1 - Lomonosov Moscow State University
2 - Institute of Mechanics
shamolin@rambler.ru

Study of the dynamics of a multidimensional solid depends on the force-field structure. As reference results, we consider the equations of motion of low-dimensional solids in the field of a medium-drag force. Then it becomes possible to generalize the dynamic part of equations to the case of the motion of a solid, which is multidimensional in a similarly constructed force field, and to obtain the full list of transcendental first integrals. The obtained results are of importance in the sense that there is a nonconservative moment in the system, whereas it is the potential force field that was used previously.

In this activity the results are systematized both certain published earlier and obtained new on study of the equations of the motion of dynamically symmetrical multi-dimensional rigid body which residing in a certain nonconservative field of the forces. Its type is unoriginal from dynamics of the real lower-dimensional rigid bodies of interacting with a resisting medium on the laws of a jet flow, under which the nonconservative tracing force acts onto the body.

Previously, the author showed the complete integrability of the equations of body planeparallel motion in a resisting medium under the conditions of streamline flow around when the system of dynamical equations has a first integral that is a transcendental (having essentially singular points in the sense of the theory of functions of one complex variable) function of quasi-velocities. At that time, it was assumed that the interaction of the medium with the body is concentrated on the part of the body surface that has the form of a (one-dimensional) plate.

Later on, the plane problem was generalized to the spatial (three-dimensional) case where the system of dynamical equations has a complete tuple of transcendental first integrals. It was assumed here that the whole interaction of the medium and the body is concentrated on a part of the body surface that has the form of a plane (two-dimensional) disk.

In this chapter the results which both were obtained earlier and now are pertained to the case when all the interaction of a medium with the body is concentrated on that part of the body surface that has the form of three-dimensional disk, herewith, the force interaction is concentrated in the direction which is perpendicular to this disk. These results are systematized and given in invariant form. Herewith, the additional dependence of the moment of the nonconservative force on the angular velocity is introduced. The given dependence can be wide-spread and on the cases of the motions in the spaces of higher dimensions.

EXISTENCE OF AN OPTIMAL SHAPE FOR THIN RIGID INCLUSIONS IN ELASTIC BODIES

Shcherbakov V.V.
Lavrentyev Institute of Hydrodynamics
sherbakov87@gmail.com

The talk is concerned with an optimal control problem for the system of equations that describes the equilibrium of an elastic body with a thin rigid inclusion. It is assumed that the rigid inclusion is delaminated, thus forming a crack. We consider the free boundary approach for modeling the phenomenon. To simulate the delamination, some nonlinear boundary conditions are used having the form of a system of equations and inequalities and providing mutual nonpenetration of the points of the elastic body and the inclusion. We introduce the cost functional, which characterizes the mean-square integral deviation of the boundary stress vector from a function defined on the exterior boundary. The shape of the inclusion is chosen as the control function. An incentive to studying the control problem is the inverse problem of identification for the shape of the rigid inclusion. The solvability of the optimal control problem is established.

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MODELS OF STRENGTH AND TOUGHNESS OF NANOSTRUCTURED MATERIALS AND GRAPHENE

Ovid'ko I.A.[1,2,3], Sheinerman A.G.[1,2,3]
1 - St. Petersburg State Polytechnical University
2 - St. Petersburg State University
3 - Institute for Problems in Mechanical Engineering
asheinerman@gmail.com

We consider the models describing the mechanical behavior of nanocrystalline, ultrafine-grained materials and graphene at high applied stresses. Within the models the effects of various mechanisms of plastic deformation of nanocrystalline materials on their fracture toughness are analyzed. We consider lattice dislocation emission from crack tips, rotational deformation, grain boundary migration and grain boundary sliding. We demonstrate that grain boundary sliding can be the leading mechanism that can increase fracture toughness of nanocrystalline materials.
We also consider experimental data on crack formation in polycrystalline graphene at comparatively low levels of the applied stress and their discrepancy with the results of computer simulations of strength exhibited by graphene bi-crystals with structurally perfect, periodic grain boundaries (GBs). To explain the discrepancy, we suggest a model describing the formation of cracks at GBs containing partial disclinations and their dipoles (associated with experimentally observed structural irregularities of real GBs in graphene) and demonstrate that these defects can be responsible for the brittle fracture of polycrystalline graphene at lower applied loads.
In consideration of the mechanical behavior of ultrafine-grained (UFG) alloys, we examine the experimental data on superstrength of such materials processed by severe plastic deformation and the formation of segregations at their GBs. We suggest models describing the emission of dislocations from GBs of UFG alloy and the formation of GB segregations. We also examine the micromechanisms responsible for the superstrength of the above UFG alloys.

The work was supported, in part, by the Russian Ministry of Education and Science (Grant 14.B25.31.0017) and St. Petersburg State University research grant 6.37.671.2013.

KEY FEATURES OF SHEAR (MODE II) CRACK PROPAGATION IN SUB-RALEIGH AND INTERSONIC REGIME

Shilko E.V.[1,2], Psakhie S.G.[1,3]
1 - ISPMS SB RAS
2 - Tomsk State University
3 - Tomsk Polytechnic University
shilko@ispms.tsc.ru

The question about physically admissible velocity of dynamic crack growth is of significance to safety engineering as well as to earthquake dynamics. Recent researches including numerical simulations, experimental observations and the analysis of strong earthquakes have shown a possibility of propagation of shear cracks in supershear regime, namely at velocities comparable with dilatational wave speed. The presentation is devoted to the results of theoretical study of some fundamental aspects of shear crack propagation in conventional sub-Raleigh regime and transition to intersonic regime. The study was carried out by means of movable cellular automaton (MCA) based numerical simulation. Mode II crack propagation through the relatively weak interface between two high-strength elastic-brittle plates was modeled.
Simulation results have shown that development of a sub Raleigh shear crack is connected with a vortex traveling ahead of the crack tip at a shear wave velocity. The stress concentration area ahead of the crack tip revealed by different authors (Burridge, Andrews, Geubelle, Rosakis and others) is connected with the central part of the vortex. Being nucleated the vortex

becomes self-dependent dynamic defect which develops of one's own rules. Since the vortex propagates faster than crack, it gradually moves away from the crack tip, and this provides conditions for formation of a new vortex. Finally the shear crack propagating in sub-Raleigh regime generates chain of vortices moving ahead of the tip at transverse wave velocity. The main feature of these vortices is concentration of shear stresses in their core regions. In real (elastic-plastic) materials propagation of a chain of elastic vortices ahead of the growing crack will provide quasi-periodic (wave) regime of inelastic deformation of the space ahead of the crack tip.

Acceleration of a shear crack towards the longitudinal wave velocity is concerned with formation of a daughter crack by the mechanism of shearing. This daughter crack is nucleated in the center of vortex by the mechanism of shearing. In such a case elastic energy is transferred ahead of the daughter crack mainly by dilatational wave. This provides the condition of further propagation of crack at higher velocity values up to P-wave speed. Analysis of sub Raleigh to intersonic transition confirmed that development of shear cracks is self-similar and therefore conditions of such transition has to depend on dimensionless material and geometric parameters. Two key dimensionless parameters are proposed.

APPLICATION OF ACOUSTIC EMISSION TO MONITOR DAMAGE MECHANISMS OF CARBON COMPOSITE MATERIAL

Shilova A. I., Wildemann V. E., Lobanov D. S.
Perm National Research Polytechnic University
cem.shilova@gmail.com

Studying of material behavior during its use is an important question in design of products and structures. Nowadays, applications of special methods of control which allow to get more information about processes occurring in the material during its loading are gaining ground. The acoustic emission method falls into this category. Specificity of the method is that it makes quantitative assessment of damage accumulation possible. Application of the acoustic emission method during mechanical tests of composite materials has been considered in [1-6].

This work is devoted to the study of the carbon composites fracture kinetics base on the analysis of acoustic emission signals. The mechanical tensile and compression tests on the flat specimens made of carbon composite material are carried out by using the electromechanical system Instron 5882 and advanced non-contacting video extensometer (AVE) Instron to measuring axial deformation [7]. The acoustic emission monitoring is applied during experiments by measurement system Vallen AMSY- 6. The peak amplitude, the energy parameter and the damage parameter are selected as main parameters of the acoustic emission signals. The damage parameter is introduced by summation of energy parameter to analyze the degree of defect accumulation in the material [8]. Prior to testing, the synchronization of acoustic emission measurement system with the mechanical test machine and the advanced non-contacting video extensometer was done.

As result, the loading diagrams and the acoustic emission characteristics versus displacement curves are constructed. The waveform and spectral distribution diagrams of some registered signals are plotted. According to these data, the analysis of materials behavior during loading are carried out. The analysis is indentified the stages of damage accumulation in material. There by, defects growth in the material begins long before reaching the ultimate load. At the time of composite destruction the fast increase values of energy parameter and peak amplitude is registered. The question of determining the fracture stages on the distribution of the characteristic of acoustic emission signals, as well as correlating them with the spectral characteristics of the basic mechanisms of composites fractures during tensile and compression tests.

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CONTACT ELASTIC BODIES WITH TAKING INTO ACCOUNT THEIR ADHESION

Romashin S. N., Frolenkova L. Yu., Shorkin V. S.
State University – Education-Science-Production Complex
Larafrolenkova@yandex.ru

Contact problems of adhesive interaction of two elastic bodies viewed in several works (Johnson K., Kendall K.L. and Roberts A.D. - model JKR; Derjaguin B.V., Muller V.M., Toporov Y.P. - model DMT; Maugis D.; Goryacheva I.G., Makhovskaya Yu. Yu.). They believed that near the surface of each bodies (outside) on the particles of the other body action potential exist adhesion forces. Their action is balanced by the action of internal elastic forces compression of the material. To carry out the calculation of the stress and strain of the material, you need to know the potential distribution of the force field, the surface energy of the creating body.
The method of determining the type and parameters of the potential force field near the free surface of a solid was offered. It is based on a continuous version of the model of an elastic medium. At the heart of this version is the supposition multiparticle potential nonlocal interaction infinitely small particles, which forms the medium.

NONLINEAR DYNAMICS OF MECHANICAL SYSTEMS PLACED IN QUASI-STATIONARY MAGNETIC AND ELECTRIC FIELD

Skubov D.Yu.[1,2], Berinskii I.E.[1,2], Indeitsev D.A.[1,2], Privalova O.V.[1], Shtukin L.V.[1,2]
1 - SPbGPU
2 - IPME RAS
skubov.dsk@yandex.ru

This article is devoted to solution of some new engineering tasks of a nonlinear dynamics of conductive and ferromagnetic solids placed into quasi-stationary magnetic and electric fields. These solutions are carried out by methods of the theory of nonlinear oscillations, in particular, by the asymptotic method. Additionally, some of nonlinear equations were solved using numerical methods for stiff systems of differential equations. These analytical and numerical solutions were checked by real physical experiments as far as possible. Also these experiments open the possibility of creating new electromechanical mechanisms with necessary dynamical characteristics.
The first task of this study is to obtain experimentally quasi-stationary magnetic field in some electromechanical systems. The obtained field distribution is compared with the numerical simulations qualitatively. The field distribution allows to find the pondero-motive forces as the functions of the generalized coordinates. The corresponding La-grange-Maxwell equations are derived and solved analytically and numerically. In some cases the asymptotical solution is possible using the methods of separation of the motions, in particular, the averaging method.
The approach proposed above is used to investigate some physical and engineering tasks. A nanoresonator based on graphene layers is considered as an electromechani-cal system. This system can be used as an ultraprecise mass sensor. Two different ways to determine the spectral characteristics changing this system are proposed. The first one is based on the jump of the stationary nonlinear characteristics. The second one is based on modulation of the beating oscillations.
Another task it is a construction of a new electrical vibro-impact machine. The improve-ment of such mechanism is based on a combination of permanent and controllable electromagnets.
Also, a new method of the overcoming of critical frequency of an unbalanced rotor is proposed. This method uses the displacement of the magnets for rapid change the stiffness of the support. A new way of cooling of the high-ampere alternating current conductor through autonomous oscillations of a suspended conductive plate is proposed.

SEALING APPLICATION OF ELASTOMER COMPOSITES BASED ON FILLERS WITH NEGATIVE THERMAL EXPANSION COEFFICIENT

Shubin S.N.[1,2], Freidin A.B.[1,3,4]
1 - Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg, Russia
2 - FMC Technologies, St. Petersburg, Russia
3 - Saint-Petersburg State Polytechnical University, St. Petersburg, Russia
4 - Saint-Petersburg State University, St. Petersburg, Russia
shubinsn@gmail.com

We consider elastomer composites with fillers made of a material with a negative coefficient of thermal expansion (CTE). Such fillers provide opportunities for creation of composites exhibiting remarkable thermo-mechanical behaviour without modifications of elastomers which could impair their chemical resistance and ageing properties. It is especially relevant to sealing applications in structures operated at low temperatures.

The point is that CTE of rubber is roughly an order of magnitude higher than that of steel. Due to this the contact pressure at the contact surface between the sealing and mating steel may dramatically decrease if the temperature drops. This in turn leads to forming leak paths for contained fluids like hydrocarbons.

The aim of the present research is to develop a composite with a proper CTE, such that the contact pressure produced by the sealing will not be lost even at low temperatures. Wide range of volume fractions and shapes of fillers with negative CTE is examined with use of self-consistent and finite element methods. The following questions are discussed:

1. How the volume fraction and shape of fillers with negative CTE affect the effective coefficient of thermal expansion and effective elastic moduli of the composite?
2. How contact pressure produced by the sealant depends on temperature, volume fraction of particles with negative CTE and material parameters?
3. What are local stresses in such composites?

INVESTIGATION OF THE STABILITY POLYMER PLATES AT BULKING

Shumova M.A., Manukhin B.G., Andreeva O.V., Chivilikhin S.A.
Saint Petersburg, Kronverkskiy pr., 49, 197101, Saint Petersburg, Russia
maria.shumova2010@yandex.ru

Consider the behavior of rod susceptible of longitudinal compressive forces. Define critical squeezing force for the rod.

KELVIN – HELMHOLTZ TYPE INSTABILITY ON A CENTRIFUGED LIQUID–LIQUID INTERFACE

Shuvalova D.A, Kozlov N.V., Kozlova A.N.
PHSPU
das69@inbox.ru

The interface of two immiscible liquids of different density in a rotating cylindrical container is studied experimentally. The dynamics is considered under external force action, periodic in the cavity frame. In experiments, liquids of various viscosity were used, the relative volume of filling was varied. Stroboscopic light was applied for observation and for measurement of rotation frequency. Light tracers, that settled on the interface in the light liquid, were used for the interface velocity measurement.

At sufficiently fast rotation of the container, the liquids are centrifuged. The angular velocity of the inner liquid is less than cylindrical cuvette rotation rate. The column of the light liquid undergoes a radial displacement (stationary in the laboratory reference system) due to gravity action, the vector of which rotates in the cavity reference system. However, the column performs circular inertial oscillations in relation to the cavity (i.e. in the rotating system of reference). As a consequence, the tangential oscillations of the liquid near the interface lead to the generation of a mean vibrational mass force in the viscous Stokes layer. This force is oriented tangentially and excites the average differential rotation of the fluid. Meanwhile, the cross section of the light liquid column keeps the form of a circle.

With the decrease of the cavity rotation velocity, a small (slow) increase in the intensity of liquids interface differential rotation is observed. In a threshold way, wave excitation on the interface occurs, similar to Kelvin – Helmholtz instability. The axial symmetry of coaxial liquid layers is broken, on the boundary of the liquid column the crests are formed extended parallel to the cavity rotation axis. The direction of motion of the liquid relative to the cavity coincides with the direction of the azimuthal wave propagation. In the research the waves with azimuthal wave numbers from 2 till 5 were observed. The further decrease of the cavity rotation velocity leads to the nonlinear increase of the wave amplitude and is accompanied with a non-stationary mode, auto-oscillations take place.

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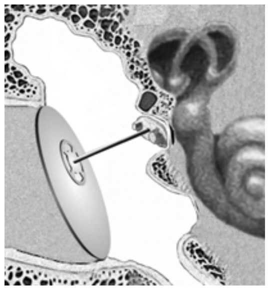
ANALYSE OF NATURAL FREQUENCIES OF RECONSTRUCTED MIDDLE EAR AFTER TYMPANOPLASTY AND STAPEDOTOMY

Slavashevich I.L., Mikhasev G.I., Urkevich K.S.
Belarusian State University
slavashevichi@yandex.ru

Introduction. The normal middle ear consists of the tympanic membrane (TM) and sound-conducting ossicular chain (malleus, incus and stapes). The eardrum is of great importance in the mechanics of sound conduction. Coming from outside the ear canal sound wave excites oscillations of the eardrum, which in turn sets in motion a chain of auditory ossicles. Limited mobility of the ossicles or otosclerotic ankylosis may results in partial or total fixation of one of the ossicles and, extremely, the stapes. Medical treatment for this pathological disease is the surgical operation of the middle ear. This procedure is often subdivided into two stages, namely, tympanoplasty and stapedotomy. Tympanoplasty is the surgical operation performed to repair the tympanic membrane after perforation or rupture by using cartilage transplants. Stapedotomy implies a perforation of the stapes footplate if it is absolutely fixed by bone growth around the oval window. The total ossicular replacement prosthesis (TORP) is used to bridge a gap in a completely destroyed ossicular chain [1]. In this case, the base of the TORP rests at the reconstructed TM and the end of its shaft is inserted into the cochlea of the inner ear through the hole in the stapes footplate [1, 2]. The singularity of the stapedotomy surgery is that the functional result strongly depends on the choice of the perforation place at the footplate [3]. If the place of drilling is selected to the point of maximum thickness, the mobility of the prosthesis may occur extremely limited (see Fig.1. a). Furthermore, one of the negative consequences of stapedotomy is lowering the total stiffness of the whole system as well as the distortion of the spectrum of natural frequencies of the vibrating system of the reconstructed middle ear (RME). In addition, for this reconstruction the results depends on the physical and geometrical characteristics of the prosthesis and cartilage transplant [4].
This study relates to the case when the middle ear subjected to tympanoplasty and stapedotomy. The perforation is performed in a place where the thickness of the stapes footplate is maximum and the prosthesis has one degree of freedom (see Fig.1. b). The basic goal of this study is to analyze the natural frequencies depending on the geometrical and physical parameters of the cartilage transplant and prosthesis. Another purpose is to clear up the influence of a position of the prosthesis at the eardrum on the natural frequencies.


a)

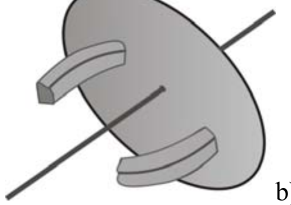

b)

Fig. 1. The cross-section of the reconstructed middle ear (a);

The prosthesis shaft entered into the hole in the footplate (b)

Mathematical model. The RME consists of the reconstructed eardrum and prosthesis like TORP. In the simplified mathematical model the reconstructed TM may be modeled as thin circular plate made from cartilage. However, applying the FEM approach, we will consider the real sizes of the eardrum closed to the ellipse. The TORP is considered as a straight absolutely rigid rod inclined to the non-deformable plate with some angle. As shown in [3], the most preferable technique for installing the prosthesis is such a way when the base of the prosthesis is placed at the reconstructed TM as close to its center as possible. We consider here the case when the centers of the TM and prosthesis base are coinciding, though its location will be any when applying the FEM simulation.

Small normal deformations of the elastic isotropic annular plate modeling the reconstructed TM is governing by the system of differential equations with respect to the normal and tangential displacements [5]. When studying free vibrations, these equations contain the inertial terms as well as the additional terms which take into account the initial stresses induced by action from the prosthesis. For this stapedotomy technique prosthesis can perform only translational displacement and the longitudinal oscillations along the perforation axis. In the static and dynamic cases, the force acting from the cochlea liquid is taken into account. This force is generated by the strained membrane of the round window.

Initial strain-stress state. The differential equations of the reconstructed TM, based on the theory of thin isotropic circular plate, were used as the governing ones. When the TM was assumed to be circular, the analytical solution was constructed in the closed form; if not, the finite element analysis based on the software ANSYS was applied. The comparison of results obtained by different methods has shown the good coincidence in the estimation of initial stresses appearing in the reconstructed TM after inserting the total prosthesis.

Free vibrations. The eardrum motion is governed by the system of three differential equations written in terms of normal and tangential displacements taking into account the initial stresses. The analysis of the initial stresses induced by installation of the prosthesis has confirmed the conclusion made by Wullstein [2] about very low total stiffness of the whole vibrating system of the RME subjected to stapedotomy. Assuming smallness of the initial stresses in the TM, the governing equations for the pre-stressed reconstructed TM were solved by using the asymptotic method. If the initial stresses are not small, the finite element approach was utilized to predict the natural frequencies. The influence of the geometrical parameters of the prosthesis and a thickness of the cartilage transplant as well on eigenfrequencies has been examined. As shown, the initial stresses in the tympanic membrane ensuring fixation of the prosthesis in the middle ear cavity result in decreasing the lowest frequency and increasing consequent frequencies of the system free from initial stresses.

The qualitative analysis of the results has shown that the natural frequencies depend strongly upon the position of the prosthesis at the eardrum.

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A TECHNIQUE FOR DETERMINING THE "STRESS-STRAIN" DIAGRAM BY NANO-SCRATCH TEST RESULTS

Smirnov S.V., Smirnova E.O
Institute of Engineering Science, Russian Academy of Science (Ural Branch)
svs@imach.uran.ru

A technique has been developed for determining coefficients in the power approximation of the "stress-strain" diagram by results of scratch testing with a Berkovich indenter under a normal load of 5 mN on the indenter. The procedure is based on a comparison of experimental results with the finite element simulation of the test process. The technique is intended for application on nanomechanical testing equipment enabling one to perform tests with recording of loading diagrams in terms of the "normal force – indenter displacement" coordinates. To obtain correct results, one must observe the following restrictions: indenter penetration depth greater than 150 nm at a loading of 5 mN with the indenter tip curvature radius R< 50 nm; indenter penetration depth greater than 250 nm with 50 <R< 100 nm; the test metal must be ductile to resist fracture while being tested.

Acknowledgements
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CHARACTERIZATION OF TWO-PHASE MATERIAL BY NANOINDENTATION

Veretennikova I.A.[1], Smirnova E.O.[1], Zybkova T.A.[2], Yakovleva I.L.[2], Karkina L.E.[2]
1 - Federal goverment-financed science organization Institute of Engineering Science of Ural Branch of Russian Academy of Sciences
2 - Federal goverment-financed science organization Institute of Physics of Metals Ural Branch of Russian Academy of Sciences
evgeniya@imach.uran.ru

One of the problems of the mechanic of multiphase material is finding of the mechanical properties of separate components. This problem can be resolved by nanoindentation method with the use of a Hysitron TriboIndenter TI 950 commercial instrument. This equipment is ideal for nanoindentation (measuring Young's modulus, hardness, fracture toughness and other mechanical properties) and scratch testing (quantifying scratch resistance, critical delamination forces, friction coefficients etc. with the simultaneous monitoring normal and lateral force and displacement). There are studied on the mechanical properties of two-phase carbon tool steel C 80W2 after different degrees of strain. The results on Young's modulus and hardness of cementite are presented. It is established that, for cementite, both characteristics change no in monotonically with the growth of the amount of deformation. The results are compared with the electronic and microscopic data on the evolution of the deformation structure of granular perlite.

The research was supported by the Russian Foundation for Basic Research, grant "RFFI-URAL" No 14-08-31262.

MECHANICAL PROPERTIES OF EPOXY PRIMER WITH SILICON DIOXIDE NANOPARTICALS AT THE MICROLEVEL

Smirnova E.O.[1], Smirnov S.V.[1], Veretennikova I.A.[1], Fomin V.M.[2], Bolesta A.V.[2]
1 - Federal goverment-financed science organization Institute of Engineering Science of Ural Branch of Russian Academy of Sciences
2 - Federal goverment-financed science organization Khristianovich Institute of Theoretical and Applied Mechanics of Siberian Branch of Russian Academy of Sciences
evgeniya@imach.uran.ru

A promising trend increasing the performance, power, operating life and reliability of electric machines is to utilize a modifying addition agents of various nature in a composite consisting of an oligomeric base and a hardener causing polymerization of the basis. Epoxy primers with silicon dioxide nanoparticals is a promising class of materials combining the advantages of the matrix and the nanofiller. Theoretical calculations of the mechanisms modifying the strength and elastic properties of polymeric materials with nanodimensional powders are carried out by methods of the molecular dynamic. However, these methods are losing its advantages at the micro- and meso-scale levels. The application of the mechanics of continua to investigations at these levels is an effective way. The methods of the mechanics of continua need empirical information in the form which can be used for calculations. For polymers, it is elastic, viscous and plastic characteristics and their time dependences. In this work using a Hysitron NanoTriboindentor TI 950 nanomechanical complex, the mechanical properties of an epoxy primer with silicon dioxide have been studied at the micro-scale level. The analysis of experimental data shows a functional relationship among loading, loading time, hold time and displacement. The result obtained in this study can be used for the optimization of existing manufacturing processes and making models for behaviour prediction under actual conditions.

The financial support is from the collective project SR RAN and UB RAN № 14-C-1-1033.

GENERATION OF RECTANGULAR PRISMATIC DISLOCATION LOOPS IN COMPOSITE NANOSTRUCTURES

Gutkin M. Yu.[1,2,3], Smirnov A. M.[3]
1 - Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics
2 - Institute of Problems of Mechanical Engineering Russian Academy of Sciences
3 - Saint Petersburg State Polytechnical University
smirnov.mech@gmail.com

For today, production and applications of nanoparticles, nanowires and nanolayers is one of the most promising areas of nanotechnology. Electronic, magnetic and optical properties of such nanostructures depend on their shape, size, chemical composition, crystal lattice type and presence of various defects. In particular, great attention is attracted to composite nanostructures [1-7] which are composed of different materials and find many applications in modern optoelectronics, photonics, spintronics, solar cells, sensors, data storage and transfer devices, catalysis, medicine, etc. Due to contacts of different materials, the composite nanostructure are the subject of residual (misfit) elastic strains and stresses which can relax through generation of various defects [8,9]. These defects can lead to degradation of electronic, optical and other functional properties of composite nanostructures, which explains a special interest to this problem. One of expectable mechanisms of this relaxation is generation of prismatic dislocation loops (PDLs).

In the present work, we considered the energetics for generation of rectangular PDLs in core-shell nanoparticles and nanowires, and in planar two- and three-layers. With the assumptions that these nanostructures are elastically isotropic and homogeneous, we derived strict analytical solutions for the energy changes accompanied the PDL generation on either core-shell (film-substrate) interface or outer shell (film) surface, and compare these cases in terms of critical misfit parameters with account for the PDL shape. We considered the following three characteristic shapes for the PDLs: (i) extended along the interface (AI-loop), (ii) square (S-loop), and (iii) extended normally to the interface (NI-loop). It was shown, that the AI-loops are the most preferable for all considered nanostructures. At the same time, PDL generation from the free surface is more favorable. On the other hand, it is more profitable from the core-shell (substrate-film) interface than from the shell (film) free surface for NI- and S-loops, and vise versa for AI-loops. Finally, we showed that hollow core-shell nanoparticles are the most stable nanostructures against PDL generation.

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COMPARISON OF ANALYTICAL AND NUMERICAL SOLUTIONS FOR A PROBLEM OF THIN BODY MOTION IN GAS NEAR RIGID SURFACE

Smirnova M.N., Zvyaguin A.V.
Department of Mechanics and Mathematics Moscow M.V. Lomonosov State University, Russia Moscow
119992 Leninskie Gory 1
wonrims@inbox.ru

The two-dimensional problem of thin body motion in gas parallel to the boundary at a distance, comparable with the length of the body, is regarded. The lift force of thin body moving parallel to rigid surface is determined and compared with the obtained numerical solution. The analytical solution is determined under the assumption of fluid being ideal and compressible. The Chaplygin-Zhukovsky hypothesis of rear-edge-limited solution is taken into consideration.

The analytical solution of a problem is first reduced to singular integral equation and then to the Fredholm equation. The generalization of Zhukovski solution was obtained, which provides the lift force dependence on the altitude of the flight. The lift force increases on decreasing altitude above the rigid surface. The screen effect becomes essential on moving wing altitude being smaller than the wing's length. The effect was detected experimentally before and gave birth to construction of a special flying vehicle named "ecranoplan".

The numerical solution is obtained using the method of boundary elements. The comparison of lift force dependence upon the altitude between the numerical and analytical solutions is done. Streamlines and the distribution of the velocity along them are shown in case of a plate moving on different altitudes and with different inclination angles.

INTERRELATION BETWEEN THE RHEOLOGICAL BEHAVIOUR OF THE AL-MG-SC-ZR ALLOY AND THE FORMATION OF MICROSTRUCTURE UNDER HIGH-TEMPERATURE DEFORMATION

Smirnov A.S., Konovalov A.V.
Institute of Engineering Science, Russian Academy of Science (Ural Branch)
smirnov@imach.uran.ru

The paper deals with the interrelation between the rheological behaviour of the Al-Mg-Sc-Zr alloy and microstructure formation at a deformation temperature of 330 and 360 $^\circ$C and a strain rate of 0.05 s^{-1}. It has been found that the strain resistance curve for this material consists of a number of portions. First there is material hardening, then softening and again hardening. The application of the electron backscatter diffraction technique (EBSD) and the use of transmission electron microscopy (TEM) has elucidated that the *in situ* dynamic recrystallization is the main process of softening at the temperatures studied. The appearance of the second portion of hardening on the strain resistance curve results from inhibited dynamic recrystallization and the barrier effect of blocking free dislocations, grain and subgrain boundaries by intermetallics.

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IDENTIFICATION OF STRAIN RESISTANCE MODEL SUBJECT TO VOLUME FRACTION OF DYNAMIC RECRYSTALLIZATION

Smirnov A.S., Konovalov A.V.
Institute of Engineering Science, Russian Academy of Science (Ural Branch)
smirnov@imach.uran.ru

The paper proposes the identification method of a rheological strain resistance model. The method uses experimental data on the strain resistance and the volume fraction of dynamic recrystallization is determined by the method of electron backscattered diffraction (EBSD). The method was tested on the 1560 (the Al-6Mg-type) alloy at 300 $^\circ$C and gave acceptable results for engineering calculations on the description of strain resistance curve and the prediction of the volume fraction of the passed dynamic recrystallization in the alloy.

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CONTINUA TRAFFIC FLOW MODELS

Smirnov N.N., Kiselev A.B., Nikitin V.F., Bogdanova A.I., Manenkova A.S.
Moscow M.V.Lomonosov State University
ebifsun1@mech.math.msu.su

The present research was aimed at mathematical modeling of essentially unsteady-state traffic flows on multilane roads, wherein massive changing of lanes produces an effect on handling capacity of the road segment. The model is based on continua approach. However, it has no analogue with the classical hydrodynamics because momentum equations in the direction of a flow and in orthogonal directions of lane-changing are different. Thus velocity of small disturbances propagation in the traffic flow is different depending on direction: counter flow, co-flow, orthogonal to the flow. Numerical simulations of traffic flows in multilane roads were performed and their results are presented.
The mathematical model for traffic flows simulations in multi-lane roads is developed. A model problem for traffic evolution in multi-lane road with non-uniform flux in different lanes was regarded. The results show that on entering the road segment high orthogonal fluxes occur in the direction of less dense lanes, which brings to slowing down flow velocity in that lanes and increasing density. Th equation of motion at brings to formation of inverse flow from those lanes back. In time flow evolution brings to a more smooth transition zone, however, on coming in contact flow zones of different fluxes always cause formation of an orthogonal flow in the direction of less density lane in the nearest vicinity followed by an inverse flow at some distance.
Russian Foundation for Basic Research (grant 13-01-12056) is acknowledged for financial support.

NUMERICAL ANALYSIS OF THE STRESS-STRAIN STATE OF THE STEEL SUPERFICIAL LAYER UNDER NANOSTRUCTURING BURNISHING

Smolin I.Yu.[1,2], Kuznetsov V.P.[3], Dmitriev A.I.[1,2]
1 - Institute of Strength Physics and Materials Science SB RAS
2 - Tomsk State University
3 - Kurgan State University
smolin@ispms.tsc.ru

The numerical study of the stress-strain state of the steel superficial layer subjected to burnishing is presented. In the framework of the finite element method in the approximation of plane strain condition a dynamic formulation of the problem which allows more accurate description of the process details than static formulation is used. The burnishing tool or indenter was modeled by an absolutely rigid body, and the model of elastic-plastic media with isotropic hardening according to the experimentally defined law was adopted for the steel piece. The patterns of stress-strain state of the material near the treated surface and mechanisms of nanostructure formation in the surface layer were analyzed. The influence of the parameters of the burnishing process as burnishing force and friction coefficient on the features of stress and plastic strain distribution formed is investigated. The simulation results are compared with experimental data.

SIMULATION OF PORE SPACE STRUCTURE AND MECHANICAL BEHAVIOR OF POROUS CERAMICS

Smolin I.Yu.[1,2], Eremin M.O.[1,2], Makarov P.V.[1,2], Buyakova S.P.[1,2]
1 - Institute of Strength Physics and Materials Science SB RAS
2 - Tomsk State University
smolin@ispms.tsc.ru

To describe the mechanical response of brittle porous materials at mesoscale, first, pore space structures are generated and, second, their deformation is modeled up to failure. Mesoscale porosity is taken into account explicitly with consideration of two types of model pore space morphology: overlapping spherical pores and overlapping spherical solids. For deformation modeling the evolutionary approach is applied with considering the material mesovolumes as non-linear dynamic systems. The nonlinear constitutive equations describe damage accumulation and their influence on the degradation of the strength properties of the elastic frame of ceramics. The obtained results of numerical simulations reveal little influence of pore space morphology on the characteristics of damage. The averaged stress-strain diagram is sensitive not only to the value of porosity but also to the pore morphology. The strength limit has analogous dependence. The simulation results are validated with experimental data for zirconia ceramics.

AIRCRAFT ENGINE PARTS OPTIMIZATION USING COUPLED TRANSIENT THERMO-MECHANICAL ANALYSIS

Sobyanin K. V.[1,2], Shardakov I.N.[2,3]
1 - NPO SATURN
2 - Perm state university
3 - Institute of continum media mechanics UB RAS
K.Sobyanin@gmail.com

In view of increasing modern aircraft engines requirements, it is very important today to advance computer modeling technologies. One of the most perspective areas in computational technologies development is optimal design. Optimal design means

consideration and variation of engine construction parameters and consequent selection of a parameters set providing the optimum conditions accordingly to chosen optimization criteria.
In this work are represented main concepts of effective optimization system, which contains basic stages of design attached to parametric CAD model: coupled transient thermo-mechanical analysis, critical frequency determination and fatigue crack life analysis. Application of proposed optimization system in industry will provide a large impetus for speed and quality of development cycle.
General idea of this investigation consists in automation of analysis process attached to parametric CAD model. Variation of geometric properties produces automatically changes in all mechanical analyses. This property allows setting the problem at one time and perform a lot of calculations for various aircraft engine configuration. Boundary conditions for current problem are recalculated automatically basing on results of other problems in considered coupled analysis. A parameter variation stability and continual response surface was evaluated after a set of calculations. The received response surface allows application of any direct or heuristic optimization methods.

MECHANICAL APPROACH FOR DESCRIPTION OF INTERATOMIC BOND SATURATION

Sokolov A., Krivtsov A.M.
Saint Petersburg State Polytechnical University, Russia
sokolovalexey1@gmail.com

A model suitable to describe interatomic bond saturation which can be used in computer simulation of wide range of different problems is proposed. The model is based on discrete element method [1], the concepts of classical mechanics and findings obtained from quantum theory. It is proposed to consider atom as a set of material points. Each material point represents the centre of mass of nucleus and electron clouds. A modification of the model proposed by R.V. Vlasov, E.A. Ivanova, A.M. Krivtsov [2] is used.
The interaction forces are chosen the following way. To describe the interaction between a material point representing the electron cloud and the nucleus it is proposed to use a linear elastic force. To describe the interaction between particles, representing the electron clouds of a single atom it is proposed to use the Coulomb force. The interaction of material points representing the electron clouds of different atoms must meet the following requirements. Electron clouds of different atoms should attract, but in the case when the distance between two clouds becomes small, the interaction of these clouds with other clouds becomes negligible, i.e. the bond will be saturated.
The expression for energy, bond stiffness and parameters are given. It is shown that diamond structure simulated using this model stays stable [3]. Examples of formation of different molecules are given.

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LOCALIZATION OF AREAS OF SEARCH AND RESCUE OPERATIONS IN THE NATURAL AND ARTIFICIAL ENVIRONMENT

Sokolov A.A., Vanushkina V.V., Krivtsov A.M., Khaytin A.L.
Saint Petersburg State Polytechnical University, Russia
sokolovalexey1@gmail.com

Search and rescue operation resources are often limited. That means that only a small area can be covered in the first hours of search. Areas with the highest probabilities are searched first in hope of finding person faster and unharmed. The probability distribution map of the most possible location of person is used to coordinate workers. Nowadays the incident commander, based on terrain features, creates the probability distribution map manually; using lost person personal profile, time elapsed since the beginning of the search, and weather conditions. This approach depends on subjective judgment, and takes a lot of time.
The approach based on human behavior modeling used for automated map generation is proposed.
Created algorithm uses terrain information and generates several meshed maps, each cell consisting information about passability coefficient and point attractors influence. On each step modeled person "check" neighboring cells and based on the information held in cells decides to move to next cell. The next cell is chosen by maximum value of weighted score of two parameters held in cell. Future development of model of human behaviour will include person condition, age and personal profile data, which affects person behaviour.
Obtained results are in good agreement with the data obtained from real search and rescue operations

MULLINS EFFECT IN THE CALCULATION OF THE STRESS-STRAIN STATE OF A CAR TIRE

Sokolov A. K.[1], Shadrin V. V.[1,2], Svistkov A. L.[1,2], Terpugov V. N.[1]
1 - Perm State National Research University, Perm, Russia
2 - Institute of Continuous Media Mechanics UB RAS, Perm, Russia
Aleksandr__Sokol@mail.ru

A peculiarity of filled elastomers is that there is softening after the first cycle of deformation. This phenomenon is known as the Mullins effect. The Mullins effect is ignored in the calculation of the stress-strain state of the tire.
In this paper, the stress-strain state calculation takes into account the Mullins effect. Experimental data are shown that demonstrate the substantial change in the properties of rubber after reloading. It is shown experimentally that the effect of the softening depends on the initial deformation of the elastomeric composite. Calculation of the stress-strain state of the tires was done both with and without the Mullins effect. This shows that there is a different softening of the material in different points of the tire, which indicates that it is necessary to take into account the Mullins effect when calculating stress-strain state, and do it considering the geometrical configuration of the tire and the strain at each point.

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MULTISCALE MODELLING OF THE STRESS-STRAIN STATE OF LAYERED COMPOSITE STRUCTURES WITHIN THE GRADIENT THEORY OF THERMOELASTICITY

Solyaev Y.O., Lurie S.A., Babaytsev A.V., Nguen D.K.
IAM RAS, Moscow, Russia
solyaev@bk.ru

The problem of the thermal stresses determination in the composite layer structures is considered. We involved the gradient model of elasticity in the form introduced by Lurie et al. [1-3] within the problem of plane strain. Thermoelasticity model for the stationary processes was obtained using classical Duhamel-Neumann hypothesis. The solution of the problem of nonuniform heating of multilayer coatings based on zirconium oxide and lanthanum oxide was constructed and studied. It is shown that the use of gradient thermoelasticity models, providing continuity of deformations in the contact zones, allows the considering of nonclassical effects associated with the localization of thermal stresses in the contact zone of heterogeneous layers. As result, gradient elasticity theory predicts the occurrence of additional local tensile/compressive stresses in the layers with lower/higher coefficient of thermal expansion. Obtained solution is a natural generalization of the classical thermoelasticity solutions and allows us to take into account the impact of scale structure parameters in the evaluation of the stress-strain state. It was assumed that an additional scale parameter of the gradient model of thermoelasticity could be proportional to the average grain size in the polycrystalline material. Thus, the model allows to take into account the influence of grain size of the structure on the localization of the stress in the coating layers. Also we took into account the effect of porosity and grain size on the physical and mechanical characteristics of the materials from which the coating layers are formed.

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THE SUPPRESSION OF VIBRATION IN PRESCRIBED AREAS OF A STRING SUBJECTED TO ACTION OF A DISTRIBUTED LOAD BY CONTINUOUS SPATIAL MODULATION OF ITS CROSS-SECTION

Sorokin V.S.[1,2]
1 - Technical University of Denmark, Nils Koppels Allé, Building 404, 2800 Kgs. Lyngby, Denmark
2 - Institute of Problems in Mechanical Engineering RAS, V.O., Bolshoj pr. 61, St. Petersburg, 199178, Russia
vladsor@mek.dtu.dk

The paper is concerned with the problem of vibration suppression in any preassigned area of a bounded structure subjected to action of an external load which is distributed over its entire area.
Continuous periodic spatial modulations of the structural parameters are proposed to be used as a means of vibration suppression. The considered problem is relevant, in particular, for the task of sound and vibration isolation which gained much attention in the recent years.
To solve the considered problem a novel approach, based on the method of direct separation of motions (MDSM), is employed. Application of the MDSM implies the separation of variables in time, i.e. the representation of the considered system dynamics as a sum of slow and fast components. The novel approach is adapted for the analysis of dynamics of spatially periodic structures, i.e. systems where separation of variables can be performed not in time, but rather in a spatial coordinate.
Oscillations of a string under action of external

distributed time-periodic load are considered as the simplest illustrative example. The suppression of vibration in predefined areas of the string is carried by continuous spatial modulation of its cross-section. As the result, the optimal parameters of the modulation are determined, which allow to completely suppress or considerably reduce (compared to the case without modulation) vibration near the prescribed point of the string. It is noted that vibration can be substantially reduced in the whole string at comparatively large amplitudes of the modulation.

HIGHLY OSTEOINTEGRATIVE, SELF-HARDENING BIOMIMETIC BONE CEMENTS FOR VERTEBRAL REGENERATION

Sprio S., Dapporto M., Tampieri A.
Institute of Science and Technology for Ceramics,
National Research Council of Italy, Via Granarolo 64,
48018 Faenza, Italy
simone.sprio@istec.cnr.it

The regeneration of vertebral bodies damaged by osteoporosis or other diseases involving bone loss still represents a relevant challenge in spinal surgery. So far, the most used devices in vertebroplasty procedures are based on acrylic compounds that harden by in vivo polymerization and soon exhibit high mechanical strength. In spite of the possibility of early recovery of the upright position, such cements exhibit several drawbacks: i) high heat development during hardening, ii) absence of relevant porosity allowing cell penetration and colonization by new bone tissue and iii) excessive rigidity compared with the surrounding bone, that is the leading factor inducing secondary vertebral fractures. In this respect, recent efforts in materials science are addressed towards the development of apatite-based injectable cements based on self-hardening bioresorbable apatites exhibiting nanosized structure and biomimetic composition, added with bio-soluble natural polymers that favour the formation, in vivo, of progressively opening macro-porosity. The optimization of the surface reactivity of the calcium phosphate precursors enables to trigger fast hardening of the apatite cements in vivo and the establishment of suitable compression strength. These features can assist the early stages of new bone formation and penetration, to create bone/cement constructs with progressively increasing biomechanical competence that in turn assist complete bone regeneration. Preliminary in vitro and in vivo tests, carried out in rabbits, confirm the aptitude of the new cements to host new bone and to be involved in a process of progressive bio-resorption. Hence, biomimetic bone cements are promising to become a next generation of bio-devices enabling the regeneration of diseased vertebrae and the recovery of the biomechanical function of the spine.

FROM WOOD TO BONE: A NEW GENERATION OF BIOMORPHIC SCAFFOLDS FOR REGENERATION OF LONG SEGMENTAL BONES

Sprio S., Ruffini A., Panseri S., Tampieri A.
Institute of Science and Technology for Ceramics,
National Research Council of Italy, Faenza, Italy
simone.sprio@istec.cnr.it

Materials science applied to the biomedical field is experiencing progressive advances. In particular the development of bioactive scaffolds addressed to regeneration of bone diseases has an ever increasing impact, also due to the progressive ageing of the population. Notwithstanding, the healing of complex and comminuted fractures affecting long segmental bones (e.g. femur, humerus, radius) is still a big concern and acceptable solutions are still lacking: in this respect the current clinical approaches still make use of metallic fixators and repeated, painful surgery with very high socio-economic impact. Moreover, due to serious and frequent complications, the endpoint of such diseases is often dramatic and may also lead to limb amputation.

Regeneration of critical bone defects requires 3D scaffolds exhibiting high chemico-physical and morphological mimesis with the natural tissue. With respect to long segmental bones this requirement is particularly crucial: in fact the morphology of the human bone is very complex, characterized by an anisotropic and multi-scale hierarchic structure that allows the activation of the bone mechanosensitivity in the presence of complex and ever changing biomechanical stimuli, that enables the continuous bone remodelling in the case of damages of low entity. However, so far the current manufacturing technology failed in producing 3D biomechanically competent scaffolds with bone-like composition and also hierarchical pore organization down to the micron scale. This leaves the problem of long bone regeneration still open.

In this respect the Nature can inspire material scientists with innumerable examples of living beings exhibiting smart and complex morphologies that are capable of extraordinary performances. Among these, ligneous structures exhibit a morphology, structural organization and mechanical properties similar to those of bone. In this respect new multi-step transformation processes can be settled, to convert native woods into hierarchically organized porous scaffolds made of biomimetic hydroxyapatite. In particular, Rattan and Sipo exhibit structures with close similarity with spongy and cortical bone parts. The control of the reaction kinetics throughout the different steps of the transformation process can enable precise control of the phase composition, crystallinity, microstructure and bioactivity. Therefore, a new generation of bone scaffolds can be generated, that may represent a breakthrough in long bone surgery, to solve a clinical need that still does not have acceptable solutions.

MULTISCALE CALCULATION FOR INCREASING THE THERMAL CONDUCTIVITY OF CARBON FIBER COMPOSITE WITH DIAMOND POWDER

Srinivasan M.[1], Mättig P.[1], Glitza K.W.[1], Sanny B.[1], Schumacher A.[2]
1 - University of Wuppertal, Department of Experimental Physics, Wuppertal, Germany
2 - University of Wuppertal, Department of Mechanical Engineering, Wuppertal, Germany
srinivasan@uni-wuppertal.de

An analytical and micromechanical modeling study was conducted to predict the through the thickness thermal conductivity of composite filled with diamond powder are developed and validated. A Finite Element Method (FEM) incorporated the microstructural characteristics to explore the effects of filler concentration, aspect ratio and interactions between the filler and reinforcing fiber on transverse thermal conductivity of multiscale composite are presented. An algorithm based on random sequential adsorption method were developed to generate the two dimensional unit cell models of randomly distribution of fibers and fillers within the matrix based on position and orientation. The heat transport mechanism of multiscale composite revealed by finite element models impinge the effects of filler volume fraction ranges, filler aspect ratio which affects the change of filler dispersion and their ability to form conductive chain. FEM results showed that the diamond powder filler developed the thermally conductive path which led to strong fiber-filler interaction to increase the transverse thermal conductivity of multiscale composite. The application of microscale diamond powder increased the transverse thermal conductivity of the multiscale composite from 0.6 (W/mK) to 4.5 (W/mK). For special reference cases, the FEM results are compared and checked with the analytical micromechanical models.

EXPERIMENTAL RESEARCH OF COMPOSITES PANELS BEHAVIOR AT SHOCK IMPACT

Staroverov O.A., Wildemann V.E.
Perm National Research Polytechnic University, Russia
cem_staroverov@mail.ru

The report centers around results of metal and composites panels tests carried out in the universal electromechanical measuring droptower impact system Instron CEAST 9350. This testing system can register dependence of force, velocity and strain on time. The system also has a special system of measuring and processing data.
In experiment, metal specimens of different size were loading with different parameters. Characteristic types of breaks of samples are given. Also we tested the influence of geometry and loading parameters on value of impact strength.
Specimens of composites panels were exposed to repeated loading at different velocity and energy of hammer. Values of spent energy and the maximum destroying force were received for all samples. Charts of force-displacement dependencies are constructed. Photos of the appearance of samples after each series of blows are provided.

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TWO-COMPONENT MODEL OF THE EYEBALL AND ITS APPLICATION TO DETERMINING THE MECHANICAL CHARACTERISTICS OF THE EYE IN CLINICS

Stein A.A., Moiseeva I.N., Lyubimov G.A.
Institute of Mechanics, Moscow State University
stein.msu@bk.ru

Tonometry, a mechanical test widely used in ophthalmology, is aimed at obtaining information about mechanical characteristics and mechanical state of the eyeball from indirect measurements, i.e., at solving an inverse problem. The standard methods of processing the measurement data are based on physically unjustified models and often yield unreliable results. On the other hand, detailed mechanical models contain numerous mechanical constants which are strongly different for different subjects and cannot be determined in clinics for the eye examined. Therefore, the inverse problem of finding the intraocular pressure (IOP) and the elastic characteristics of the eyeball cannot be solved within such models efficiently.

To solve the above-mentioned inverse problem we developed a simple model of the eyeball loaded by an external device (tonometer) which contains two important elastic constants. The cornea to which the tonometer is applied is represented by an isotropic, linearly elastic homogenous two-dimensional soft (membrane) shell, which can be mainly characterized by a "corneal stiffness". The applicability of the membrane approximation is confirmed by experimental data and observations. This approximation is correct if the tonometer has the shape of a stamp with a sufficiently broad contact area (such as in the Maklakoff tonometer) or a narrow rod used in the Schiøtz tonometer but incorrect for a stamp with a narrow contact area (Goldmann tonometer). The sclera with surrounding tissues is modeled by an elastic element which responds to IOP and can be characterized by a single elastic constant ("scleral stiffness").

The dependence of the intraocular volume on IOP and the load applied and the dependence of IOP on the load at a constant volume (tonometry problem) are studied for several tonometer types. The approach developed enables us to find the intraocular pressure and the two elastic constants basing on standard tonometry measurements. Nevertheless, the almost linear form of the IOP-load curves does not allow us to do this efficiently by means of varying the load in a single tonometer. However, the inverse problem can be solved using tonometers of two different types: applanation (flat stamp) and impression (convex stamp or thin rod) tonometers. Moreover, if the elastic characteristics of the eyeball are close to normal, the impression tonometry alone yields the scleral stiffness and IOP with practical accuracy. The applanation tonometry can be used for additionally to determine the corneal stiffness.

NONLINEAR DYNAMICS OF THE "ROTOR - MASSIVE-COMPLIANT SUPPORTS" SYSTEM

Pasynkova I. A., Stepanova P. P.
Saint Petersburg State University
polinastepanova@ya.ru

Dynamics of a rigid rotor on an elastic shift mounted in non-linear massive compliant supports is studied. The system of the rotor and massive-compliant supports has eight degrees of freedom. Under some assumptions nonlinear resonances, two of which appear due to supports dynamics, are obtained. Analysis of cylindrical precession stability is carried out at the full range of frequencies. Auto-vibration and chaotic vibration are found at between and after resonances regions and confirmed by computation of full Lyapunov exponents spectrum. Comparison with dynamics of a rotor in massless supports is made.

VORTEXES AND WAVES IN THE "VIBRATIONAL HYDRODYNAMIC TOP"

Subbotin S.V., Kozlov N.V., Kozlov V.G.
Laboratory of Vibrational Hydromechanics, Perm State Humanitarian Pedagogical University, Perm, Russia
subbozza@mail.ru

In [1] it is found that the action of an external periodic force on a light spherical body centrifuged in a rotating about horizontal axis cavity filled with liquid leads to the excitation of the body differential rotation (vibrational hydrodynamic top). As a result, the flow in a 2D column form oriented along the rotation axis is generated. Inside the column the intense azimuthal fluid motion is observed [2].

In this paper the supercritical flow regimes are experimentally studied. With increase of the body differential rotation the axisymmetrical flow becomes unstable: 2D vortex structures appear inside the column. The rotation direction of each vortex coincides with the rotation direction of the cavity. At the same time, the vortex system as a whole rotates in the opposite direction relative to the cavity with a velocity considerably exceeding the body differential rotation velocity. The vortex structures in the column center are independent from its boundary, that remains cylindrical. With increase of the supercriticality the number of vortices grows to three.

Another type of instability is associated with the appearance of an azimuthal wave on the column boundary, which can develop irrespective of the vortex system presence. The 2D wave on the boundary has another phase velocity, and the wave numbers are different. Interaction of the two different instability types manifests itself in their synchronization.

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DERIVATIVE-FREE LOCAL SEARCH IN HYBRID ALGORITHMS FOR HYDROMECHANICAL SYSTEM MODEL UPDATING

Sulimov V. D., Shkapov P.M.
Bauman Moscow State Technical University
spm@bmstu.ru

Multitudinous practical studies related to the safety and early diagnostics of significant objects in the nuclear power industry are based on reliable mathematical modeling in hydromechanical system dynamics. Procedures of model updating are powerful tools for producing adequate models. Consideration is being given to problems of building accurate mathematical models for detecting anomalies in the phase constitution of the coolant flowing throw the reactor primary circuit. Main dynamical characteristics of the object under diagnosing are considered as continuous functions of the bounded set of control variables. Possible occurrence of anomalies in the phase constitution of the coolant can be fond out owing to changes in dynamical characteristics of the two-phase gas-liquid flow. Computational model updating techniques are used for adjusting selected parameters of hydrosystem models in order to make the models compatible with measured experimental data. This is performed by minimizing the differences of analytical and measured data with the use of numerical optimization methods. Incompleteness of measured spectral data and presence of multiple frequencies result in the error function of the extremal problem being non-convex and non-differentiable. Two novel hybrid algorithms with derivative-free local search for solving the corresponding global minimization problem are proposed. The first algorithm M-PCASFC combines the stochastic Multi-Particle Collision Algorithm (scanning the search space) and deterministic Space Filling Curve method (local search). The second algorithm M-PCAMNM implements the Modified Nelder-Mead simplex method for local minimization. Results of successful computational experiments are presented to show the efficiency of the approach.

INTERNAL COMBUSTION ENGINE IGNITION LOW-RPM TRANSDUCER

Sviyazheninov E.D.
IPME RAS
sviage@gmail.com

The invention relates to contactless pickups to be used in Internal Combustion Engine (ICE) ignition systems and, moreover, in switch, telemetry and weapons, for example, for control over charge activation.
The optimal rotational speed of the crankshaft of the modern ICE is higher than 3000 rpm. So the rotor of the traditional ignition transducer has to revolve faster than 1500 rpm which is severely harmful for this exacting mechatronic device.
Low-rpm transducer of ICE with n cylinders consists of shielding cylindrical shell rotating jointly with rotor that has n+1 or n–1 slots uniformly distributed along the shell circle to separate n sensor pairs uniformly mounted along the stator circle radially with gap: Hall pairs (Hall sensor and permanent magnet) or optical pairs (photo sensor and light emitter).
Revolving shield (magnetic or light) allows forward or reverse spark formation relative to the rotor revolution direction: forward at n+1 slots and reverse at n–1 slots.
The effect consists in ensuring:

- [1] multiply slower rotational speed of the rotor and, therefore,
- [2] multiply longer time for activation of the igniter spark discharge, as well as
- [3] sufficient reduction of vibration and wear of the transducer elements,
- [4] reduction of heating and
- [5] reduction of operational property instability.

As a result functionality and reliability of such a precision device as a transducer of ignition of ICE increases significantly.

MODELING STRESS-ASSIST OXIDATION OF SILICON

Telezhko I.V.[1], Freidin A.B.[1,2]
1 - Saint-Petersburg State Polytechnical University, St. Petersburg, Russia
2 - Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg, Russia
deemerd@yandex.ru

We develop a model for describing the processes of silicon oxidation taking into account the influence of stress-strain state on the kinetics of the oxide growth on the planar and cylindrical surfaces. Following [1] we use a kinetic equation in a form of the dependence of the chemical reaction front on the normal component of the chemical affinity tensor. The growth kinetics of the plane viscous oxide layer is compared with the kinetics that follows from Deal – Grove model [2]. The viscosity of the oxide provides the relaxation of stresses produced by the transformation strain. The model parameters are selected and after that it is demonstrated that the model based on the notion of the chemical affinity tensor predicts the kinetics of the planar reaction front that corresponds to experimental data. Then we apply the model for the description of the oxidation of a cylinder, using the selected material and reaction parameters. We demonstrate the possibility of the locking effect – blocking the reaction at some relationships between the parameters, cylinder radius and oxide thickness. We show that theoretical results correspond to experimental results obtained by Kao [3] and explain the influence of the surface curvature on the reaction front kinetics.

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CRITICAL CONDITIONS FOR BUCKLING WITH DELAMINATION AND OTHER MISFIT DEFECTS IN ALN(0001)/SIC/SI(111) THIN FILM HETEROSTRUCTURE

Telyatnik R.S.
IPME RAS
statphys@narod.ru

Profilometry of AlN epitaxial thin film (~500 nm) deposited by HVPE on unstrained SiC/Si(111) substrate exhibits hexagonally intersecting linear buckles with amplitude ~10 nm and periodicity ~10 μm. We prove that this morphology occurs because of delamination of AlN from SiC and not due to elastic-plastic instability as it was supposed earlier.

Delamination explains ultrahigh ~99.9% relaxation of lattice misfit stresses observed by measurements of the multilayered composite plate curvature in dependence on temperature (thermal expansion mismatch). This relaxation allows to grow additional ~90 nm of AlN without generation of new misfit dislocations badly affecting semiconductors conductivity.

Critical thicknesses for AlN/SiC delamination (~120 nm) and possible cracking were calculated with the cohesive (3.97 J/m^2) and surface energies of different planes of Si, SiC, AlN, GaN obtained by means of computational quantum chemistry implementing DFT LDA method. The bonding energies predict priority for propagation of delaminated buckles along [1000], [0100], [1100] crystallographic directions, while cracks should release planes equivalent to (1200) for biaxially stretched AlN, GaN(0001) but (1-10) for Si, SiC(111).

DYNAMICS OF CAVITATIONAL CLUSTERS AND VORTEX RINGS IN WATER

Teslenko V.S., Drozhzhin A.P., Medvedev R.N.
Lavrentyev Institute of Hydrodynamics SB RAS
teslenko@hydro.nsc.ru

This work presents the results of experimental investigations of development of vortex cavitational processes generated by pulse pushing of water projectile from flooded cylindrical tube into water (the inner tube diameter D_0 varies from 20 to 40 mm). The dynamics of cavitation development on the cylinder cut and propagation of cavitational vortex rings (CVRs) in water depending on the velocity of water pushing and cylindrical tube sizes are investigated.

Threshold values of velocity of water piston V, at which a cavitational cluster arises, vary from 2 to 3 m/s. With increasing the velocity of water projectile pushing, CVRs are formed in the form of a hollow tore with the following parameters: d is a diameter of the ring, D is a diameter of the tore cross-section along the forming axis of the ring. Stable CVRs in the form of a hollow tore are observed for the Reynolds numbers $Re > 2{\cdot}10^5$.

Radial damping pulsations of CVRs, i.e., periodical change parameters of d and D in time, are found. At the initial stage of the motion, the period of pulsations of CVRs is approximately proportional to flow velocity of liquid pushed from the cylinder. When moving from the tube, the period of pulsations of CVRs decreases.

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CINEMATIC AND DYNAMICS OF THE STEWART PLATFORM

Tovstik P.E.[1,2], Tovstik T.P.[1,2]
1 - SPbGU
2 - IPME RAS
tovstik_t@mail.ru

The cinematic and dynamics of the classic Stewart platform supported by six rods of variable length is studied. The well known differential equations [1] are used to describe the platform motion. The forces in rods which provide the given platform motion are also found from these equations. The some control problems of the platform motions are studied.

We study the case when the construction is symmetric with the angle of symmetry equal to $2\pi/3$. It is assumed that the rods lengths are changed in the given limits. In this assumption the main attention is paid to workspace boundary determination in the 6D space of the generalized coordinates of platform. The projections of this boundary to the sub-spaces with less dimensions are found. In partial, 1D and 2D subspaces are studied in details.

Some other restrictions on the workspaces for the partial types of platform motion are studied. Among them there are restrictions on the forces in rods and on the velocities of rod lengths changing.

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ON THE PROBLEM OF FORCED PLANE VIBRATIONS OF TRANSVERSALLY INHOMOGENEOUS ELASTIC LAYER

Uglich P.S.
South mathematical institute of Vladikavkaz Scientific Center of the Russian Academy of Sciences and the Government of Republic of North Ossetia-Alania, Russia
puglich@inbox.ru

A problem of forced plane vibration of the transversally inhomogeneous elastic layer is considered. A calculation scheme for the wave field evaluation is presented. It's based on the Fourier transform and the initial problem is reduced to the boundary value problem. This problem can be solved numerically using the shooting method. Then the wave field can be evaluated using the residue theory, or it can be obtained using numerical integration methods.

An inverse problem of mechanical parameters reconstruction using surface wave field data is also considered. The inverse problem is reduced to the iterative sequence of integral equations. Results of both direct and inverse problem solution are presented.

MICROFLOWS AND PERIODIC DISTORTIONS IN NEMATIC LIQUID CRYSTAL CELLS IMPOSED BY A STRONG ORTHOGONAL ELECTRIC FIELD

Vakulenko A.A., Zakharov A.V.
IPME RAS
avak2vale@mail.ru

The dynamics of the periodic distortions in confined nematic liquid crystals (LCs) has been investigated theoretically based on the hydrodynamic theory of anysotropic liquid. Analysis of the numerical results for the turn-on process provides evidence for the appearance of the spatially periodic orientation patterns in confined LC cell, only in response to the suddenly applied strong electric field. It has been shown that there is a threshold value of the amplitude of the thermal fluctuations of the director over the LC sample which provides the nonuniform rotation mode rather than the uniform one, whereas the lower values of the amplitude dominate the uniform mode. During the turn-off process, the reorientation of the director to the direction preferred by the surfaces is characterized by the complex destruction of the initially periodic structure to a monodomain state. Microflows have been simulated due to turn-on and turn off processes.

Analysis of evolution of the director distribution in the LC film under the influence of the pretransitional fluctuations when the temperature goes to the bulk nematic-smectic A transition temperature T_{NA} shows that there is two scenarios of the evolution. First, in the reduced temperature range $-5<\lg(T/T_{NA}-1)<-2$, dominate the nonuniform rotation mode and the growing pretransitional fluctuations does not destructed the initially periodic structure, whereas at the lower temperature towards T_{NA}, the reorientation of the director field is characterized by the complex destruction of the initially periodic structure to a monodomain state with the director field aligned parallel to the direction preferred by the surfaces.

MICROMECHANICS OF THE DEFORMATION AND FAILURE KINETICS OF SEMICRYSTALLINE POLYMERS

Van Dommelen J.A.W., Sedighiamiri A., Govaert L.E.
Eindhoven University of Technology
J.A.W.v.Dommelen@tue.nl

The elasto-viscoplastic behaviour of semicrystalline polymeric materials is strongly dependent on the underlying microstructure consisting of both amorphous and crystalline domains. A micromechanically-based model for the constitutive behaviour of semicrystalline polymeric material based on layered two-phase inclusions has previously been developed [1, 4]. The present work is directed towards the prediction of the stress-dependence of the rate of plastic deformation, referred to as the yield kinetics, for semicrystalline polymers based on the underlying microstructure. A critical factor is the stress-dependence of the rate of plastic deformation, the slip kinetics, which is the mechanism underlying time-dependent, macroscopic failure. As a first step in achieving this goal, an Eyring flow rule is used for each slip system. In order to predict the response in both tension and compression, a non-Schmid effect (i.e. a dependence on the normal stress acting on the slip system) is included in the slip kinetics. The re-evaluation of the slip kinetics is performed using a combined numerical/experimental approach taking into account uniaxial compression and tension data of isotropic HDPE, for different strain rates and temperatures [2].

The mechanical response of extruded and drawn semicrystalline materials, in which a stacked lamellar morphology is commonly observed, depends on the direction of loading with respect to the direction of flow. Plastic deformation and failure are, therefore, both anisotropic. The predictive ability of the micromechanical model, including the characterization of the kinetics of crystallographic slip and amorphous yield based on isotropic material, is next evaluated for oriented high-density polyethylene [3]. The initial morphology of the material is generated based on pole figures from wide-angle X-ray diffraction experiments, which show a strong alignment of molecular chains with the drawing direction for specimens produced with a large draw ratio. Uniaxial loading of this aggregate shows the potential of oriented systems for unambiguously determining the yield kinetics of individual slip systems. In doing so, however, also the presence of a potentially oriented amorphous phase should be dealt with. Finally, the macroscopically anisotropic response of oriented polyethylene is described using an elasto-viscoplastic formulation, incorporating different physical sources of anisotropy.

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DYNAMICS OF TWO-COMPONENT MEDIUM WITH NONLINEAR INTERACTION FORCE

Indeitsev D.A., Skubov D.Yu., Vavilov D.S.
Institute for Problems in Mechanical Engineering
londr@yandex.ru

The present paper investigates the possibility of describing phase transitions in solids through considering two-component medium with nonlinear interaction force. For this purpose we introduce an additional degree of freedom responsible for structural conversion . The investigation is motivated by the experiments on high-speed deformation of materials which demonstrate that the microstructure may have a serious effect on dynamics of material.

A MODEL OF DAMAGE AND FRACTURE OF THE INTERMEDIATE LAYER IN METAL MATERIALS PRODUCED BY EXPLOSIVE WELDING DURING PLASTIC DEFORMATION

Veretennikova I.A., Smirnov S.V.
Federal goverment-financed science organization
Institute of Engineering Science of Ural Branch of Russian Academy of Sciences
irincha@imach.uran.ru

Weld damage is one of the typical forms of material damage under deformation. Establishing of a feasible model describing this process is a significant problem of the material damage theory. The paper proposes a model which can help the solution of this problem. The proposed model pertains to the phenomenological class of continual models of scattered damage. It is considered that the material preserves macroscopic continuity up to the initiation of a lamination crack. The intermediate layer including a weld of different metal materials and the border zone is the object for study. There occurs opening mode and shear fracture. By analogy with cohesive fracture models we introduce a conception of damage ω describing the rate of the plasticity resource use in the intermediate layer under failure. The plasticity of the intermediate layer depends on the deformation mechanism and is significantly different for the normal and shear fracture. Therefore damage is represented as a vector $\varpi\{\omega_n, \omega_s\}$, where ω_n is normal damage (accumulated due to deformation in the normal direction of to the intermediate layer), ω_s is shear damage (accumulated due to deformation in the plane the intermediate layer). The vector length is used as a damage measure. It is assumed that as soon as the vector $\varpi\{\omega_n, \omega_s\}$ reaches the fracture surface representing an arc of a circle with radius ω = 1 lamination starts. The processes under study limit the monotonic deformation of the intermediate layer. A linear model of damage accumulation is used. The total damage is defined by the summation of damage vectors at separate stages. The proposed damage and fracture model can be used for innovative activity and the optimization of existing manufacturing processes of plastic deformation of layered metal materials for the purpose of minimizing weld damage.

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ON KINETICS OF CHEMICAL REACTION FRONT IN AXIALLY-SYMMETRIC PROBLEMS

Vilchevskaya E.N.[1,2], Freidin A.B.[1,2,3]
1 - Institute for Problems in Mechanical Engineering of Russian Academy of Sciences, St. Petersburg, Russia
2 - Saint-Petersburg State Polytechnical University, St. Petersburg, Russia
3 - Saint-Petersburg State University, St. Petersburg, Russia
vilchevska@gmail.com

Basing on the expression of the chemical affinity tensor derived in [1, 2] as a consequence of mass, momentum and energy balances and entropy inequality we consider a stress-assist chemical reaction front propagation in a deformable linear-elastic isotropic bodies. We suppose that the reaction is localized at the front that divides two solid constituents and sustained and controlled by the diffusion of the gas constituent through the transformed material. We also assume that the gas diffusion is not affected by strains and does not produce additional strains in the solid phases. In a linear thermodynamic approach a velocity of the reaction front is proportional to a normal component of the chemical affinity tensor which depends on stresses and the gas constituent concentration. We say that the gas concentration is equilibrium at the reaction front if, given temperature, front position and stresses, the normal component of the chemical affinity tensor is equal to zero.

Then we examine axially-symmetric mechano-chemistry problems comparing displacement and traction boundary-value problem statements and study in detail how the kinetic of the chemical reaction front depends on chemical reaction parameters, external loading and the chemical reaction front curvature. Given transformation strain we show that in the absence of external stresses the reaction rate in the case of a convex surface is greater than in the case of nonconvex surface. At the same time the oxide layer growth leads to the equilibrium concentration increase in the case of the convex surface, which in turn may lock the reaction. External pressure applied can make the reaction possible at all thicknesses of oxide layer but further pressure increase may lead to total locking of the reaction. This effect is a consequence of the nonmonotonic dependence of the equilibrium concentration on pressure. In contrast, in the case of nonconvex surface, the oxide layer growth decreases the equilibrium concentration that in turn enhances the chemical reaction front propagation.

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EFFECT OF VISCOSITY ON CONVECTION AND HEAT TRANSFER IN ROTATING HORIZONTAL CYLINDRICAL LAYER OF LIQUID

Vjatkin A.A., Sabirov R.R., Kozlov V.G.
The Laboratory of Vibrational Hydromechanics, Perm State Humanitarian-Pedagogical University, Perm
a.a.vjatkin@mail.ru

Thermal convection of liquid in a coaxial horizontal gap rotating around its own axis is investigated experimentally. The dependence of threshold of the averaged convection excitation on the fluid viscosity and the temperature difference between the layer boundaries is determined. The inner boundary has higher temperature, the centrifugal force in this case plays stabilizing role. It is found that in viscous liquids the crisis of heat transfer is associated with the appearance of the vortices extending along the azimuth (three-dimensional structures), on which background the longitudinal two-dimensional rolls appear. The convection is excited by thermovibrational mechanism [1]. In experiments with low-viscosity fluids, the sequence of the development of convective processes is reverse – two-dimensional structures appear initially, three-dimensional – later in overcritical domain [2].

With the advent and development of convective flows their slow azimuthal drift relative to the cavity is recorded. The dependence of the drift velocity on the Prandtl number, the rotational speed of the cavity and the temperature difference between the layer boundaries is studied. It is shown that the drift is associated with azimuthal fluid movement; it has also vibrational nature and is generated in Stokes layers by progressive waves. It is found that with increase of fluid viscosity the wavelength of longitudinal rolls and the drift velocity of the entire system significantly reduce.

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VIBRATIONAL SUSPENSION OF SOLID BLOCK IN LIQUID

Vlasova O.A., Kozlov V.G.
Laboratory of a vibrational hydromechanics, Perm State Humanitarian Pedagogical University, Perm
vlasova_oa@pspu.ru, victorkozlov2012@mail.ru

Vibrational dynamics of rectangular solid in filled with liquid rectangular cavity is investigated. The experiments are conducted with heavy and light solids. Amplitude and frequency of vibration, viscosity and density of fluid, aspect ratio of body, its density and shape of the edges (sharp or smooth edge) vary in experiments.
Without vibrations the heavy solid occupies a stable position at the bottom of the cavity (light one – at the top). With increasing the vibration frequency the heavy solid repulses from the cavity bottom (the light one repulses from the top) and takes the quasi-steady position at some distance from the wall. The repulsion of one of the body edges precedes the full solid repulsion. It is found that all transitions of the bodies occur in a threshold manner and with hysteresis in the studied range of vibration amplitude and frequency.
The analysis of high-speed video recording shows that there is a phase shift between the body and the cavity oscillations in case of mechanical contact of solid and cavity border. After repulsion (in suspension) the oscillations of light body and cavity occur in the same phase, the amplitude of body oscillations in the cavity frame increases. In case of heavy body it's oscillations concerning the cavity occur in the opposite phase.
It is shown that the threshold curves of the light and heavy solid suspension in the fluids of different viscosities are in satisfactory agreement on the plane of the governing dimensionless parameters ω, W, here ω is frequency, W – vibrational parameter (vibrational analogue of Froude number). The hysteresis in the threshold transitions disappears with increasing the fluid viscosity.
It is found that decrease of liquid viscosity brings to change in the character of the threshold transitions: the heavy solid repulses from the cavity bottom abruptly. It is conjectured that the character of solid oscillations changes due to the change of the regime of flow.
It is found that the solid (light or heavy) performs the translational inertial oscillations along the cavity boundary and synchronous angular oscillations of small amplitude. It is conjectured that not only vibrational lift force studied in [1] is responsible for repulsion of solid from the top, but also some additional lift force associated with the angular oscillations of body relative to the cavity.
The theoretical model of generation of vibrational lift force acting on the rectangular solid in filled with liquid cavity in high-frequency approximation is constructed. The comparison demonstrates good agreement of experimental and theoretical results.

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EXTREME VALUES OF POISSON'S RATIO FOR TRICLINIC AND MONOCLINIC CRYSTALS

Volkov M.A.
A. Yu. Ishlinsky Institute for Problem in Mechanics RAS
Volkovmikhl@gmail.com

Poisson's ratio is defined as the ratio of lateral deformation to longitudinal one in the case of an uniaxial tension. This coefficient is bounded between -1 and 0.5 for isotropic materials and, generally speaking, has no bounds for anisotropic materials. Many anisotropic crystals can have positive or negative Poisson's ratio depending on orientation of strained crystal (partial auxetics).
Extreme values of Poisson's ratio were analyzed for crystals of triclinic and monoclinic crystal systems with highest crystal anisotropy. Analytical analysis of the extreme values of Poisson's ratio of some particular orientations was performed. Numerical values for the global extrema and extrema for particular orientations were obtained using experimental data from Landolt-Börnstein database. Average Poisson's ratio over all possible directions was also obtained. Negative Poisson's ratio is found for only one triclinic crystal. The majority of monoclinic crystals from Landolt-Börnstein database are partial auxetics.
This work was supported by the Basic Research Program of the Presidium of the Russian Academy of Sciences, no. 24, and grant RFBR 14-01-32145 mol_a.

MODEL OF A ROTOR OSCILLATIONS HAVING AN INITIAL DEFLECTION AND MOUNTED ON ANISOTROPIC SUPPORTS

Volokhovskaia O.A.
A.A.Blagonravov Mechanical Engineering Research Institute of RAS, Moscow, Russia
olgaavol@yandex.ru

We develop a mathematical model of motion of one disk rotor installed on anisotropic supports and having an initial deflection of the shaft, which is manifested only during n the operation of turbine unit. Features of model are that the system of oscillations equations as variables include horizontal and vertical displacements of the axis connecting the centers of the end cross-sections of the shaft, and that the resulted imbalance vector is the sum of the imbalance disk vector and the vector of the initial disk deflection at the point of the disk attachment to the shaft. It is shown, that when the shaft torsion is taken into consideration, the parametric members appear in equations of the system motion and lead to the possibility of parametric resonances in the system. It is proposed the example of calculating the resonance oscillations amplitudes for the turbine K - 300- 23.5 high pressure rotor and it is assessed the contribution of the initial shaft deflection in the values of the rotor vibration amplitudes near the supports and in the center of the span.

SHELL THEORY BASED MODELS FOR PRESSURE VOLUME RELATIONSHIP IN THE HUMAN EYE

Bauer S.M.[1], Voronkova E.B.[1], Kotliar K.[2]
1 - St-Petersburg State University, Russia
2 - FH Aachen University of Applied Sciences, Germany
e.voronkova@spbu.ru

The stress-strain state of a pressurized spherical shell are studied by means of the exact 3D theory of elasticity and the 2D approximate shell theories of moderate thicknesses. The pressurized sphere is one of simplest representations of the human eye and models the correlations between the intraocular pressure (IOP) and the intraocular volume (IOV).

Refined theories for orthotropic plates of moderate thicknesses worked out by Paliy-Spiro (PS) [1], by Rodinova-Titaev-Chernykh (RTC) [2] and by Amabili (Amb) [3] are employed to study the stress-strain state of the shell. The theories are based on different principals, but take into account deformations, rotation and bending of the fibers and, what is more important, their elongations in the direction of the thickness of the shell.

The exact relationships for displacements and stresses are derived from the 3D theory and the asymptotical analysis of these solutions has been performed. The accuracy of the approximate solutions, obtained with the approximate theories is analyzed.

The effect of the thickness changes are also discussed.

The presented 2D shell theories give acceptable fit to the 3D exact solution for spherical shells with a transversal isotropy. For orthotropic spherical shells or/and ellipsoidal shells adequate results can be obtained by means of these theories.

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ANTISYMMETRIC HIGHER ORDER EDGE WAVES IN PLATES WITH FIXED FACES

Ardazishvili R.V., Wilde M.V.
Saratov State University
mv_wilde@mail.ru

Surface waves in plates, propagating along the edge (edge waves) are well-known in two-dimensional approximate structural theories, which describe long-wave low-frequency motions. In the theory of generalized plain stress the edge wave is described by classical Rayleigh wave solution [1] with only difference in longitudinal wave speed. Edge wave in the classical theory of plate bending was derived in [2]. Existence and uniqueness of bending edge wave in anisotropic plates was studied in [3]. Free vibration of shells connected with edge waves are considered in [4, 5]. But approximate structural theories describes only the first, so-called fundamental wave. By using three-dimensional theory of elasticity we will have an infinite family of edge waves, which can be called higher order edge waves. In [6] a simple analytical solution for such waves in a plate with mixed boundary conditions on the faces is obtained. In [7, 8] the higher order edge waves in a plate with free or fixed faces are studied for the case of symmetric plate motions with respect to its mid-plane. In [9] the antisymmetric higher order edge waves are considered in the plate with free faces. This study deals with antisymmetric higher order edge waves in plates with fixed faces.

Asymptotic analysis for the case of large wave numbers allows us to obtain approximate analytical formulae for wave speeds and to show the existence of an infinite family of higher order waves. It is demonstrated that in the short-wave limit the phase velocities of all higher order edge waves tend to the velocities of Rayleigh wave. All these waves except the first one are damped by propagating modes, but for each wave there is a critical wave number, after which the wave becomes non-damped. These critical wave numbers are also estimated asymptotically.

Numerical investigations based on the modal expansion method are also performed. Numerical results for the several higher order edge waves are presented in a wide frequency range. By numerical investigation in some frequency ranges the additional resonance peaks were discovered which also correspond to higher order edge waves. The reason of that phenomenon not observed in previous papers is discussed.

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TURBULENT PULSATILE FLOW IN AN AXISYMMETRIC STENOTIC TUBE

Hechter R., Rozovsky K., Yakhot A.
Department of Mechanical Engineering, Ben-Gurion University, Beersheva 84104, Israel
yakhot@bgu.ac.il

An incompressible viscous fluid, which is forced to move under a pulsatile pressure difference, has a number of characteristic properties. One of the features of such a flow is the occurring a phase shift of a flow rate with respect to the imposed pulsatile pressure. In a straight tube, it is well known since Sexl's paper [1] published in 1930. In the present study, we consider a pulsatile flow in a stenotic tube. In the case of a high degree of occlusion, a turbulent flow state has been revealed by direct numerical simulations [1, 2]. The presence of turbulence affects the phase shift, and the influence of the both factors, the occlusion degree and turbulence level, is discussed.

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NUMERICAL INVESTIGATION OF THE GAS DYNAMICS IN THE VIBRATING CYLINDRICAL CAVITY

Gubaidullin A.A., Yakovenko A.V.
Tyumen Branch of the Khristianovich Institute of Theoretical and Applied Mechanics SB RAS, Russia
annyakovenko@yandex.ru

We often deal with vibration in the modern world. It can be both an accompanying factor and a part of a technological process. Vibration has significant influence in aircraft and rocket technology. One of the crucial problems of the present day is to study in detail the influence of vibration in the gas-filled cavity. The effects of nonlinearity appear at high amplitudes of vibration velocity of the cavity. Let us consider a cylindrical cavity (tube) filled with a viscous perfect gas (air). No-slip boundary conditions are used for all solid walls. Initially, the gas in the cavity stays still at constant temperature and constant pressure. The equilibrium state is disbalanced due to the vibrational effect $A\cos(\omega t)$ with amplitude A and frequency ω. Let us study two types of thermal boundary conditions: adiabatic and isothermal. The system of governing equations in non inertial frame of reference was solved numerically. The numerical method was verified by some problems with analytical solutions and other numerical tests. Also there was carried out the comparison with the experimental results where was considered a closed tube with a vibrating piston and with analytical solution of the problem in linear approximation. The computation grid was uniform and the number of sells was taken depending of the vibrating frequency.

It was found that in the case of low-frequency vibration the process can be described by the analytical solution with the linear approximation at the steady-state oscillation mode. In the case of high-frequency vibration (for the same amplitude of vibration) the nonlinear effects are observed. In the initial period of time the shock waves are formed. When the shock waves impact the boundary the near boundary pressure significantly exceeds the initial pressure. The oscillations of temperature, density and pressure have the double frequency in the center of the cavity as opposed to the linear case when there is a node of the standing wave. Due to nonlinearity of the process at adiabatic boundary conditions gas heating and increase of the mean pressure due to the influence of viscous dissipation are observed. Also there is the gas rarefaction in the central part of the cavity. Due to nonlinearity of the process at isothermal boundary conditions the average for the period values of temperature, pressure and density are reduced in the central part of the cavity in comparison with their initial values. Time and surface averaged heat flux increases with the frequency of vibration, and its value at the ends of the cavity is greater than at the lateral surface.

THE DYNAMIC BEHAVIOR OF VISCOELASTIC POLYMER COMPOSITES WITH A BIHARMONIC (TWO-FREQUENCY) LOADING

Yankin A.S., Bulbovich R.V., Wildemann V.E., Slovikov S.V.
Perm National Research Polytechnic University
yas.cem@yandex.ru

During the operation of structures made of viscoelastic composites, various kinds of static and dynamic loads arise. The need to study the total effect of such loads leads to the necessity for perfection of the method of dynamic mechanical analysis.
Known studies devoted to research of dynamic mechanical properties at the monoharmonic vibration at different parameters of this vibration (frequency, amplitude, pre-static deformation, etc.). It was revealed that the static deformation almost does not render effect on the phase angle (loss angle), but render a significant effect on the dynamic modulus (complex modulus).
The pre-static deformation can be viewed as a deformation changing with low frequency and a harmonic signal - with high frequency. In this case, we can speak of a biharmonic vibration characterized by a frequencies ratio and varies from 0 to 1.
To determine the dynamic mechanical properties of viscoelastic composites at biharmonic loading was developed method [1, 2]. Biharmonic loading comprises low-frequency component and the high-frequency component. The low-frequency component of loading is regarded as a slowly varying (quasi-static) harmonic load, while the high-frequency component - as a dynamic load operating on its background. For low-frequency and high-frequency components are determined by the dynamic modulus and loss angle. Dynamic modulus and the loss angle low-frequency component is constant in time and equal to the dynamic modulus and the loss angle at a monoharmonic load at equal loadings parameters (frequency, amplitude, etc.). Dynamic modulus and loss angle the high-frequency component varies during one period of oscillation low-frequency component. Thus, we can say that the low-frequency component has influence on dynamic mechanical properties of the high-frequency component, just as the pre-static deformation has influence on the dynamic mechanical properties at a monoharmonic loading.
Also found effect strain amplitude [3], frequency on the dynamic mechanical properties.

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RESEARCH OF SELF-SYNCHRONIZATION OF THE TWO BIHARMONIC EXCITERS ON THE BEARING BODY THAT MADE PLANE VIBRATIONS

Yaroshevych O.N., Sylyvonyuk A.V., Yaroshevich N.P.
Lutsk national technical university
andriy.sylyvonyuk@gmail.com

In many cases vibromachines with biharmonic rule of motion have substantially higher technological efficiency. Due to the high stability of antiphase synchronous rotation mode in the opposite directions of the two exciters on the bearing body, that carries out plane vibrations, possibility of the practical use of such mode of motion is considered for machines with two biharmonic exciters. Each of the biharmonic exciters consists of the two unbalanced monoharmonic exciters, connected to each other with toothed belt with gear ratio 1:2.
By means of the integral criterion of stability of synchronous motions it was conducted the research of self-synchronization of exciters. Is got the expression for a potential function. The values of difference of phases between exciters in possible synchronous motions were defined. It was found that the oscillating system, which was considered, admits three stable synchronous motions in irresonance area. However, only one among the really possible parameters of a vibrational machine can be resistant – the mode of

antiphase synchronous rotation of exciters in the opposite directions. It is shown that the magnitude of the vibrational moments, that ensure the stability of the synchronous mode, are of the same order of vibrational moments for oscillating systems with the two monoharmonic exciters, that found practical deployment.
A numerical modeling and experimental research of self-synchronization of the biharmonic exciters was conducted. As a result, the practical possibility of the stable mode of antiphase synchronous rotation in the opposite directions of biharmonic exciters on the bearing body, that can made plane vibrations, was confirmed.

ON NEW TECHNIQUE FOR BONE FRACTURE FIXATION

Yurkevich K.S.[1,2,3], Mikhasev G.I.[1,2,3], Dosta A.D.[1,2,3], Korolev I.K.[1,2,3]
1 - Belarusian State University, Minsk, Belarus and JSC Altimed, Minsk, Belarus
2 - Institute for Problems in Mechanical Engineering RAS, St.-Petersburg, Russia
3 - CADFEM CIS, St.-Petersburg, Russia
kirill.bsu@gmail.com

During the surgical treatment of the long bones fractures different kinds of metal plates are used. Rigid plates stabilize the fracture site, provide good contact between the bone fragments and don't limit patient mobility. However, treatment with rigid metal plates may cause localized bone loss due to stress-shielding effect and interference with blood circulation in the bone tissue. Circulatory disorders can lead to serious complications and pathologies. Also stresses in places of bolt connections can cause repeated fracture after plate removal. The determination of an optimal plate shape and choosing plate material for saving bone tissue is one of the major problems of traumatology. The placement and type of bolt connections is also very important.
A number of scientific articles devoted to the solution of stress-shielding effect problem. Some researchers suggest to use composite plates which allows to decrease deformations and stresses in the bone stock. Presence of the gap between plate and bone is also one of the ways for decreasing contact pressure on the bone surface. A number of methods to decrease stress-shielding effect are suggested. But until now there are no specific recommendations how to fix the damaged bone without breaking the blood circulation in the bone.
The authors of given paper developed new technique for the fixation of bone fractures. The metal plate, special bolt connections and polytetrafluoroethylene (PTFE) material are used for bone fracture treatment. This technique gives possibility to reduce significantly the contact pressure on the bone surface and avoid blood flow disturbance.
The finite element model for stress-strain state definition of the bone and fixation plate is developed. Calculations for different plate sizes under axial and torque loading were performed. Time-dependent load and plasticity effects were also taken into account. As a result of the finite element simulation optimum parameters for the biomechanical system (plate sizes, thickness of the PTFE material, initial stresses generated by bolts) were obtained. Numerical results have showed a good correlation with experimental data.

TO THE MODELLING OF CRACK IN THE BIMATERIAL ANISOTROPIC STRUCTURES

Zagnetko A.
Aberystwyth University, Department of Mathematics and Physics, Ceredigion, Wales, UK
alz4@aber.ac.uk

This work is dedicated to the problem of interface crack steadily propagating in an elastic anisotropoc solid which is in the case of ceramic materials. We are particularly interesting in how anisotropy in the applied load influence the process. We use for analysis the commercial FEM software COMSOL.
The results are compared with analytical findings. Both interfacial models: perfect and imperfect ones are analysed. We show that the loading profile may together with specific contrast of the material properties may affect the major fracture mechanics parameters of the process.

MINE THERMODYNAMIC PARAMETERS CONTROL BY MEANS OF SUBALLOCATED CONDITIONED AIR DISTRIBUTION SYSTEM

Kazakov B. P., Shalimov A. V., Zaitsev A. V., Klyukin Yu. A., Semin M. A.
Perm Mining Institute, Aerology and Thermal Physics Department
aerolog.artem@gmail.com

At the present time mining companies are taking into recovery deep-lying mineral reserves in order to increase mining output capacity. Greater depth and intensity of mining enable deterioration of climatic conditions in mine workings. The uncomfortable climatic conditions in working places leads to lost productivity, serious human illnesses, impossibility of technical processes management, e.g. increase of failure number while blasting workings.
In the present work, we consider normalization of mine thermodynamic parameters using heat engineering tools with suballocated conditioned air distribution system.
A mathematical model of mine working with environmental unit and air conduit is formulated. At a first approximation a continuous air flow Q(x) from

conditioning air conduit was considered. Cooled air flow influence on mine workings temperature conditions is investigated.
At a next step developed mathematical model was modified in terms of discrete number of cooled air inlets. We investigate efficiency of environmental unit usage as a function of number of discrete cooled air inlets. The “cooled airflow- coordinate” function Q(x) provided uniform temperature field is mine working was found. Uniformity was concerned with equilibrium between two antagonistic thermal processes: air cooling due to environmental unit and air heating due to heat exchange with rock massif.
Developed mathematical model was used in design development in application to 3T-9 block climatic conditions normalization on “Yareganeft” oil mines.

EXPERIMENTAL INVESTIGATION COEFFICIENT OF FRICTION AND WEAR RESISTANCE PLASMA-SPRAYED INSULATION COATING BY ELEVATED TEMPERATURES

Zayatzev A.N.[1], Morozov A.V.[2]
1 - Federal budget - funded research Institute of Machines Science named after A.A.Blagonravov of the RAS
2 - A. Ishlinsky Institute for Problems in Mechanics RAS
odin221@yandex.ru

One of the task of development thermonuclear experimental reactor (TER) is the creation of the insulation coatings working at high operating temperatures, intensive fluence radiation as well as cycle mechanical and thermal loads leading to wear and microcracks in the coating and consequently be able current flowing.
The friction coefficient of plasma-sprayed ceramic coatings working without lubricant applied to TER operation were investigated at constant pressure 7 MPa and temperature 250 °C by range of sliding speed 0.1 – 10.0 mm/s. Linearly reciprocating pin-on-plate dry sliding tests (ASTM G133) were performed with a multifunctional tribometer UMT-2. Three plasma-sprayed ceramic insulation coatings, namely Al_2O_3-$13TiO_2$, ZrO_2-$8Y_2O_3$, Al_2O_3 (laser melting), have been manufactured onto 40X steel plates. The thickness of deposited layer wsa range 300 – 350 µm. Finish processing was mechanical grinding by used a circle of green silicon carbide (SiC). The coating thickness after grinding was 200 - 250 µm, surface roughness Ra = 0,8 - 1,2 mm. Surface melting (modification) was conducted on Al_2O_3 coating after grinding by used the laser system MLP-2 with optical fiber laser (Esto, Russia). Pins were made of stainless steel 316L(N)-IG and alumimium bronze БрАЖНМц 9-4-4-1.
Before testing the samples were kept in a heat vessel (furnace) at 250 °C after that nominal load was applied 200 H (7 MPa). Then the linear reciprocation module with top carriage and fixed pins started motion ensuring relative sliding of the samples at a given sliding speed. For each test wear rate of the sample was determined by measuring wear mass and calculating the wear volume.
Results of the tribological tests:

- by speed range 0.1 -10 mm/s at a constant pressure 7 MPa and elevated temperate 250 °C wear rates and friction coefficient all coatings against both steel and bronze do not depend on the sliding speed;
- friction coefficients investigated coatings against bronze is 1.5 times less than against steel ($f_{\text{БрАЖНМц9-4-4-1}}$ = 0,43 - 0,5, $f_{316L(N)\text{-}IG}$ = 0,54 - 0,64), the minimum value are characterized for the modified coating Al_2O_3;
- the modified coating Al_2O_3 undergoes lowest wear rates $I_h = 5{,}6 \cdot 10^{-6}$.

Analysis of experimental data showed that additional modification coating, for example, using the proposed method of laser melting is an effective way to improve the tribological characteristics of ceramic insulating coatings.

METHODS OF IMPROVING THE TRIBOLOGICAL PROPERTIES OF PLASMA-SPRAYED INSULATING OXIDE COATINGS APPLIED TO THE DETAILS BLANKET OF ITER

Zayatzev A.N.[1], Morozov A.V.[2], Aleksandrova Yu.P.[3]
1 - Federal budget - funded research Institute of Machines Science named after A.A.Blagonravov of the RAS
2 - A. Ishlinsky Institute for Problems in Mechanics RAS
3 - Moscow Aviation Institute
odin221@yandex.ru

An ever increasing demand for reliability thermonuclear experimental reactors (TFTR, ITER, NET etc.) has made very high insulating and mechanical requirements for thermally sprayed oxide coatings (Al_2O_3, $MgAl_2O_4$). During operation electro-insulating oxide coatings (EIC) undergo significant static (up to 450 MPa) and dynamic (up to 200 MPa) loads that will necessarily lead to high shear stress depending on the coefficient of friction pair "EIC - metal".
That is to say there is a possibility of shift oxide coatings owing to high shear stresses. It is necessary to improve the tribological properties of EIC on account of high friction coefficient for pairs "Al_2O_3 - metal", "$MgAl_2O_4$ - metal".
The article reviews various ways concerning improvement tribological properties of EIC. Plasma-sprayed coatings were manufactured on plasma spray equipment YPY-8M with plasma torch M8-27 (capacity: 10-15 kW), operated in Air Plasma Spraying (APS). Carbonitriding process onto niobium alloy (VN-3) plates were conducted in glow-discharge plasma by

specially designed semi-industrial equipment.

The friction properties and wear resistance plasma-sprayed EIC (Al_2O_3) against carbonitrided niobium (VN-3) plates has been investigated through pin-on-disk dry sliding tests (ASTM G99) by different normal loads (100-500 H) at room and elevated temperature (25-250 °C) in air. Sliding speed ($V=1\cdot10^{-5}$ m/c) and distance (L=2 m) were the same in all test. Tribological tests were carried out on a rotary module tribometer Nanovea HL-TRB. For each test wear rates (I_h) of the pin, plate were determined by measuring wear mass and calculating the wear volume. Mechanical properties (microhardness, elastic module) were determined by via a depth-sensing micro/macroindenter Nanovea.

Results of the tribological tests:

- using carbonitrided niobium (VN-3) plates between EIC and mating part allows to reduce friction coefficient up to 0,08 at room temperate by increase wear resistance;
- at low speed ($V=1\cdot10^{-5}$ m/c) the dry sliding wear mechanism of oxide coating was mainly crack propagation induced detachment the most brittle and weakly bound splats;
- the tests at evaluated temperature (250 ºC) in air have been displayed loss antifriction and wear resistance properties Al2O3 in pair carbonitrided niobium by sliding distance more 2 meters;
- the obtained results make it possible to talk about the perspective of applying carbonitrided niobium intermediate plates in pair with EIC (Al2O3) while further research is needed in order to achieve low friction coefficient and high wear resistance at elevated temperatures.

BEAM-BEAM INTERACTION: FROM LOCALIZATION TO NON-GAUSSIAN SPECTRUM

Fedorova A.N., Zeitlin M.G.
MMM, IPME RAS, St. Petersburg, V.O. Bolshoj pr., 61, 199178, Russia
zeitlin@math.ipme.ru

We consider very important in the high-energy beam physics and in plasma physics numerical-analytical modeling for the process of strong-strong beam-beam interactions beyond standard linearized/perturbative methods such as soft gaussian approximation, or Fast Multipole Method (FMM), or related Hybrid FMM, etc. In our approach, the full spectrum of beam-beam interaction consists of discrete coherent modes, discovered before, and the zoo of stochastic incoherent oscillations, appearing as a result of the complex nonlinear inter-mode evolution in the full tower of hidden internal fundamental (eigen)modes or some sort of interference between orbits of the representation of the hidden generic symmetry of the underlying functional space.

We consider the proper multiresolution/multiscale fast convergent decomposition in the bases of high-localized exact nonlinear modes represented by wavelets or wavelet packets as the best tool, allowing to describe the most important in many areas of high-energy physics non-gaussian effects leading to non-trivial dynamical effects, which are very important in the modern accelerator and plasma physics.

The constructed solutions represent the full multiscale spectrum in all internal hidden scales, starting from coarse-grained approximation to finest one. The underlying variational method provides, in principle, the possibility for the algebraical control of spectral data.

LOW-FREQUENCY VIBRATIONS OF A SEMI-INFINITE FLOATING ELASTIC PLATE INTERFACED WITH A RIGID VERTICAL WALL

Kouzov D. P.[1,2], Zhuchkova M. G.[1]
1 - IPME RAS
2 - SMTU
m.zhuchkova@list.ru

A semi-infinite thin elastic plate floating upon a fluid of finite and constant depth is dealt with. The plate is in a contact with a rigid vertical wall. Reflection of the incident surface waves by the plate-wall interface is studied. Exact analytical solution for the wave motion of the plate is derived. Different edge conditions are considered. Comparison of the obtained results with other authors is shown.

NUMERICAL SIMULATION OF GRAIN GROWTH DURING SOLIDIFICATION AND RECRYSTALLIZATION OF METALLIC MATERIALS

Zinovieva O.S.[1,2], Zinoviev A.V.[1], Romanova V.A.[1], Balokhonov R.R.[1], Ploshikhin V.V.[3]
1 - Institute of Strength Physics and Materials Science SB RAS, Russia
2 - National Research Tomsk State University, Russia
3 - University of Bremen, Germany
emelyanova@ispms.tsc.ru

Grain structure of metallic materials formed during solidification and recrystallization influences the resulting mechanical properties and plays a key role for prediction of thermo-mechanical behavior of material by a number of manufacturing processes like casting, welding or additive manufacturing.

A two-dimensional (2D) model for grain growth during the solidification was developed using the cellular automata (CA) method. The implemented algorithm is based on the approach of Rappaz and Gandin and includes the following procedures: i) calculation of the temperature field; ii) calculation of the number of grains

nucleated at each time step; iii) nucleation of grains with randomly chosen crystallographic orientation, satisfying certain conditions; iv) calculation of the solid fraction increment. Using this algorithm, grain growth in aluminum and titanium alloys was calculated for different thermal boundary conditions. Recrystallization process is calculated taking into account the net pressure and the mobility of grain boundary.
The grain growth model proposed offers various opportunities as, for example, to predict mechanical properties of metallic materials or to investigate mechanical defects arising during solidification and/or recrystallization such as e.g. hot cracks.

Results were obtained in the framework of international cooperation with the University of Bremen with funding from the National Research Tomsk State University (TSU) (International Youth Mobility Program).

STUDY OF DEFORMATION PROCESSES IN A POLYCRYSTALLINE ALUMINUM ALLOY USING THREE-DIMENSIONAL MODELS

Zinovieva O.S.[1,2], Romanova V.A.[1], Balokhonov R.R.[1]
1 - Institute of Strength Physics and Materials Science SB RAS, Russia
2 - National Research Tomsk State University, Russia
emelyanova@ispms.tsc.ru

Deformation-induced surface roughening is known to be common phenomenon in metal forming processes, resulting in cosmetically undesirable surfaces, impairment of mechanical properties etc. In this work, uniaxial tension of a polycrystalline aluminum alloy is simulated using three-dimensional (3D) finite-difference (FD) model in order to study surface roughening common behavior and bearing factors as loading conditions and grain size. 3D microstructure models with equiaxial grains, used in the calculations, are developed using step-by-step packing method on a regular mesh. We consider the structural heterogeneity explicitly through the dependence of physical-mechanical properties (density, yield strength, etc.) on the coordinates. The microstructure model developed was implemented in a 3D FD code for parallel computations.
The role of free surface and grain boundaries in the evolution of deformation processes at the mesolevel is investigated. The results indicate that the mesoscale surface roughening in AL6061-T3 aluminum alloy is strongly dependent on the loading conditions and grain size. Optimal thickness of a 3D model for the study of surface roughening is defined.

The work is supported by the RFBR (grant No 14-08-00277-a).

NUMERICAL SIMULATION OF DEFORMATION AND FRACTURE OF COMPOSITION "STEEL SUBSTRATE - POROUS CERAMIC COATING"

Zinoviev A.V., Balokhonov R.R.
Institute of Strength Physics and Materials Science SB RAS
zav@ispms.tsc.ru

In this work we investigate deformation and fracture behavior of composition “steel substrate – porous ceramic coating” under uniaxial compression and tension. The boundary-value problem in a plane strain formulation is solved numerically using the finite difference method. In calculations the composite microstructure is taken into account explicitly. An algorithm to obtain curvilinear computational mesh was developed. Calculations show that due to the mutual influence of pores and interface “coating-substrate” we can observe a complex distribution of compressive and tensile stresses. Obtained results show that stresses concentrate near the interfaces “coating-substrate” and “pore-coating”. In both cases of loading in these places we can observe areas of tension and compression; cracks occur in the tension areas. In tension cracks propagate perpendicular to the axis of loading and in compression parallel. In tension we can see debonding of coating fragments along the interface that leads to a loss of functionality and protective properties of the coating. In compression the pores prevent the rise of main crack: cracks propagate from one pore to another and stop there. Coating peels off gradually, and a thin coating layer without pores stays near the substrate. This character of fracture leads to preservation of the functional and protective properties of the coating.

The work is supported by the RFBR (grant No 12-01-00436-a).

INFLUENCE OF LOADING SCHEME ON THE DEFORMATION BEHAVIOUR OF TITANIUM CRYSTALS

Zolnikov K.P., Kryzhevich D.S., Korchuganov A.V.
Institute of Strength Physics and Materials Science of Siberian Branch Russian Academy of Sciences (ISPMS SB RAS)
kost@ispms.tsc.ru

The behaviour of titanium crystallites during nanoindentation and uniaxial tension is studied in the framework of molecular dynamics. Interatomic interactions are described by many-body potential constructed in terms of modified embedded atom method. All the samples are shaped as parallelepipeds. Tensile loading is carried out at room temperature with strain rates varied between $3.3 \cdot 10^7$ and $3.3 \cdot 10^8$ s^{-1}.

Periodic boundary conditions are applied along the direction of tension and one of the directions normal to it. Free surfaces are simulated in the third direction. Indenter is represented by repulsive force field, which is shaped as a cylinder. Periodic boundary conditions are applied along the axis of cylindrical indenter. The indented face is free surface, while atoms on the opposite face are not allowed to move in the indentation direction. Side faces are simulated as free surfaces. Indenter velocity is varied between 1 and 10 m/s for different simulations.
It has been shown that the nucleation of plastic deformation of loaded specimens corresponds to the generation of local structural changes in crystallites. This is followed by a rapid decrease in the system potential energy. Nanoindentation simulations have showed that local structural changes are generated in the vicinity of the indenter and propagate through the crystallite to the side faces. During tensile loading, local structural changes nucleate on the free surface and propagate through the crystallite to the opposite side. For both loading types, the escape of defects onto free surfaces leads to the formation of a step.

ON NON-LINEAR DYNAMICS OF COUPLED 1+1DOF VERSUS 1+1/2DOF ELECTRO-MECHANICAL SYSTEM

Darula R., Sorokin S.
Department of Mechanical and Manufacturing Engineering, Aalborg University, Denmark
dra@m-tech.aau.dk

The electro-mechanical systems (EMS) are used from nano-/micro-scale (NEMS/MEMS) up to macro-scale applications. From mathematical view point, they are modelled with the second order differential equation (or a set of equations) for mechanical system, which is non-linearly coupled with the second or the first order differential equation (or a set of equations) for electrical system, depending on properties of the electrical circuit. For the sake of brevity, we assume a 1DOF mechanical system, coupled to 1 or 1/2DOF electrical system (depending whether the capacitance is, or is not considered). In the paper, authors perform a parametric study to identify operation regimes, where the capacitance term contributes to the non-linear behaviour of the coupled system. To accomplish this task, the classical method of multiple scales is used. The parametric study allows us to assess for which applications the capacitance term needs to be considered and in contrary, when the investigation of the coupled system can be simplified neglecting the capacitance of the electrical system and treating the electric circuit as a diffusion type system (i.e. contributing with 1/2DOF). The outcomes presented in this study can be generalized also for multi DOF systems.

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Contacts:
tel. +7 (812) 335 2055, fax +7 (812) 335 2039
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