XLI Summer School – Conference
“Advanced Problems in Mechanics”
July 1 – 6, 2013, St. Petersburg (Repino), Russia

A P M 2 0 1 3
BOOK OF ABSTRACTS

http://apm-conf.spb.ru
GENERAL INFORMATION

The International Summer School – Conference “Advanced Problems in Mechanics – 2013” is the forty
first 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
12/31/1982) from different all over the world, specializing in the sphere of theoretical and applied me-
chanics 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 pur-
poses 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.

SCIENTIFIC COMMITTEE

- D. A. Indeitsev (IPME RAS, St. Petersburg, Russia) — Co-Chairman
- A. M. Krivtsov (St. Petersburg State Polytechnical University, IPME RAS, Russia) — Co-Chairman
- I. E. Berinskii (IPME RAS, St. Petersburg State Polytechnical University, Russia) — Scientific Sec-
  retary
- O. S. Loboda (St. Petersburg State Polytechnical University, IPME RAS, Russia) — Scientific Sec-
  retary
- H. Altenbach (Martin-Luter University Halle Wittenberg, Otto-von-Guericke-University Magdeburg,
  Germany)
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] Workshop: “Recent advances in numerical simulation of hydraulic fracture”
Gennady Mishuris (UK), Alexander Linkov (Russia, Poland)

[MS2] Minisymposium “Modelling and numerical methods in biomechanics”
Udo Nackenhorst (Germany), Leah Sharipova (Russia)

Alexander Karapetyan (Russia), Alexander Kuleshov (Russia)

[MS4] Minisymposium “Nonlinear dynamics of media with micro- and nanostructures and related nonlinear wave problems”
Eron L. Aero (IPME, Russia), Alexey V. Porubov (IPME, Russia)

[MS5] Minisymposium “Diamonds and related materials”
Nikita F. Morozov, (IPME, SPbSU, Russia), Anton M. Krivtsov (IPME, SPbSPU, Russia)

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.
Monomax Ltd.
professional congress organizer
in Saint Petersburg and Northwest Russia

Monomax Ltd is a fully licensed professional travel and business cooperation company with 20 years of practical experience in destination management. Our activity past 19 years helped us to gain the reputation of a reliable partner in Russia and abroad. Company’s staff of highly trained professionals always offers its full assistance. Monomax Ltd provided services for about 150 international and more than 1000 local events held in St. Petersburg in 1991-2013.

Monomax Ltd offers from A to Z services to the major international conferences, congresses, symposia, festivals and exhibitions as well as to incentive and educational tourism groups.

We plan all events imaginatively and organize them efficiently and economically to the last detail.

Services we offer include:

- consulting on congress planning & management
- participants registration and administration, database developing and on-line registration
- financial management of the event budget, developing of bid, preliminary budget, accumulation of registration fees, fundraising
- highly skilled congress secretariat, informative work on event, original software for congress management
- congress venue selection, all kinds of presentation equipment, including simultaneous translation equipment
- interpreter services, simultaneous translation, guides-interpreters, individual and group guidance, written translation
- exhibitions and poster sessions facilities, exposition project, fitting, technical assistance
- handling and printing all kinds of congress materials, including programs, announcements, abstracts, proceedings, brochures, etc.
- participant packets, congress bags
- hotel accommodation & visa support
- catering & meal services: coffee breaks, lunches, dinners, fourchettes, banquets, receptions
- transportation services, transfers, shuttle buses
- concert and special programs, theater events
- social and cultural programs, excursions, post-congress tours
- special programs for VIP, corporative clients
- presentations

Address for correspondence: PO box 168, 195112 Saint Petersburg, Russia
tel. +7 (812) 335 2055, fax +7 (812) 335 2039
E-mail: feedback@monomax.org Web site: http://www.monomax.ru
### Day 1 – Monday, July 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Room A</th>
<th>Room B</th>
<th>Room C</th>
</tr>
</thead>
<tbody>
<tr>
<td>08.30–09.45</td>
<td>REGISTRATION</td>
<td>15.30–16.50 SOLIDS AND STRUCTURES – I</td>
<td>15.20–16.50 WAVE MOTION – I</td>
</tr>
<tr>
<td>09.45–10.00</td>
<td>OPENING CEREMONY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.00–11.30</td>
<td>PLENARY LECTURES – I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.30–11.50</td>
<td>COFFEE BREAK</td>
<td>16.50–17.10</td>
<td></td>
</tr>
<tr>
<td>11.50–13.20</td>
<td>PLENARY LECTURES – II</td>
<td>17.10–18.30 SOLIDS AND STRUCTURES – II</td>
<td>17.10–18.30 WAVE MOTION – I</td>
</tr>
<tr>
<td>15.30–16.50</td>
<td>ADVANCES IN NUMERICAL SIMULATION OF HYDRAULIC FRACTURE – I</td>
<td>15.30–16.50 WAVE MOTION – I</td>
<td></td>
</tr>
<tr>
<td>16.50–17.10</td>
<td>COFFEE BREAK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.10–19.00</td>
<td>ADVANCES IN NUMERICAL SIMULATION OF HYDRAULIC FRACTURE – II</td>
<td>15.20–16.50 WAVE MOTION – I</td>
<td></td>
</tr>
<tr>
<td>20.00</td>
<td>WELCOME PARTY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Day 2 – Tuesday, July 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Room A</th>
<th>Room B</th>
<th>Room C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00–11.30</td>
<td>PLENARY LECTURES – III</td>
<td>11.50–13.50 MECHANICS OF MEDIA WITH MICROSTRUCTURE – I</td>
<td>11.50–13.50 NONLINEAR DYNAMICS, CHAOS AND VIBRATION – I</td>
</tr>
<tr>
<td>11.30–11.50</td>
<td>COFFEE BREAK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.50–13.50</td>
<td>MODELLING AND NUMERICAL METHODS IN BIOMECHANICS – I</td>
<td>15.30–16.50 MECHANICS OF MEDIA WITH MICROSTRUCTURE – II</td>
<td>15.30–16.50 DIAMONDS AND RELATED MATERIALS</td>
</tr>
<tr>
<td>15.30–16.50</td>
<td>RELATED PROBLEMS OF GEOMECHANICS – I</td>
<td>15.30–16.50</td>
<td>15.30–16.50</td>
</tr>
<tr>
<td>16.50–17.10</td>
<td>COFFEE BREAK</td>
<td>16.50–17.10</td>
<td></td>
</tr>
<tr>
<td>17.10–19.10</td>
<td>RELATED PROBLEMS OF GEOMECHANICS – II</td>
<td>17.10–18.50 MECHANICAL AND CIVIL ENGINEERING APPLICATIONS</td>
<td>17.10–18.50 DYNAMICS OF A RIGID BODY CONTACTING WITH A SURFACE: VARIOUS ASPECTS – I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Location</td>
<td>Event</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>10.00–11.30</td>
<td>ROOM A</td>
<td>PLENARY LECTURES – IV</td>
<td></td>
</tr>
<tr>
<td>11.30–11.50</td>
<td></td>
<td>COFFEE BREAK</td>
<td></td>
</tr>
<tr>
<td>11.50–13.50</td>
<td></td>
<td>MODELLING AND NUMERICAL METHODS IN BIOMECHANICS – II</td>
<td></td>
</tr>
<tr>
<td>15.20–16.50</td>
<td></td>
<td>LUNCH BREAK</td>
<td></td>
</tr>
<tr>
<td>16.50–17.10</td>
<td></td>
<td>MODELLING AND NUMERICAL METHODS IN BIOMECHANICS – III</td>
<td></td>
</tr>
<tr>
<td>17.10–19.10</td>
<td></td>
<td>COFFEE BREAK</td>
<td></td>
</tr>
<tr>
<td>17.10–19.10</td>
<td></td>
<td>NONLINEAR DYNAMICS OF MEDIA WITH MICRO- AND NANOSTRUCTURES AND RELATED NONLINEAR WAVE PROBLEMS – II</td>
<td></td>
</tr>
<tr>
<td>21.00</td>
<td></td>
<td>CONFERENCE DINNER</td>
<td></td>
</tr>
</tbody>
</table>

Day 3 – Wednesday, July 3

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.50–14.10</td>
<td>ROOM B</td>
<td>NANOMECHANICS</td>
</tr>
<tr>
<td>15.30–16.50</td>
<td></td>
<td>NONLINEAR DYNAMICS OF MEDIA WITH MICRO- AND NANOSTRUCTURES AND RELATED NONLINEAR WAVE PROBLEMS – I</td>
</tr>
<tr>
<td>16.50–17.10</td>
<td></td>
<td>COFFEE BREAK</td>
</tr>
<tr>
<td>17.10–19.30</td>
<td></td>
<td>NONLINEAR DYNAMICS OF MEDIA WITH MICRO- AND NANOSTRUCTURES AND RELATED NONLINEAR WAVE PROBLEMS – II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.50–13.10</td>
<td>ROOM C</td>
<td>SOLIDS AND STRUCTURES– III</td>
</tr>
<tr>
<td>15.30–16.50</td>
<td></td>
<td>AEROSPACE MECHANICS</td>
</tr>
<tr>
<td>16.50–17.10</td>
<td></td>
<td>COFFEE BREAK</td>
</tr>
<tr>
<td>17.10–19.30</td>
<td></td>
<td>IN COMMEMORATION OF YA.G. PANOVKO</td>
</tr>
</tbody>
</table>

Day 4 – Thursday, July 4

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.15–11.30</td>
<td>ROOM A</td>
<td>PLENARY LECTURES – V</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>EXCURSION</strong></td>
</tr>
</tbody>
</table>
## Day 5 – Friday, July 5

<table>
<thead>
<tr>
<th>Time</th>
<th>Room A</th>
<th>Room B</th>
<th>Room C</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.45</td>
<td>OPENING OF MWM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>PLENARY LECTURES – VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.30</td>
<td>COFFEE BREAK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.30</td>
<td>MWM PRESENTATIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.30</td>
<td>PLENARY LECTURES – VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.45</td>
<td>LUNCH BREAK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.30</td>
<td>MWM POSTERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.00</td>
<td>COFFEE BREAK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.30</td>
<td>POSTERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.30</td>
<td>LUNCH BREAK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.00</td>
<td>MWM ACTIVITIES</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NIGHT EXCURSION**

## Day 6 – Saturday, July 6

<table>
<thead>
<tr>
<th>Time</th>
<th>Room A</th>
<th>Room B</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00</td>
<td>PLENARY LECTURES – VII</td>
<td></td>
</tr>
<tr>
<td>10.30</td>
<td>COFFEE BREAK</td>
<td></td>
</tr>
<tr>
<td>11.30</td>
<td>FLUID AND GAS</td>
<td></td>
</tr>
<tr>
<td>11.45</td>
<td>LUNCH BREAK</td>
<td></td>
</tr>
<tr>
<td>15.30</td>
<td>DYNAMICS OF A RIGID BODY CONTACTING WITH A SURFACE: VARIOUS ASPECTS – II</td>
<td></td>
</tr>
<tr>
<td>15.45</td>
<td>LUNCH BREAK</td>
<td></td>
</tr>
<tr>
<td>17.30</td>
<td>NONLINEAR DYNAMICS, CHAOS AND VIBRATION – II</td>
<td></td>
</tr>
<tr>
<td>17.45</td>
<td>COMPUTATIONAL MECHANICS</td>
<td></td>
</tr>
</tbody>
</table>
Day 1 – Monday, July 1

ROOM A

08.30–09.45  REGISTRATION
09.45–10.00  OPENING CEREMONY
10.00–11.30  PLENARY LECTURES – I
   Chair: A.M. Krivtsov
11.30–11.50  COFFEE BREAK
11.50–13.20  PLENARY LECTURES – II
   Chair: D.A. Indeitsev

LUNCH BREAK

15.30–16.50  ADVANCES IN NUMERICAL SIMULATION OF HYDRAULIC FRACTURE – I
   Chair: S. Cox
15.30–15.40  Introduction
16.50–17.10  COFFEE BREAK
17.10–19.00  ADVANCES IN NUMERICAL SIMULATION OF HYDRAULIC FRACTURE – II
   Chair: A. Savitski
18.00–18.20  G. Mishuris, M. Wrobel, P. Kuśmierczyk. PKN model of hydrofracturing under various fluid flow regimes. numerical implementations in different dependent variables.
18.20–18.40  S. Golovin, V. Isaev, S. Kalinin, D. Kuznetsov. Motion of binary fluid in a crack in elastic porous media.
18.40–19.00  Discussion

20.00 Welcome Party
Day 1 – Monday, July 1

ROOM B

15.30–16.50 **SOLIDS AND STRUCTURES – I**
*Chair: S.A. Lychev*

15.30–15.50 **S.M. Aizikovich, A.S. Vasiliev, S.S. Volkov.** Distribution of contact stresses under circular flexible plate lying on a two-layer foundation, with soft interlayer thickness and substrate stiffness taken into account.

15.50–16.10 **N.V. Banichuk, S.Y. Ivanova.** On optimal anisotropic bodies in the heat conduction problems.


16.30–16.50 **O. Bocharov, V. Rudyak, A. Seryakov.** Model hierarchy and peculiarities of the deformation of porous media saturated with fluids.

16.50–17.10 **COFFEE BREAK**

17.10–18.10 **SOLIDS AND STRUCTURES – II**
*Chair: N.V. Banichuk*

17.10–17.30 **R.A. Arutyunyan.** Reliability of complex mechanical systems under the action of cyclyc loading and corrosive media.


17.50–18.10 **S.A. Lychev, A.V. Manzhirov, I. Fedotov.** Nonstationary vibrations of a growing thermoelastic parallelepiped.

ROOM C

15.20–16.50 **WAVE MOTION – I**
*Chair: S.N. Gavrilov, M.G. Zhuchkova*

15.20–15.40 **S.N. Gavrilov, E.V. Shishkina.** A strain-softening bar revisited.


16.00–16.20 **Z. Yang, Z. Jianwei, S. Zhaoqun.** The scattering of inclusions by elastic wave in two-phase media.

16.20–16.35 **M. Babenkov, E. Ivanova.** Propagation processes of the heat waves in a layer with regard to the heat flux relaxation.

16.35–16.50 **A.V. Yakovenko.** Nonlinear effects in the vibrating cavity filled with a perfect gas.

16.50–17.10 **COFFEE BREAK**

17.10–18.50 **WAVE MOTION – II**
*Chair: M.G. Zhuchkova*

17.10–17.30 **M.V. Siltikov, M.V. Chernysh.** Formation of the shock-wave pattern in a closed cluttered volume at non-ideal blast wave propagation


17.50–18.10 **I.N. Soldatov, N.V. Klyueva, M.E. Tkach.** The effect of viscosity on waves and stability of the Rankine vortex with axial flow.

18.10–18.30 **V.M. Kolykhalin.** Wave estimation of volume of the liquid, granular and mixed compositions in cylindrical tanks.

20.00 Welcome Party
Day 2 – Tuesday, July 2

ROOM A

10.00–11.30  **PLENARY LECTURES – III**  
Chair: E.V. Lomakin  
10.00–10.45  **V.A. Babeshko, O.V. Evdokimova, O.M. Babeshko, M.N. Kolesnikov, V.L. Shestopalov.** Bodies with cracked coatings.
10.45–11.30  **A. Castellanos.** The role of triboelectricity in powder behavior.

11.30–11.50  **COFFEE BREAK**

11.50–13.50  **MODELLING AND NUMERICAL METHODS IN BIOMECHANICS – I**  
Chair: J. Schröder  
11.50–12.20  **U. Nackenhorst, G. von Lewinski.** Computational biomechanics of bones.
12.50–13.20  **N. Kizilova.** Mathematical modeling of cell growth in active biodegradable scaffolds for tissue engineering.
13.20–13.50  **I.N. Dashevskiy, S.E. Nikitin.** Measurement and modeling of the unloading function of Lower limbs orthoses.

**LUNCH BREAK**

15.30–16.50  **RELATED PROBLEMS OF GEOMECHANICS – I**  
Chair: G. Mishuris  
15.30–15.50  **I. Sevostianov, A. Giraud.** Elastic properties of oolitic limestone: micromechanical modeling and verification.
15.50–16.10  **V.I. Kushch, I. Sevostianov.** Effect of crack density, orientation and clustering on SIF statistics and anisotropy of randomly cracked solid.
16.10–16.30  **I.N. Dashevskiy.** On the formation of regular crack networks around oil and gas wells under uniform compression.
16.30–16.50  **V. Koshelev.** Semi-analytical method for solving boundary value problems for multi-wedge body containing a domain with internal structure.
16.50–17.10  **COFFEE BREAK**

17.10–19.10  **RELATED PROBLEMS OF GEOMECHANICS – II**  
Chair: A. Krivtsov  
17.10–17.30  **T.P. Miroshnichenko.** The gas outflow from underground storage under high pressure gradient.
17.30–17.50  **A.K. Belyaev, V.A. Polyanskiy, Y.A. Yakovlev.** The conditions of parametric instability in materials containing the hydrogen.
17.50–18.10  **M.I. Samoilov, V. Dreiman.** Samotlor field: multifrac integrated design for horizontal well.
18.10–18.30  **D. Ferguson.** Foams in porous media.
18.50–19.10  **Discussion**
Day 2 – Tuesday, July 2

ROOM B

11.50–13.50 **MECHANICS OF MEDIA WITH MICROSTRUCTURE – I**  
*Chair: A.B. Freidin*

11.50–12.10 **E. Grekova.** A theoretical way to construct materials with resonant frequencies, forbidden bands, and apparent history dependence.

12.10–12.30 **V.I. Kushch.** Micromechanical model of interface damage accumulation in fibrous composite.


**LUNCH BREAK**

15.30–16.50 **MECHANICS OF MEDIA WITH MICROSTRUCTURE – II**  
*Chair: E. Grekova*

15.30–15.50 **E.E. Mukhin, A.M. Polyanskiy, V.A. Polyanskiy, Y.A. Yakovlev.** The destruction of interface of silicon’s heterogeneous structures as a result the hydrogen diffusion.

15.50–16.10 **O.V. Sadovskaya.** Numerical simulation of deformation of a metal foam.


16.30–16.50 **V. Somsikov.** Why it is necessary to construct the mechanics of structured particles and how to do it.

16.50–17.10 **COFFEE BREAK**

17.10–18.50 **MECHANICAL AND CIVIL ENGINEERING APPLICATIONS**  
*Chair: V.A. Eremeyev*

17.10–17.30 **S.V. Petinov, R.V. Guchinsky.** Fatigue design of expansion joint in ship superstructure.

17.30–17.50 **N.V. Makarova, A.S. Lipovoy.** Properties investigation of the cement composites containing nanostructured mineral fibers.

17.50–18.10 **A.V. Zaitsev, A.A. Fukalov, A.V. Kutergin.** Exact analytical solutions to problems on equilibrium state of elastic orthotropic heavy bodies with axial symmetry and their geomechanical applications.


Day 2 – Tuesday, July 2

ROOM C

11.50–13.50 **NONLINEAR DYNAMICS, CHAOS AND VIBRATION – I**  
*Chair: A.G. Knyazeva*

11.50–12.10 **I.I. Blekhman.** Complex (“chaotic”) behaviour of dynamical systems as a consequence of its multimode character.

12.10–12.30 **A.K. Abramian, S.A. Vakulenko.** Nonlinear oscillations of a beam made from dynamic material.

12.30–12.50 **G.Y. Panovko, A.M. Gouskov.** Bifurcation analysis of vibrations mechanical system with an electric drive with limited capacity.

12.50–13.10 **D.G. Arseniev, V.V. Kotov, V.A. Polyanskiy, N.A Smirnova.** Biomorphic control of the stochastic vibrations.

13.10–13.30 **A.D. Sergeyev.** Torsional oscillations of a curved drillstring at sloping directional drilling.


**LUNCH BREAK**

15.30–16.50 **DIAMONDS AND RELATED MATERIALS**  
*Chair: N.F. Morozov, A.M. Krivtsov*

15.30–15.50 **A.K. Rebrov.** Gas dynamic deposition of nano-size films.

15.50–16.10 **S.A. Kukushkin, A.V. Osipov.** A new method for the synthesis of epitaxial layers of silicon carbide on silicon owing to formation of dilatation dipoles.

16.10–16.30 **S.A. Voropaev.** The methods of synthesis and different crystal forms of nanodiamond.

16.30–16.50 **Discussion**

16.50–17.10 **COFFEE BREAK**

17.10–18.50 **DYNAMICS OF A RIGID BODY CONTACTING WITH A SURFACE: VARIOUS ASPECTS – I**  
*Chair: A.S. Kuleshov, A.V. Karapetyan*

17.10–17.30 **A. Aleksandrova, T. Salnikova.** Some aspects of the thermodynamics of the dissipative system.

17.30–17.50 **A.S. Kuleshov, G.A. Chernyakov.** Investigation of the problem of motion of a heavy dynamically simmetric body on a perfectly rough plane by the Kovacic algorithm.

17.50–18.10 **A.S. Kuleshov, S.V. Ifraimov.** Motion of a rigid rod on a convex surface.

18.10–18.30 **A.V. Karapetyan, M.A. Munitsyna.** Dynamics of an ellipsoid on the horizontal plane with friction.

18.30–18.50 **A.S. Kuleshov, M.O. Itskovich.** Motion of a rigid body consisting of two symmetric laminae on a horizontal plane.
Day 3 – Wednesday, July 3

ROOM A

10.00–11.30 PLENARY LECTURES – IV
   Chair: E. Vilchevskaya
   10.00–10.45 A.M. Krivtsov. Analytical and computer modelling in mechanics of discrete media
11.30–11.50 COFFEE BREAK
11.50–13.50 MODELLING AND NUMERICAL METHODS IN BIOMECHANICS – II
   Chair: L. Sharipova
   11.50–12.20 I.G. Goryacheva, G.M. Anferov. Analysis of stresses in thumb carpometacarpal joint based on the tomography data
   13.20–13.50 A.A Koroleva, S.M. Bosiakov. The prediction of the fracture risk of the long bones after sectoral resection.

LUNCH BREAK

15.20–16.50 MODELLING AND NUMERICAL METHODS IN BIOMECHANICS – III
   Chair: N. Kizilova
16.50–17.10 COFFEE BREAK
17.10–19.10 MODELLING AND NUMERICAL METHODS IN BIOMECHANICS – IV
   Chair: U. Nackenhorst
   18.30–18.50 V.S. Yushutin. Non-Newtonian flow in a collapsible tube: does rheology of blood affect stability of a vessel?

21.00 Conference Dinner
Day 3 – Wednesday, July 3

ROOM B

11.50–14.10 **NANOMECHANICS**
Chair: V.A. Kuzkin

11.50–12.10 **W.H. Mueller, C. Liebold.** FE-implementation of higher gradient theories and its use for experimental analysis.

12.10–12.30 **I. E. Berinskii, A. M. Krivtsov.** On the bending rigidity of graphene membranes.


12.50–13.10 **R. Yang, Q. Zhang, F. Ke, Y. Bai.** Approaches to probe the free-surface-induced size effect of material by indentation.

13.10–13.30 **W. Shan, U. Nackenhorst.** Transition from MD to continuum based on statistical mechanics.

13.30–13.50 **K.B. Ustinov.** On problem of interface crack parallel to free boundary; equivalent elastic clamping conditions.


LUNCH BREAK

15.30–16.50 **NONLINEAR DYNAMICS OF MEDIA WITH MICRO – AND NANOSTRUCTURES AND RELATED NONLINEAR WAVE PROBLEMS – I**
Chair: E.L. Aero, A.V. Porubov

15.30–15.50 **E.L. Aero, A.N. Bulygin, Yu.V. Pavlov.** Especial effects of reconstruction of structure of superthin crystal layers at intensive loading.

15.50–16.10 **E.L. Aero, A.N. Bulygin, Y.V. Pavlov.** Propagation of waves in thin crystal layers at different potentials of interaction of sublattices.

16.10–16.30 **V.I. Erofeev, I.S. Pavlov, V.V. Kazhaev.** Interaction of solitons propagating in a granular medium.


16.50–17.10 **COFFEE BREAK**

17.10–19.10 **NONLINEAR DYNAMICS OF MEDIA WITH MICRO – AND NANOSTRUCTURES AND RELATED NONLINEAR WAVE PROBLEMS – II**
Chair: E.L. Aero, A.V. Porubov

17.10–17.30 **A.V. Porubov.** Nonlinear dynamics of diatomic lattices.

17.30–17.50 **S. Lurie, A. Gusev, N. Tuchkova.** The principle of symmetry and simple gradient theory.

17.50–18.10 **D. Shepelev, V.V. Smirnov, L.I. Manevitch.** Energy exchange and localization in carbon nanotubes.

18.10–18.30 **L.V. Mirantsev.** Squeezing out of matter between crystalline substrates.

18.30–18.50 **E.L. Aero, A.L. Korzhenevskii.** The theory of squeeze-out of a crystal layer with formation of defects of structure.

18.50–19.10 **A.L. Korzhenevskii.** Diffusion-induced oscillations of extended defects.

21.00 Conference Dinner
Day 3 – Wednesday, July 3

ROOM C

11.50–13.10 **SOLIDS AND STRUCTURES – III**  
*Chair: A.V. Zaitsev*


12.30–12.50 **T.B. Lavrova.** The threshold extent of softening and the incipiency of fracture in the Tresca-type materials.


**LUNCH BREAK**

15.30–16.50 **AEROSPACE MECHANICS**  
*Chair: P.Yu. Georgievsky*


15.50–16.10 **A.A. Tikhonov, A.Yu. Aleksandrov.** On the satellite's electrodynamic attitude stabilization.


16.50–17.10 **COFFEE BREAK**

17.10–19.30 **IN COMMEMORATION OF YA.G. PANOVKO**

21.00 Conference Dinner
Day 4 – Thursday, July 4

ROOM A

09.15–11.30  PLENARY LECTURES – V  
Chair: E. Vilchevskaya

10.00–10.45  Y. V. Petrov. Strain rate effects on rock materials
10.45–11.30  R.Z. Valiev. Physics and mechanics of bulk nanostructured metals
11.30–11.50  COFFEE BREAK

EXCURSION
Day 5 – Friday, July 5

ROOM A

09.45–10.00 OPENING OF MWM
10.00–11.30 PLENARY LECTURES – VI
   Chair: I. Asonov
10.00–10.45 S. Cox. The mechanics of liquid foams.
10.45–11.30 V.A. Eremeyev. Introduction to micropolar mechanics.
11.30–11.50 COFFEE BREAK

LUNCH BREAK

ROOM B

15.30–17.00 MWM POSTERS
17.00–17.20 COFFEE BREAK
17.20–18.50 POSTERS

ROOM C

17.20–19.20 MWM activities

Night excursion
Day 6 – Saturday, July 6

ROOM A

10.00–11.30  **PLENARY LECTURES – VII**
*Chair: O.S. Loboda*
10.00–10.45  **R.R. Mulyukov.** Properties and applications of bulk nanostructured materials.
11.30–11.50  **COFFEE BREAK**
11.50–13.50  **FLUID AND GAS**
*Chair: V.A. Kuzkin*
11.50–12.10  **N.N. Smirnov, V.F. Nikitin, Yu.G. Phylippov.** Hydrogen engines numerical modeling.
12.10–12.30  **M.N. Smirnova, A.V. Zvyaguin.** High velocity gliding of a plate with final length cavity formation.
12.30–12.50  **I.F. Melikov, A.S. Amosov, S.A. Chivilikhin.** Response of a stratified viscous half-space to a perturbation of the free surface.
12.50–13.10  **S.F. Urmancheev.** Pattern formation in the layer of anomalous thermoviscous liquids.
13.10–13.30  **N.A. Lutsenko.** On mathematical modeling of gas cooling of axisymmetric porous heat-evolutional objects with partial closure of the object's outlet.
13.50–14.10  **V.I. Zapryagaev, V.M. Boiko, A.A. Pivovarov.** Experimental investigation of a high-speed jet velocity field by using optical methods.

**LUNCH BREAK**

15.30–16.50  **DYNAMICS OF A RIGID BODY CONTACTING WITH A SURFACE: VARIOUS ASPECTS – II**
*Chair: A.S. Kuleshov, A.V. Karapetyan*
15.30–15.50  **E.V. Filatkina.** Control problem of wheeled mobile platform with slipping.
15.50–16.10  **A. Rusinova.** On the dynamics of a homogeneous puck on an inclined plane with friction.
16.10–16.30  **M.V. Shamolin.** Review of integrable cases in dynamics of small- and multidimensional rigid body in a nonconservative field.
16.30–16.50  **A.A. Zobova, M.V. Ishhanyan.** Dynamical stress distribution in the motion of a ball on a rough plane.

16.50–17.10  **CLOSING CEREMONY**
Day 6 – Saturday, July 6

ROOM B

11.50–13.50  NONLINEAR DYNAMICS, CHAOS AND VIBRATION – II

Chair: A.S. Kuleshov

11.50–12.10  M.Ya. Panovko. The point elastohydrodynamic contact under non-steady state loading.

12.10–12.30  D. Skubov, D. Vavilov. Dynamics of conductive solid bodies in high-frequency alternating magnetic field.

12.30–12.50  V.S. Sorokin. Motion of a pendulum with vibrating suspension axis at unconventional values of parameters.


LUNCH BREAK

15.30–16.50  COMPUTATIONAL MECHANICS

Chair: I.E. Berinskii, V. Bratov


15.50–16.10  V. Bratov, Y. Petrov. Erosion-type fracture of asphalt concrete as a result of automobile studs impacts.


7. A. V. Plashchynska, P. N. Baranova. Fatigue fracture of thin rectangular plates with central crack under uniaxial high-cyclic symmetrical loading.
10. A. Boudine, L. Kalla, K. Benhizia, M. Zaabat. 2 deg spinfet model.
12. I. N. Dashevskiy. Symmetric Cracking in Bending of a Plate and a Wedge.
17. A. I. Dmitriev, W. Oesterle, H. Kloss, G. Orts-Gil. Modification of automotive brake pad-disc interface in order to provide smooth sliding conditions. Comparison of nano-scale modeling with experiment.
22. A. Hakem, Y. Bouafia. Influence of ripening, molding processes and the addition of Mg on the evolution of the main mechanical and structural properties of the binary alloy 42000.
25. K. Hamouda. Surface treatment by using granular flexible particles as working environment.
27. N. V. Klyueva, I. N. Soldatov. A model of imperfect interface and delamination detection by normal waves.
30. T. Korepanova, V. Korepanov, N. Svedova. Analytical and numerical investigations of the character of stresses in the vicinity of singular points in the framework of the classical and asymmetric theory of elasticity.
31. **S. Kouachi, M. Bouhenguel.** Theoretical study of the Fluid flow and bubble velocity effect on the flotation rate constant at the application of the inertialless collision efficiency models models.

32. **M. Kouznetsov, A. Yakirevich, S. Sorek.** Flow patterns at the Ramat Hovav disposal site, Israel.

33. **O. N. Kryukova, A. G. Knyazeva.** Influence of particle mixing in the melt on the characteristics of electron-beam treatment process of metal surface.


35. **S. Osmani.** Stochastic finite elements, kriking and Ito's integral on proprieties distribution estimation.

36. **V. E. Petrov.** Models and solutions of forced quasi 2D turbulence with chemical reactions.

37. **M. Podolsky.** Field description of rotational motion.

38. **M. Podolsky.** Coriolis inertia forces in the problem of Euler’s turbine equation.


40. **E. V. Prozorova, A. V. Shadrin.** Influence dispersion in solid and gas-solid for moving body.

41. **S. O. Gladkov, R. G. Rabadanov.** Onsynergetic oscillations a thin string.

42. **E. Schwab, R. Balokhonov, V. Romanova, V. Kovalev.** Numerical simulation of deformation and fracture in a material with composite coating.

43. **N. V. Sevodina, A. Yu. Fedorov.** Singular solutions at singular points of composite wedges for different types of boundary and contact conditions.

44. **O. K. Garishin, V. V. Shadrin, I. A. Morozov.** Experimental studies of polymer-silicate nanocomposites structure.

45. **D. N. Sheydaakov, A. G. Fedorenko.** Buckling of nonlinearly elastic rods of inhomogeneous micropolar materials.

46. **S. G. Psakhie, E. V. Shilko, E. V. Ovcharenko, S. V. Astafurov.** The influence of characteristics of mesoscopic internal structure on the mechanical properties and fracture pattern in metal-ceramic composites.

47. **E. Shishkin.** Self-synchronization of pair vibration exciters in the cone crusher.


49. **V. Dushin, V. Nikitin, Yu. Philippov, N. N. Smirnov.** Displacement of miscible viscous fluids from thin gaps.

50. **V. V. Sokurov, I. K. Sokolovskiy.** Investigation of the aggregate state changes of clay soils.


52. **R. M. Sultanalieva.** Loss of strength rocks under the influence microwave.

53. **E. Svijazheninov.** Multibeam ignition transducer-distributor for internal combustion engine.

54. **T. Tada, N. Kawamura, K. Urayama.** Separability of strain and time effects on viscoelasticity of filled elastomers.

55. **E. L. Tarunin.** Electrostatic interaction of charged conducting bodies on small distances.

56. **P. Uglich.** On the inverse coefficient problem for the transversally inhomogeneous elastic layer.


58. **V. Vinnikov, M. Gritsevich, D. Kuznetsova, V. Lukashenko.** Drag, ablation and fragmentation of a meteor body in the atmosphere.


60. **B. Zak, S. Hoiyc.** About method of identification of unmanned underwater vehicle for control its movement.

5. E. Batukhtina, V. Romanova, R. Balokhonov. Design of periodical polycrystals basing on Voronoi tessellation.
7. C. A. Bushueva, K. G. Kostarev. Dynamics of the ferrofluid layer on a liquid substrate in vertical magnetic fields.
13. P. Grigorieva, N. Markov, R. Lapin. Development of algorithms for computing the collisional dynamics of gravitating particles to simulate the formation of the earth-moon system through the gravitational collapse of a dust cloud under the influence of Sun gravity.
25. A. O. Lemza, E. V. Murashkin. Calculation of residual deformations at rotary motion of the elastic creep material.
30. V. S. Moreva. On simulation of the flow around an airfoil using different numerical schemes of vortex element method.

32. **L. V. Nadkrinichnyi.** Modeling of a wave disturbance caused by the shock-wave moving above a liquid surface.


35. **A. Osokina.** Simulation of the interatomic interactions in crystal lattices.


37. **T. N. Pogosian, S. A. Chivilikhin, I. Yu. Popov, V. V. Gusarov.** Research of instability development of nanoparticle surface shape.

38. **D. A. Potianikhin.** Self-similar solution of the problem of a longitudinal shock wave reflection from the elastic solid free boundary.

39. **M. V. Polonik, E. E. Rogachev.** About the problem of removal of residual stress in solid at heating.

40. **V. N. Aptukov, P. V. Romanov, N. E. Skryabina.** Approximate solution of the equal channel angular extrusion using variational methods.

41. **A. A. Manzubora, M. M. Rusanov.** Flat automodel problem unloading elastoplastic half-space.


44. **A. S. Sadovskii, V. L. Ganimedov, M. I. Muchnaya.** The comparative analysis of the results of airflow numerical modeling in a human nasal cavity.

45. **A. S. Sadovskii, V. L. Ganimedov, M. I. Muchnaya.** Distinctive features of the air flow in various parts of a human respiratory tract obtained by numerical simulation.


47. **A. A. Shapovalova, R. M. Sultanalieva.** Modeling of rocks hardening and softening.

48. **V. Shcherbakov.** Optimal rigidity of thin inclusions in elastic bodies.

49. **A. V. Shatina, E. V. Sherstnev.** The evolution of a satellite motion in the gravitational field of a viscoelastic planet with a core.

50. **E. Azarov, S. Rumyantsev, A. Shihov.** Test bench for the research of non-linear dynamics of vibration transport machines.

51. **E. Shilvan, M. Zakrzhevsky.** New bifurcation groups in the forced damped Duffing equation with rare attractors and weak unknown chaos.

52. **M. I. Karyakin, I. V. Pozdnyakov, N. Shubchinskaya.** On the influence of internal stresses caused by the isolated defects on the stability of elastic cylinder under compression and tension.


55. **A. A. Sokolov, A. M. Krivtsov.** Modelling of bond saturation in hydrocarbons.

56. **M. Srinivasan, G. Chiandussi, M. Rossetto.** Evaluation of fatigue strength of notched specimens by the Point method with high stress ratios in the low cycle regime.

57. **V. G. Kozlov, S. V. Subbotin.** Positioning of a sphere in a rotating cylinder under condition of vibrational hydrodynamic top.

58. **A. Svetenkov.** Influence of near-surface ionic nano-convection on the formation of self-organized nanoscale porous structures in anodic aluminum oxide.

59. **M. P. Tretiakov, V. E. Vildeman.** Postcritical deformation stage of materials in plane stress state.

60. **T. V. Tretiakova, V. E. Vildeman.** Experimental research of space-time inhomogeneity in inelastic deformation processes in solids by using the digital image correlation method.

61. **D. V. Tsvetkov.** Modeling dynamics of crowd in hard geometry area.
62. **A. A. Burenin, L. V. Kovtanyuk, A. S. Ustinova.** Viscosimetric flow of an elastoviscoplastic material under the presence of a lubricant on the rigid cylindrical surfaces.

63. **N. I. Uzhegova, O. K. Garishin, A. L. Svistkov.** Simulation of atomic force microscope taking into account capillary and van der Waals forces.

64. **A. A. Sokolov, V. V. Vanushkina, A. I. Khaytin, A. M. Krivtsov.** Modeling of human behavior in the natural and man-made environment.


67. **O. Yavruyan, A. Vatulyan, I. Bogachev.** About one approach to reconstruction of inhomogeneous properties for layered medium.


69. **V. Lalin, E. Zdanchuk.** Nonlinear dynamics of the reduced Cosserat continuum. Conditions at the surface of discontinuity.

70. **J. Zhang, Z. Yang.** The present situation of the research on SH-WAVE in the past 2 decades.


SHOCK WAVE CHARACTERISTICS OF DUSTY PLASMA CLUSTERS

A. V. ABRDRASHITOV  K. P. ZOLNIKOV
S. G. PSAKHIE
Simoom@sibmail.com

Behavior of dusty plasma clusters in cylindrical confinement under shock loading using molecular dynamics approach was carried out. The interaction between dusty particles was described by using the Yukawa isotropic pair potential. The theoretical estimation of the dust particle charge was made on the base of the known charge theory in the orbit motion limited (OML) approximation. Simulated dusty plasma cluster had shell structure. Shock wave loading was set by high rate displacement of boundary of dusty plasma cluster. Influence of loading intensity on peculiarities of formation and propagation of perturbations in simulated system was investigated.

The work was supported by RAS Scientific Program No 2 “Matter under high energy density”.
Andrey V. Abdrazhito, 2/4, pr. Akademicheskii, Tomsk, 634021, Russia

NONLINEAR OSCILLATIONS OF A BEAM MADE FROM DYNAMIC MATERIAL

A. ABRAMIAN  S. A. VAKULENKO
andabr33@yahoo.co.uk

We consider asymptotic solutions for nonlinear beams made from dynamic materials that can be described by a fourth order hyperbolic equation with an integral nonlinearity and some space and time dependent coefficients. These coefficients can describe varying mass and rigidity perturbations. A two-time scales perturbation method reduces this complicated equation to an infinite dimensional Hamiltonian system for the Fourier modes. An analysis of this system shows that the corresponding dynamics is quasiperiodic and periodic in time if the coefficients are constant. For non-constant coefficients the dynamics changes significantly. For some special non-constant coefficients the Hamiltonian dynamics can be simplified. We obtain a simpler finite dimensional system. Analytical investigations and numerical simulations show existence of new interesting dynamical effects due to resonances between some Fourier modes. These resonances can lead to large oscillations even for small nonlinearities. The phase portraits which correspond to these resonance cases will also be presented as a stability analysis as well.

Andrei K. Abramian, V.O.Bolshoi pr.61, St.Petersburg, 199178, Russia

ESPECIAL EFFECTS OF RECONSTRUCTION OF STRUCTURE OF SUPERTHIN CRYSTAL LAYERS AT INTENSIVE LOADING

E. L. AERO  A. N. BULYGIN  YU. V. PAVLOV
16aero@mail.ru

Crystals with the complex lattice consisting from two sublattices are considered. Big shifts of the sublattices are investigated. The additional element of translation symmetry is put in a basis of creation of the nonlinear theory. It is characteristic for complex lattices, but earlier not entered in solid states physics. Flat and two-dimensional problems are solved for superthin crystal layers in which effects of nanoscale interactions take place. The discrete forces are considered. They are cause of boundary reorganization of molecular structure together with the continuous forces. Also numerical solutions on distribution of shock surface waves such as kinks and solitons, and also the surface perturbations are considered.

Eron L. Aero, V.O., Bol’shoy pr. 61, Saint Petersburg, 199178, Russia

PROPAGATION OF WAVES IN THIN CRYSTAL LAYERS AT DIFFERENT POTENTIALS OF INTERACTION OF SUBLATTICES

E. L. AERO  A. N. BULYGIN  YU. V. PAVLOV
buligin_an@mail.ru

The continual significantly nonlinear theory of elastic and inelastic deformations of solid crystal media with the complex lattice consisting of two sublattices is developed. Shifts of the center of inertia of couple of atoms (elementary cell) are described by vector $U$ (acoustic mode), and mutual shifts of atoms in a cell vector $u$ (optical mode). Unlike the theory of T. Karman, M. Born, K. Huang shift of sublattices can be arbitrary big magnitude. The new element of translational symmetry is entered into the theory of one sublattice relative to another for one period (or their integer) again reproduces structure of the complex lattice. The equations for finding macroscopic $U$ and microscopic $u$ shifts are received from Lagrange variation principle. The equations represent system of six connected nonlinear differential equations in partial derivatives.

The case of plane deformation for which the system of the equations becomes much simpler is considered. The equations for $U_{x}, U_{y}$ become the usual equations of the theory of elasticity with internal sources of tension which unambiguously are defined by microshifts $(u_{x}, u_{y})$. The system of the connected nonlinear equations with the potential of interaction of sublattices of $F(u)$ is received for $(u_{x}, u_{y})$. In general case $F(u)$ is an arbitrary periodic function. Microshifts $(u_{x}, u_{y})$ are found by the method of functionally invariant solutions and obtained in the form of any functions from a certain ansatz. This ansatz is a root of the algebraic equation. In case of arbitrary potential of interaction of sublattices the microshifts $(u_{x}, u_{y})$ are given by the solution of the nonlinear Klein-Fock-Gordon equation. If in Fourier expansion of $F(u_{x}, u_{y})$ one uses only a finite number of series members then microshifts $(u_{x}, u_{y})$ are defined by the harmonics number. In case of one or two harmonics $(u_{x}, u_{y})$ are expressed through theta functions of one variable and given by formulas of the inversion of elliptic integrals. Taking into account higher harmonics leads to a solution of the problem of the inversion of the hyperelliptic integrals. The genus of hyperelliptic integral is defined by a number of harmonics. The inversion of the hyperelliptic integral of a genus of $p$ is given by theta-functions of $p$ variables which have $2p$ periods. Microshifts $(u_{x}, u_{y})$ for different potentials of interaction of sublattices are found and the specifics of solutions depending on a type of potential are discussed.
THE THEORY OF SQUEEZE-OUT OF A CRYSTAL LAYER WITH FORMATION OF DEFECTS OF STRUCTURE

E. L. AERO  A. L. KORZHENЕVSKII
16aero@mail.ru

Problem of squeezing of a nanoscopic layer up to the loss of the material continuity is considered. Force and geometric parameters of crystalic substrates are fixed. Two fields are introduced: a field of reciprocal displacements of two material sublattices $u$ and the convential elastic field of macrodisplacements $U$. Energy of the field $u$ is written as a sum of the square gradient term and $\cos U$ contribution. Variational equations for the fields $u$ and $U$ mean the momentum and nonaxial momentum conservation. The equations have the form of the two-dimensional generalized sine-Gordon equation. It is shown that at some critical values of loads there are solutions describing qualitative material structure reconstructions.

Eron L. Aero, V.O., Bol’shoi pr., 61, St. Petersburg, 199178, Russia

DISTRIBUTION OF CONTACT STRESSES UNDER CIRCULAR FLEXIBLE PLATE LYING ON A TWO-LAYER FOUNDATION, WITH SOFT INTERLAYER THICKNESS AND SUBSTRATE STIFFNESS TAKEN INTO ACCOUNT

S. M. AIZIKOVICH  A. S. VASILIEV  S. S. VOLKOV
saizikovich@gmail.com

We consider axisymmetric contact problem about bending of a circular plate lying on inhomogeneous foundation. Foundation is modeled by elastic inhomogeneous soft interlayer and elastic homogeneous half-space. Interlayer can be stratified or continuously inhomogeneous with arbitrary varying elastic properties. Layer also can be significantly softer than an underlying half-space. Plate bends under the action of distributed load and elastic response from a foundation. Analytical solution of the problem is constructed using bilateral asymptotic method. Analytical expressions for contact stresses and deflection of the plate are provided. Constructed solution is bilateral asymptotically exact both for large and small values of characteristic geometric parameter of the problem (ratio of layer thickness to plate radius). Also it is effective both for flexible and stiff plates. Numerical results demonstrate that found approximations for kernel transform of integral equation of the problem allows one to construct analytical solution that is effective in the whole range of values of inhomogeneous layer thickness and plate stiffness.

Sergey M. Aizikovich, 1 Gagarin sq., Rostov-on-Don, 344000, Russia

SOME ASPECTS OF THE THERMODYNAMICS OF THE DISSIPATIVE SYSTEM

A. A. ALEKSANDROVA  T. V. SALNIKOVA
A.anna_A@inbox.ru

In this article we consider the dynamical system with isotropic viscous friction.

Assume that the Hamiltonian of system $H$ depends on $m$ parameters $\lambda_1, \ldots, \lambda_m$. Following the ideas of the Gibbs, comparable to a finite system of some thermodynamic system with variable temperature. $\lambda_1, \ldots, \lambda_m$ - will external parameters of a thermodynamic system. Based on this, we investigated two models: 1) We studied the asymptotic behavior of a point math pendulum with isotropic viscous friction in the gravity field. In this model we have come to conclusion:

1.1) Point can not get at any other position other than equilibrium after the stabilization of the system. Therefore density at all points, but $(0, 0)$ is equal zero;

1.2) When the system comes into equilibrium, $\rho(t) \to +\infty$.

Hence, we have shown that the density distribution is $\delta$-function.

2) We studied the asymptotic behavior of mass-points on the two potential wells with isotropic viscous friction. In this model we have come to result:

The lower the coefficient of friction of the more committed to the analytical result.

At the smallest values of the coefficient of friction convergence to three decimal places. As a result, we were able to numerically illustrate the Arnold theorem (1963).

Anna A. Aleksandrova, Lomonosov Moscow State University, Faculty of Mechanics and Mathematics, Leninskie Gory, GSP-1, Moscow, 119991, Russia

NUMERICAL SIMULATION OF COAGULATION PROCESS IN COLLOIDAL SOLUTIONS OF ZINC OXIDE NANOPARTICLES

A. V. ALFIMOV  E. M. ARYSLANOVA
alfimov.anton@gmail.com

There are a large number of studies on the physical and chemical properties, methods of synthesis of nanoparticles to the date. However, the description of the transport processes, coagulation, and relaxation of nanoparticles in liquids and gases is an urgent task of modern science [1, 2].

The presented work is a theoretical study of the coagulation process of spherical zinc oxide nanoparticles suspended in water, synthesized using the hydrothermal method. The typical particle size is 40-100 nm.

A mathematical model is created using the modified DLVO theory to describe the interaction forces between nanoparticles and method of the fluctuation-dissipation Langevin dynamics to simulate the coagulation process. The effects of system parameters variation (initial concentration and particle size) on the character of particle size distribution’s evolution are studied.
For systems under consideration it was possible to find an analytical expression for the interaction force between nanoparticles in a carrier environment, taking into account the following effects: the long-range repulsive force due to the overlap of nanoparticles' shells forming in the water – weak electrolyte; the short-range forces of attraction and repulsion due to Van der Waals interaction.

The resulting expression for the interaction force was used in the numerical simulations of the nanoparticle coagulation by means of the fluctuation-dissipation Langevin dynamics. The described model was used to perform a number of numerical experiments. The character of the dependences obtained in the limits of applicability of the model corresponds well to the experimentally determined curves for similar systems [3].

REFERENCES


Anton V. Alfinov, Kronverkskiy pr., 49, Saint Petersburg, 197101, Russia

APPROXIMATE SOLUTION OF THE EQUAL CHANNEL ANGULAR EXTRUSION USING VARIATIONAL METHODS

V. N. APTUKOV P. V. ROMANOVA N. E. SKRYABINA

petr.rom@yahoo.com

Nowadays there is a fast increasing demand for eco-friendly energy sources. Conventional sources of energy are not sufficient to meet up-to-day requirements and will be exhausted in a short time. While during the use of alternative energy sources the sun, winds and tides it is necessary to apply a stand-alone power generation system because of natural phenomena variability. Hydrogen is a universal and ecologically clean energy source material. Moreover, its heating value is greater than hydrocarbon calorific value by 3-4 times.

Magnesium alloys owning to the high reversible adsorption capacity are intriguing as a material for hydrogen storage in more effective and safe way. As a result, when magnesium and hydrogen are heated, it is obtained magnesium hydride. There were established that magnesium microstructural refining to nanoparticles leads to sufficient sorption properties improvement.

For effective refining of metals and alloys microstructures it is necessary to accomplish preliminary severe plastic deformation by means of equal channel angular extrusion (ECAE), which brings to nanoscale structure. Different known solutions of the flow of the plastic material through the angular matrix are based on rigid-plastic deformation scheme, where the energy dissipation occurs at the rigid areas boundaries with a flow constant velocity.

In this work an approximate continuous solution of material flow under angular extrusion in the place of channels connection has been obtained by using of the variation methods. The area of channel turning, where material points trajectories are like a family of curves different from circular arcs, is of interest. In the simulation region its used a polar coordinate system. On the border of this region entry zone it is set a null radial speed. There has been obtained radial and circular velocities distribution for different values of friction factor. Accumulated plastic strain of different material points passing through the region of channels connection has been analyzed.

Petr V. Romanov, Bukireva, Perm, 614000, Russia

BIOMORPHIC CONTROL OF THE STOCHASTIC VIBRATIONS

D. G. ARSENIEV V. V. KOTOV V. A. POLYANSKIY

vapol@mail.ru

Passive suppression of vibrations is difficult. They have a very wide range. Even in the case of non-linear shock absorbers, they should be high yielding. In this case, the construction will be too soft, and in some cases, it may become unstable and collapse.

Active control of vibrations of structures and elastic bodies is a challenge. Location feedback sensors and active agents must comply with the mechanical properties of the structure. Research needs and controllability and observability of the object.

The report describes the approach that by modal expansion modules to obtain measurements of natural forms of elastic vibrations. For these modules offer close negative feedback. Biomorphic is based on the possibility of selecting the desired number of modes, depending on the task. Thus, by the control algorithm with a variable number of feedback.

The application of the biomorphic algorithm to the problem of random forced vibrations simply supported beam shown the high efficiency of the algorithm. Comparison with conventional local connections based on PID - regulators, shows that a much smaller amount of feedback, this algorithm provides a greater degree of vibration reduction. Also were investigated the robustness of the algorithm biomorphic control.

Vitaly V. Kotov, V.O., Bolshoj pr., 61, St. Petersburg, 199178, Russia
ENERGY CRITERION OF FATIGUE STRENGTH

A. R. Arutyunyan

Robert.Arutyunyan@paloma.spbu.ru

Fatigue strength criterion based on the energy conservation law is suggested. The energy conservation law applied to fatigue problem can be formulated as follows. The total mechanical energy expended during cyclic loading is consumed to the accumulation of heat energy and increasing of internal (latent) energy. Considering the fracture moment, the energy conservation law is written for limit values and using this relation the fatigue criterion is simplified. The experimental results of latent energy accumulation during cyclic loadings at the fracture moment for different construction steels are used to concretized the functions and parameters of fatigue criterion. The theoretical curves of latent energy accumulation and fatigue curves are plotted. They are compared with the corresponding experimental results.

Financial support of the Russian Foundation for Basic Research (Grant N 12-01-31257) is gratefully acknowledged.

Reliability of Complex Mechanical Systems

R. A. Arutyunyan

Robert.Arutyunyan@paloma.spbu.ru

The reliability problem of complex mechanical systems composed of some number of elements with the crack type defects which growth rate is essentially governed by the processes of corrosion fatigue is considered. Among these systems are different engineering constructions: energetic, transport, chemical and others. Taking into account that the reliability of a system as a whole depends on the reliability of individual elements and the way of their connection, the systems with the elements connected in parallel, in series and with reserved elements are considered. For each system the reliability function, based on the Poissons and Weibulls distribution, is defined. The fatigue corrosion criterions for each system are formulated and corresponding fatigue curves are constructed. In accordance with these results the practical suggestions how to design the most reliable systems are derived.

Financial support of the Russian Foundation for Basic Research (Grant N 12-08-00594) is gratefully acknowledged.

Experimental Investigation of Fatigue Strength of Construction Materials in High Cycle Regime

A. R. Arutyunyan B. A. Zimin I. V. Smirnov

Robert.Arutyunyan@paloma.spbu.ru

The experimental methods are applied to investigate the fatigue problem of different construction materials in high cycle regime. The servo-hydraulic test machine on fatigue loadings with variations of loading frequency, stress ratio and form of loading impulse is used. The evolution of defect structure during cyclic loadings is studied by sound velocity and attenuation of elastic waves measurements applying the method of optical-acoustic defectoscopy. The thermal camera is used to investigate the dissipative processes during the cyclic loadings.

The aim of these investigations is working out the theoretical approaches to the problem of high cycle fatigue strength and analyze the working capacity of different engineering systems subjected to fatigue loadings. Financial support of the Russian Foundation for Basic Research (Grant N 12-01-31257) is gratefully acknowledged.

Modeling the Process of Aluminum Anodization

E. M. Aryslanova A. V. Alifimov

S. A. Chivilikhin I. Yu. Popov V. V. Gusarov

elizabeth.aryslanova@gmail.com

Artificially on the surface may build a thick layer of Al2O3, which has a porous structure. Electrochemical oxidation is a process of formation of oxide film on the metal surface, placed as an anode in an electrolyte. The benefits of anodizing include shortness of process, high firmness and heat-resistant material, good adhesion to the surface of aluminum, electrical insulation, etc. Anodizing aluminum in hydrogen sulfate can occur using direct and alternating current. When an alternating current the film grows slower and is more friable.

In the anodizing process, aqueous solutions of acids (oxalic acid, phosphoric acid, chromium, etc.) moderately dissolve oxide Al2O3. 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. This way on the metal aluminum oxide film is formed, the top layer of which is a microporous partially hydrated metal oxide, under which is the lower layer - anhydrous microscopically thin 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 the disturbance of alumina for the initial stage of anodizing aluminum oxide porous border aluminum-alumina and alumina-electrolyte, with the influence of surface diffusion of aluminum oxide.

Elizaveta M. Aryslanova, Kronversky pr., 49, Saint Petersburg, 197101, Russia

INVESTIGATION OF INFLUENCE OF PARAMETERS OF STRESS-STRAINED STATE OF BLOCK-STRUCTURED GEOLOGICAL MEDIA ON MECHANISMS OF DILATANCY UNDER SHEAR LOADING

S. V. Astafurov E. V. Shilko A. V. Dimaki S. G. Psakhie

svastafurov@gmail.com shilko@ispms.tsc.ru
dav@ispms.tsc.ru sp@ms.tsc.ru

On the basis of computer-aided simulation by movable cellular automaton (MCA) method influence of degree of nonequiaxial of compression on value of dilatancy of fragment of shearing fault zone at the early stage of activation (at the beginning of stage of fast weakening) was theoretically investigated. Results of investigation show that at the moment of beginning of the stage of fast weakening of fault zone (interface) value of dilatancy depends on the degree of nonequiaxial of compression. This dependence has nonlinear character with reaching of the saturation. The major contribution to the change of the volume of the medium is the dilatancy mechanism connected with slippage along the surfaces of damages. It is established that the contribution of this mechanism to the change of the fault zone volume is largely determined by the interrelation of the two characteristics of the stress state of the system - the current pressure and average stress intensity. The increase of these characteristics complicates the realization of slippage mechanism, and their decrease increases its contribution to dilatancy. This is due to physical sense of these characteristics of the stress state. Thus, with increasing of pressure (the value of compression of the system) discontinuities, existing in the system, are constrained, and slippage along their surfaces is hampered. The value of the stress intensity characterizes the resistance of changing of the form of the medium, i.e. to the shear deformation. Therefore, the increase in the value of average stress intensity also reduces the contribution of slippage to change of the volume of the fragment of block-structured medium. Analysis of simulation results showed that at low degrees of nonequiaxial of compression when the magnitude of the stress intensity is relatively low and varies slightly, the decrease in pressure leads to an increase in the fault zone dilatancy. Further with increase of the degree nonequiaxial of compression whith reducing of pressure is a significant increase in average stress intensity takes place. As a result, the influence of these two opposing factors on realization of the mechanism of slip is balanced and dependence of the volume of the medium on the degree of nonequiaxial of compression reaches the saturation.

The investigation has been carried out within the SB RAS Program III.23.1.4 for Basic Research and at partial financial support of the Project No. 4.1 of the Program No.4 of Presidium of RAS.

Sergey V. Astafurov, Akademicheskii ave., 2/4, Tomsk, 634021, Russia

INVESTIGATION OF THERMOCOUSTIC AND SHOCK WAVES INTERACTION IN THE CAVITY FILLED WITH GAS

M. B. Atmanskikh P. T. Zubkov

MariaAtmanskih@gmail.com pzubkov@utmn.ru

This article is considered with numerical investigation of propagating shock and thermoacoustic waves effecting temperature, pressure, velocity and density distribution in a flat layer of gas with thermophysical characteristics of air. It is assumed that the case is one-dimensional and the gravity force is absent. The motion of gas under the assumptions made is described with the one-dimensional time-dependent system of equations in a Cartesian coordinate system, governing conservation of mass, momentum and energy. The Clapeyron ideal gas law is considered as the equation of state. A rectangular area is divided by an impermeable heat-conducting membrane into two equal parts. The initial density distribution has an arbitrary discontinuity in the left part. Therefore complicated wave motion arises consisting of shock waves, rarefaction waves and contact discontinuity, propagating through the first chamber. This motion produces wave processes in the right chamber. The wall’s interaction with a shock wave is expressed by partial dissipation of kinetic energy on compression shock. This process manifests itself in local temperature increase, gas expansion behind the central wall and pressure increase near the membrane. As a result the compression wave is formed in the right chamber. It propagates with adiabatic sound velocity and is named thermoacoustic wave. The complicated interaction of waves takes place in the bounded domain. Numerical analysis of stationary mode time dependence on parameter, defining initial jump in the first chamber, and thermal boundary conditions are also conducted in this study.

Maria B. Atmanskikh, 15A, Perekopskaya, Tyumen, 625000, Russia

TEST BENCH FOR THE RESEARCH OF NON-LINEAR DYNAMICS OF VIBRATION TRANSPORT MACHINES

E. Azarov S. Rumyantsev A. Shihov O. Bogdanova

EAzarov@usurt.ru SRumyantsev@math.usurt.ru
usart@inbox.ru oalekseeva88@mail.ru

Vibration transport machines are intended for transporting and/or separating variable bulk materials and are used in various industries. Most of these machines are constructed as solid bodies (working elements) fixed on springs or by means of other elastic elements that enable their plane-parallel motion.

The motion of working elements is excited by special devices called vibration excitors. Vibration exciters act as unbalanced rotors driven by electric motors. Three basic ways are applied in practice to match the rotation of the rotor vibration
exciters: kinematic synchronization, electric synchronization and self-synchronization.

The Ural State University of Railway Transport is actively engaged in research of vibration transport machines, operating on the principle of self-synchronization. While researching mathematical model is being used, based on a system of differential equations describing the nonlinear dynamics of the machine (in its various versions).

To verify the theoretical research, we have developed a test bench of the vibration transport machines, designed to conduct field studies of this machine motion with different parameters. Its use will allow to check the results of mathematical modeling in practice, and see the validity of the mathematical model.

The basic functions of a test bench are the following:
- horizontal, vertical and angular vibrations of the test bench;
- replaceable sets of spring units (to change the stiffness of the system);
- install up to three nodes of vibration exciters;
- control the horizontal and vertical movements of the axes of rotation of vibration exciters in the working element of the test bench;
- change of mass and radii of gyration of the unbalanced masses;
- replace of engines of unbalanced vibration exciters;
- the possibility of adding a second working element for the creation of a two-mass machine;
- mapping system oscillations in digital form.

An extension of the classical Fourier’s law (1) proposed by Cattaneo [1] and Vernotte [2] includes a heat flux relaxation constant \( \tau \), which means that the heat flux does not disappear instantly, but gradually fades if the temperature gradient is suddenly unloaded.

\[
\tau \dot{h} + h = -\lambda \nabla T 
\]  

(1)

The hyperbolic heat equation, derived by means of the Cattaneo-Vernotte law, associates the wave propagation of the heat with the finite speed \( c = \sqrt{\lambda/(\rho c_v \tau)} \). In the case if the volumetric heat sources are absent it can be written as:

\[
e^2 \Delta T - \ddot{T} - \tau^{-1} \dot{T} = 0
\]

(2)

This model, according to [3], is used to describe a variety of processes such as rapidly moving heat sources, travelling waves in systems with a moving phase transition edge, or a short pulse laser heating of metals.

The hyperbolic heat [1, 2] wave propagation processes in the layer under the laser radiation was investigated. The laser radiation was modelled by defining the heat flow at the layer boundary for the opaque media and by defining the intensity of the internal heat sources according to Bouguer’s law for the semi-transparent media. The laser pulse intensity in this study could optionally depend on time as the Dirac delta function or as the Heaviside function, which allowed us to simulate instant and continuous laser exposure on the medium.

The temperature distributions in the layer with the internal heat sources were obtained as a series by the means of Green’s functions method. The behavior of the temperature curves near the irradiated boundary and the reflection of the temperature waves from the opposite boundary of the layer were examined both for the boundary conditions of thermal insulation and for the homogeneous boundary conditions. The temperature curves were compared respectively with the ones obtained by the means of the classical Fourier’s theory and the pure wave equation as the limiting cases. The temperature distribution in the opaque medium was compared with the temperature distribution in the semi-transparent medium.

In the case if the homogeneous boundary conditions were considered it was found that the temperature at the vicinity of the irradiated boundary drops below its initial value for a short time period of the order of the heat relaxation constant \( \tau \). The numerical analysis showed that for a fixed \( \tau \) it is possible to find such an optimal value of the laser attenuation in the medium, that the value of the absolute temperature minimum would be the lowest.

REFERENCES


Mikhail B. Babenkov, Politekhnicheskaja 29, St. Petersburg, 195251, Russia

BODIES WITH CRACKED COATINGS

V. A. BABESHKO O. V. EVDOKIMOVA
O. M. BABESHKO M. N. KOLESNIKOV
V. L. SHESTOPALOV

babeshko41@mail.ru evdokimova.olg@mail.ru
babeshko49@mail.ru kolesnikov@kubsu.ru
vlshestopalov@gmail.com

We consider a boundary-value problem, which describes the behavior of materials with coatings under conditions of vibrational harmonic actions. The coatings are considered mutually contacting, deformable two-dimensional objects with polytypic properties and parameters averaged over thickness (in particular, this can be thin-walled plates), forming a layer on a three-dimensional deformable substrate.

In general, the coatings are assumed to be cracked. Such a model of coating arises traditionally in seismology and in aircrafts after long using.

Andrey M. Shihov, Kolmogorov str., 66, Ekaterinburg, 620034, Russia

PROPAGATION PROCESSES OF THE HEAT WAVES IN A LAYER WITH REGARD TO THE HEAT FLUX RELAXATION

M. BABENKOV E. IVANOVA
babenkov.michail@gmail.com elenaivanova239@post.ru

An extension of the classical Fourier’s law (1) proposed by Cattaneo [1] and Vernotte [2] includes a heat flux relaxation constant \( \tau \), which means that the heat flux does not disappear instantly, but gradually fades if the temperature gradient is suddenly unloaded.

\[
\tau \dot{h} + h = -\lambda \nabla T 
\]  

(1)

This model, according to [3], is used to describe a variety of processes such as rapidly moving heat sources, travelling waves in systems with a moving phase transition edge, or a short pulse laser heating of metals.

The hyperbolic heat [1, 2] wave propagation processes in the layer under the laser radiation was investigated. The laser radiation was modelled by defining the heat flow at the layer boundary for the opaque media and by defining the intensity of the internal heat sources according to Bouguer’s law for the semi-transparent media. The laser pulse intensity in this study could optionally depend on time as the Dirac delta function or as the Heaviside function, which allowed us to simulate instant and continuous laser exposure on the medium.

The temperature distributions in the layer with the internal heat sources were obtained as a series by the means of Green’s functions method. The behavior of the temperature curves near the irradiated boundary and the reflection of the temperature waves from the opposite boundary of the layer were examined both for the boundary conditions of thermal insulation and for the homogeneous boundary conditions. The temperature curves were compared respectively with the ones obtained by the means of the classical Fourier’s theory and the pure wave equation as the limiting cases. The temperature distribution in the opaque medium was compared with the temperature distribution in the semi-transparent medium.

In the case if the homogeneous boundary conditions were considered it was found that the temperature at the vicinity of the irradiated boundary drops below its initial value for a short time period of the order of the heat relaxation constant \( \tau \). The numerical analysis showed that for a fixed \( \tau \) it is possible to find such an optimal value of the laser attenuation in the medium, that the value of the absolute temperature minimum would be the lowest.

REFERENCES


Mikhail B. Babenkov, Politekhnicheskaja 29, St. Petersburg, 195251, Russia

BODIES WITH CRACKED COATINGS

V. A. BABESHKO O. V. EVDOKIMOVA
O. M. BABESHKO M. N. KOLESNIKOV
V. L. SHESTOPALOV

babeshko41@mail.ru evdokimova.olg@mail.ru
babeshko49@mail.ru kolesnikov@kubsu.ru
vlshestopalov@gmail.com

We consider a boundary-value problem, which describes the behavior of materials with coatings under conditions of vibrational harmonic actions. The coatings are considered mutually contacting, deformable two-dimensional objects with polytypic properties and parameters averaged over thickness (in particular, this can be thin-walled plates), forming a layer on a three-dimensional deformable substrate.

In general, the coatings are assumed to be cracked. Such a model of coating arises traditionally in seismology and in aircrafts after long using.
In this paper, we describe an algorithm for constructing solutions of such boundary-value problems, which have not been studied in this general formulation so far. The problem is reduced to investigating a new class of sets of pseudodifferential equations, for which the determinant of the matrix function of the kernel symbol is identically zero. The conventional methods of investigation are inapplicable to such systems. In this study, we derive approximate formulas for solving these sets of equations.

Materials described in the boundary-value problems formulated above can possess a complicated set of the properties, depending on the physical and mechanical characteristics of the substrate and coatings, their shapes, and the mutual arrangement of the surface. They also depend on the conditions of interaction of coatings with the substrate and with each other in all areas of contact, as well as on the external actions upon the substrate-coating system. In particular, the properties can include a dissimilarity in the concentration of stresses under coatings and in the localization of strain.

This work was supported by the Russian Foundation for Basic Research (12-01-00330), (12-01-00332), (11-08-00381), the Presidential Program of Support for Leading Scientific Schools in Russia (project no. NSh-914.2012.1), and the programs of the EMMPC Department and the Presidium of the Russian Academy of Sciences executed by the Southern Scientific Center of the Russian Academy of Sciences.

Vladimir Babeshko, Chehov av.41, Rostov on Don, 344006, Russia

MESOMECHANICAL ANALYSIS OF DYNAMIC DEFORMATION AND FRACTURE IN COATED MATERIALS

R. Balokhonov V. Romanova S. Martinov
rusy@ispms.tsc.ru varvara@ispms.tsc.ru martins88@sbmail.ru

The deformation and fracture of a coated material are simulated. A dynamic boundary-value problem in a plane strain formulation is solved numerically by the finite-difference method. To simulate the mechanical response of the steel substrate use was made of the relaxation constitutive equation based on microscopic dislocation mechanisms. A fracture criterion takes into account crack origin and growth in the elastic-brittle coating. Numerical experiments were conducted for varying strain rate of tension and compression. Macroscopic behavior of the coated material is shown to be controlled by interrelated processes of localized plastic flow in the substrate and cracking of the coating that strongly depends on an external strain rate.

Ruslan R. Balokhonov, pr. Akademicheskii 2/4, Tomsk, 634021, Russia

CONSTITUTIVE MODELING OF DAMAGE MECHANISMS IN ARTERIAL WALLS AND RELATED EXPERIMENTAL STUDIES

D. Balzani T. Schmidt A. Schriefl
G. A. Holzapfel
daniel.balzani@uni-due.de

To decrease the risk of fatal consequences resulting from diseased cardiovascular systems, often a balloon angioplasty is applied, thereby an atherosclerotic artery is subjected to a supra-physiological internal pressure, which induces damage in the arterial wall. This damage may be explained by a subsequent loss of proteoglycan (PG) bridges based on the sliding filament model [3], which states that PG bridges can store reversible strains in a certain domain. Here, a micromechanically-based approach incorporating statistical distributions of microscopic fiber properties is presented. The damage variable is evaluated as the fraction of failed PG bridges and is used within the constitutive framework proposed in [1], see also [2]. Stochastic distributions of different microscopic quantities are compared in their capability of reproducing experimental data. In particular, cyclic tension-tests are performed with arterial tissues treated with collagenase and elastase. The obtained stress-strain relations are investigated with respect to a possibly component-specific stress-softening behavior. Finally, a numerical example is presented showing the application of the proposed damage model within a finite element calculation.

REFERENCES


Daniel Balzani, Universitaetsstr. 15, Essen, 45141, Germany

ON OPTIMAL ANISOTROPIC BODIES IN THE HEAT CONDUCTION PROBLEMS

N. V. Banichuk S. Yu. Ivanova
banichuk@ipmnet.ru

Some problems of internal structural optimization are formulated for heat conduction bodies made of locally orthotropic material. State variable (inverse temperature) is determined with the help of solution of heat propagation boundary value problem. The orthogonal tensor of rotation defining the optimal orientation of
Design of Periodical Polycrystals Basing on Voronoi Tessellation

E. Batukhtina V. Romanova R. Balokhonov
batuhtina10902@mail.ru varvara@ispms.tsc.ru

Methods of numerical modeling are widely used to study deformation processes in materials with internal structure. An advanced method of modern computational materials science implies the material microstructure to be included in calculations of the stress-strain state in an explicit form. The structure is taken into account through coordinate dependence of the material properties (i.e. density, yield strength, elastic modules, thermal conductivity, etc.). The definition of the dependence is a nontrivial task in the case of two-dimensional geometry and it is more difficult in three dimensions. In the former case, the information about distribution of structural elements in a plane section can be obtained by processing experimental metallographic images whereas in a three-dimensional case introduction of a real microstructure assumes availability of information about microstructural composition of every layer of specimen. Existing methods of specimen scanning which can provide information about distributions of structural elements throughout the volume are complicated and expensive. An alternative way is to design model microstructures similar to those of real materials by geometrical characteristics of structural elements.

A Voronoi tessellation is a widely used method to model polycrystalline structures. Advantage of this method is an analytical representation of polycrystals which enables using computational mesh with elements of any type. In this work, two- and three-dimensional polycrystals with a periodical microstructure have been created basing on Voronoi tessellation. The initial conditions were a set of points (grain nuclei) randomly distributed within the computational domain, their coordinates are found by a random number generator. To create a periodical structure the initial set of points was translated by a half period to all dimensions. Doing so, we make it possible to apply periodical boundary conditions to opposite sides of the computational domain when solving mechanical problem. Grain size and grain side distributions were analyzed. The results were compared with similar distributions for polycrystals designed by a step-by-step packing method and with experimental data. Financial support of RFBR (No 12-01-00436-a) is acknowledged.

MODELLING OF COMPLEX RHEOLOGICAL EFFECTS IN ESSENTIALLY NONLINEAR PROBLEMS

A. A. Bazhin E. V. Murashkin
murashkin@dvo.ru

In the theory of large elastoplastic deformation proposed earlier, reversible and irreversible deformations are determined by the appropriate transport equations. Separation of strains on the reversible and irreversible components has always been arbitrary defined by the author of the model, because it is possible to measure experimentally only the total strain. The assumption of constancy of the tensor of irreversible deformation during unloading and rigid body rotation is taken as a basis in constructing of this theory, also thermodynamic principles of the independence of the free energy of the permanent deformation are considered. In this model the plastic strain rate tensor is proposed as a source of permanent deformation in the areas of plastic flow. For modeling creep deformations, in the areas free of plastic flow, some creep strain rate tensor should be taken as a source of irreversible strains. This source tensor can be defined through any certain creep law, such as power law.

As an example of the proposed model usage the problem of “healing” the micropore under hydrostatic pressure is solved. In such a problem the small deformations assumption can not be used, and considering only plasticity as part of a permanent deformation is not enough to explain the effect of “healing” of micropore. The inclusion of the Norton creep law as an additional source of permanent deformation, allowed simulating the “healing” of a cavern, and also stress relaxation when removing the stress from the body.

This work was supported by the grant of the President of the Russian Federation (MK-776.2012.1) and RFBR (mol_a_ved 12-01-33064).

Alexander A. Bazhin, Radio, 5, Vladivostok, 690041, Russia

UNCONSOLIDATED SANDSTONE UNDER COMPACTION STRESS: NUMERICAL MODELLING OF 3-D MULTIBODY CONTACT INTERACTION OF PARTICLES WITH IRREGULAR SHAPES

A. Bekker M. Pervukhina V. Shulakova S. Mayo B. Clennell
Andrey.Bekker@csiro.au Marina.Pervukhina@csiro.au Valeriya.Shulakova@csiro.au Sherry.Mayo@csiro.au Ben.Clennell@csiro.au

Elastic stress dependant rock property models are important in both the building and calibration of geomechanical models. Elastic properties of a porous granular medium can be nonlinear due to inter-granular contact interactions and/or heterogeneity of the grains. Elastic moduli of sandstones simulated from microtomograms that take into account only porosity resolvable by micro-CT scanners, but not the contacts properties, strongly overestimate experimentally measured elastic properties of samples especially at low stresses (Shulakova et al., 2011; 2012).

We develop a new method for numerical simulation of stress-dependent elastic properties of granular media that takes into ac-
count the inter-granular contact properties. Stress dependency of bulk modulus of an unconsolidated sandstone can be simulated using its microtomographic images. The inter-particle contact friction is captured in the model.

The micro-CT images of the clean quartz Lochaline sandstone have been obtained with a voxel size of 1.94 μm using x-ray phase-contrast micro-CT reconstruction (Mayo et al., 2012). We process these microtomograms using the software package AVIZO (Visualization Science Group). The processing includes filtering, smoothing and segmentation to solid grains and pore space. The solid phase is then separated into individual grains using AVIZOs bin separation technique. Tetrahedral volumetric mesh for each solid grain is generated and transferred to finite element analyser ABAQUS (Simulia Inc.). The grains are assumed to be homogeneous, isotropic and linear elastic with bulk and shear moduli of 37 and 43 GPa, respectively.

A dynamic implicit finite element method is chosen for the modeling of 3D grain displacements and contact interactions. Inter-granular friction force is assumed to be proportional to the normal force in the contact interaction. The non-linearity associated with the contact interaction is treated by a numerical algorithm based on implicit Newton’s method. A cubic sample of the granular medium is compressed up to 100 MPa by the displacement of the sample boundaries inward. The numerical results are verified quantitatively on the Hertz model and on a system of eight identical spheres with known analytical solutions. The numerical solutions for the total contact area and for the bulk modulus are in good agreement with the analytical ones.

Visualization of numerical solution shows that during compaction irregular grains slide and twist relative to each other. These large particles displacements make the dynamic model of the sandstone more efficient compared with steady-state finite element models.

The numerically simulated bulk modulus exhibits strongly non-linear variation with the increase of compaction stress and it is in a qualitative agreement with the theoretical unconsolidated sand model (Brandt, 1955). The developed approach might be further benchmarked with the results of experimentally measured elastic properties of unconsolidated sandstones. Further work should be done to extend the developed approach to consolidated sandstones and other types of rocks.

THE CONDITIONS OF PARAMETRIC INSTABILITY IN MATERIALS CONTAINING THE HYDROGEN
A. K. BELYAEV  V. A. POLYANSKIY  YU. A. YAKOVLEV
vapol@mail.ru yura.yakovlev@gmail.com

The hydrogen is always dissolved in metals and it has strong influence on mechanical properties. It accumulates in trips of different nature with various bond energy. The metals properties depend on as the hydrogen concentration as the bond energy of hydrogen.

The cyclic loading of material leads to redistribution of hydrogen in volume (Gorsky effect) and redistribution of hydrogen in energy levels. It can lead to the loss of strength. The are multiple cases of accidents, and situations when decrease of resource material happen due to hydrogen embrittlement

The full description of the hydrogen concentration change in volume and binding energy were done by two-continuum model. The main feature of this model is use of two energy state of the hydrogen. They are state with low binding energy and state with high binding energy. In state with high binding energy the hydrogen is moved with lattice of material. The hydrogen can freely move in the state with low binding energy. In this stage hydrogen may be modeled as a perfect fluid inside material.

The entire article is based on the experimental research work that study of the influence of the low hydrogen concentration upon mechanical properties of materials. It carried out analytical simulation of periodic uniaxial strain with taking into account of hydrogen with different binding energy. In the case of uniaxial deformation of material the equation of number hydrogen particle can be transformed in to Mathieu equation. This equation has instability area.

The investigation of this instability area had made. We determine the critical value of the hydrogen concentration and amplitude of the deformations. The model also gives the correlation among the hydrogen concentration, amplitude and frequency of the cyclic loading.

This result allows us to describe the process of destruction as instability caused by parametric resonance. Also, solution of this equation gives critical hydrogen concentration and safety level of loadings.

Yuri A. Yakovlev, V.O., Bolshoj pr., 61, St. Petersburg, 199178, Russia

ON THE BENDING RIGIDITY OF GRAPHENE MEMBRANES
I. E. BERINSKIY    A. M. KRIVTSOV
iberinsk@gmail.com

This work is devoted to the determination of the bending rigidity of graphene membranes. Such membranes are expected to be used in the novel NEMS, so that this parameter is crucial to evaluate the frequencies of the transversal oscillations. As graphene is considered as a 2D material it does not have unambiguous definition of its thickness. Hence, its bending rigidity cannot be found using the classical approaches of continuum mechanics. Another way to determine graphene bending modulus is proposed. It is based on the moment interactions between the carbon atoms in the crystal lattice in addition to the acting forces. As a result, the equivalent solid medium is characterized by the moments elasticity tensor in addition to the classical elasticity tensor. It is shown that the bending rigidity of graphene layer is defined by one of the moment tensor components. As a result, an explicit analytic expression to calculate the bending rigidity is found.

Igor Berinskii, Bolshoy pr. V/O 61, St.Petersburg, 199178, Russia
PROPERTIES OF SPACE DEBRIS SHIELD PROTECTIONS WITH DISCRET BUMPERS

L. N. BEZUKOV    N. N. MYAGKOV
T. A. SHUMIKHIN
bezukov@gosniias.ru  nn_myagkov@mail.ru
tshumikhin@gmail.com

A series of 12 advisable impact experiments were performed with the objective to learn about the effectiveness of shield protection constructions made of steel meshes of different types. The range of impact velocities is 2.66-3.44-km/s; a projectile is an AD-1 aluminum sphere of 6.35-mm diameter. The constructions include 2 or 3 spaced mesh bumpers and a number of meshes in each bumper varies from a single mesh to 5 meshes stacked together. The distance from the first bumper to the Rear Wall varies from 100 to 200-mm and the specific weight from 10.82 to 15.04-kg/m2. The Rear Wall in all experiments is a 2.35-mm thick AMg6 aluminum plate. The ratio of the critical projectile diameter to the total specific weight (including RW) of the scheme is taken as the measure of construction scheme effectiveness (efficiency factor).

The experiments reveal that the mutual positions of bumpers in a construction do not affect considerably its resistant ability but the total amount of meshes in the construction and distribution of weight between the bumpers seems to be crucial. Meshes coated with zinc expose no specific advantage over common steel meshes. For some shield constructions the reliable estimate of the efficiency factor is assessed.

Timofey A. Shumikhin, Leningradskiy prospekt d.7, Moscow, 125040, Russia

COMPLEX ("CHAOTIC") BEHAVIOUR OF DYNAMICAL SYSTEMS AS A CONSEQUENCE OF ITS MULTIMODE CHARACTER

I. I. BLEKHMAN
iliya.i.blekhan@gmail.com

This study puts under consideration dynamic systems, whose visible complex ("chaotic") behavior is caused by transition from one motion mode to another. Such motion modes may be represented in particular by some stable in the small periodic motions with different periods.

Two types of such systems are singled out. In the first case a number of motion regimes with closely located domains of attraction coexist in the phase space of the system at certain values of parameters. The transition from one stable regime of motion to another is due to the inaccuracy of computer calculations and variation of parameters in the corresponding physical system.

In the second case a systematic transition from one regime of motion (which is not necessarily stable) to another occurs due to the internal properties of the system. As an example is the situation, when one of the phase variables may be considered as a relatively slowly varying parameter passing through the existence and steadiness domains of various regimes.

The behavior of a particle over a horizontal vibrating plane and emergence of a turbulent surface layer in liquid placed in a vibrating vessel are considered in this paper as illustrative examples. The analogue of this process to that of the thermoconvection is pointed out.

The other example is an analogue of the Lorenz oscillator marked by a phase pattern projection similar to the well-known "butterfly" pattern. Some thoughts corroborating Landau turbulence theory are suggested.

It is noted that the complex motion under consideration is characteristic for sufficiently wide scope of dynamic systems such as a pendulum with a vibrating axis, the self-synchronizing oscillating and rotating objects, the systems with period doubling, the parametrically excited distributed systems.

Iliya Blekhman, V.O. Bolshoy av. 61, Saint - Petersburg, 199178, Russia

ARRANGEMENT OF MHD INTERACTION FOR EFFICIENT IMPACT ON SUPersonic WEAKLY IONIZED Gas FLOW AROUND Conical BODY

S. V. BOBASHEV    A. S. CHERNYSHYEV
YU. A. KURKIN    S. A. PONYAEV    A. A. SCHMIDT
alexander.schmidt@mail.ioffe.ru

Efficient and reliable control of aerodynamic characteristics of a body flying at super- or hypersonic speed is a challenging problem of perspective high speed vehicles development. One of feasible ways of such a control is MHD impact on plasma flow around the body. In the Ioffe Physical Technical Institute of Russian Academy of Sciences during last decade experimental and numerical investigations of supersonic plasma flow around "cone-cylinder" body have been carried out. Effect of external magnetic field induced by a coil installed inside the body and of electric discharge rotating in the magnetic field on cone surface between electrodes located on the cone apex and cone-cylinder conjugation has been considered.

The paper is devoted to numerical analysis of the influence of arrangement of the magnetic coil and the electrode system installed in the model body on the high speed plasma flow around the body. Investigations were based on a mathematical model of non-equilibrium three-component and two-temperature plasma flows subjected to the applied magnetic field. Processes of ionization/recombination were taken into account. Simulations were based on high resolution finite volume conservative shock capturing method.

Parameters of the simulations correspond to experiments carried out in the Ioffe Institute. As in experiments in the simulations xenon was chosen as a working gas since it characterized by long recombination time. In the experimental setup preliminary ionized in the shock tube plasma accelerates in a supersonic nozzle. The geometry of the nozzle provides the Mach number of the flow about 5.0. Magnetic field is generated by the magnetic inductor built in a model body. The magnetic induction on the center inductor is about 1.0 T. Two configurations of the inductors installed in the model to generate the magnetic field were considered. In the first configuration, the coil is situated just after the cone, its diameter is the same as the diameter of the cylindrical part of the body. In the second configuration the small inductor-coil is positioned near the cone apex. Variation of position of the coil enables one to shift intensive electron heating
domain, in particular, even upstream the shock wave. Though at parameters under study there is no significant effect of the magnetic field on the shock wave shape and position, it can be seen that MHD interaction leads to thickening of the boundary layer. This fact can be explained by heating of the flow.

Thus, it was demonstrated that MHD interaction provides mechanism of influence on the high speed flow structure about the model.

Alexander Schmidt, Polytekhnicheskaya 26, Saint Petersburg, 194021, Russia

**NANODISTURBANCES IN MECHANICALLY LOADED METALLIC AND CERAMIC NANOWIRES**

S. V. Bobylev N. R. Kudinova I. A. Ovdi’ko

bobylev.s@gmail.com natalii@sibmail.com

ovdiko@gmail.com

A special physical mechanism of plastic deformation in nanowires is suggested and theoretically described. This mechanism represents formation of near-surface nanodisturbances – nanoscopic areas of plastic shear with tiny shear vectors – in mechanically loaded nanowires. The formation of isolated nanodisturbances in metallic and ceramic face-centered cubic (fcc) nanowires having square cross sections is analyzed. We calculated the energy characteristics for nanodisturbance formation and compared them with those for conventional dislocation generation. It is shown that this deformation mode tends to dominate over conventional dislocation generation and glide fcc nanowires at high stresses and zero temperature.

Sergey V. Bobylev, Natalia R. Kudinova, Bolshoj 61, Vas. Ostrov, St. Petersburg, 199178, Russia

**MODEL HIERARCHY AND PECULIARITIES OF THE DEFORMATION OF POROUS MEDIA SATURATED WITH FLUIDS**

O. Bocharov V. Rudyak A. Seryakov

oleg.bocharov@bakerhughes.com

valery.rudyak@mail.ru

alexander.seryakov@bakerhughes.com

Over the past 70 years different authors attempt to construct, extend and generalize the saturated porous media theory. The model of rock deformation with multiphase saturation is demanded and potentially applied for wide class of problems in geotectonic, hydrogeology, mining and oilfield engineering. The coupled fluid-rock matrix interaction was described for the first time in consolidation theory [1, 2]. Generalization and extension of the Biot-Frenkel model was made by W. Brutsaert [3], J. Berryman [4] and Wei-Cheng Lo [5] from the point of view of multiphase continuum mechanics for acoustic applications. However in this case the constitutive equations contain the terms of the different order.

We present the analysis of equations of the generalized deformation model of a rock with multiphase saturation. Porous medium is described by the mass and momentum conversation law that is written for mixture and some components. We take the constitutive equations in the form of generalized Hooks law for unit of representative volume. The difference in deformation scales for solid and liquid phases allow us to introduce the small parameters. Equations decomposition on this term yields the sequence of approximation models satisfying the specific physical conditions. We present in current work the analysis of zero-order approximation which corresponds to filtration flow in porous media with bulk volume remains constant. It has been shown that in some case the zero-order equations permit solutions with tangential stresses which produce the rock failure.

**REFERENCES**


Alexander V. Seryakov, Kutateladze st., 4a, Novosibirsk, 630128, Russia

**MULTISTAGE BREAKUP OF LOW VISCOUS DROPS IN ACCELERATED FLOW**

V. M. Boiko A. A. Pivovarov S. V. Poplavski

bvm@itam.nsc.ru pivovarov@itam.nsc.ru

s.poplav@itam.nsc.ru

Aerodynamic liquid drops breakup is an actual problem of the physical gas dynamic, which finds numerous applications in science and engineering. All available data on this term were obtained in the uniform flows or in the shockwaves, and on this base modes of drops dispersion they usually classifies in six type depending on Weber number We. In particular it is accepted that at low Weber number We < 50 two similar modes are realized: at 12 < We < 20 the so-called mode “bag”; at 20 < We < 50 mode “bag and stamen”, but latest investigations has shown that in gradients flows, firstly, the mode existence bounds change, secondly, that is more important, proper picture of dispersion defers. As regards the second question, one of peculiarity of the process, found out in an accelerating flow, is multistage drop breakup. In the paper the results of the experiments on the drop interaction with the accelerating flow in the vertical confusor will be presented for the range of Weber number We = 10 - 90. Two mechanisms of the drops breaking up are discovered which are of interest as applied to modern approach to aerodynamic liquids dispersion in gradient flows.
To describe and study processes of cold compaction within discrete element method (DEM) a 3D model of nanosized powder is developed. Elastic forces of repulsion, tangential forces of "friction" (Cattaneo-Mindlin), and dispersion forces of attraction (Van der Waals - Hamaker) as well as the formation/break of solid bridges between individual particles are taken into account. Uniform-sized powders, with particle size equals 10, 16, 21 or 38 nm, are simulated. Simulation results are compared with experimental data on alumina nanopowders compaction. It is revealed that the model developed makes it possible to reproduce experimental data exactly and, in particular, describes the size effect in the compaction processes. Theoretical and experimental researches on nanopowder compaction under different conditions of external loading are performed: the uni-axial strain (closed-die compaction), the biaxial (radial) strain, and the uniform compaction (cold isostatic pressing). Results of actual and computer experiments show the best correlation. A weak sensitivity of oxide nanopowders to the pressing geometry is revealed. The adaptability of the continuum theory of plasticity of hardening porous bodies, which is in routine use for description of powder properties, is considered.

The work is supported by the RFBR (projects 12-08-00298 and 11-08-00005) and the Presidium of the Ural Branch of RAS (project 12-C-1-1018).

Grey S. Boltachev, Amundsen street, 106, Ekaterinburg, 620016, Russia

G. S. BOLTACHEV K. E. LUKYASHIN
V. A. SHITOV N. B. VOLKOV

The evolution of solidification microstructures and corresponding evolution of micro residual stresses, and plastic strains during the welding process were numerically investigated. The sub-modeling technique (a separate analysis that can be used to any number of levels) was used to mesh a local part of the model with a refined mesh based on interpolation of the solution from an initial (undeformed), relatively coarse, macro global model. The meso-sub-model is the global model for the subsequent micro sub-model.

Edison A. Bonifaz Conto, Diego de Robles S/N y Pampite, Cumbaya, 17-12-841, Ecuador

S. BOSIAKOV A. VINOIKUROVA A. DOSTA
bosiakov@bsu.by

The important place in orthodontics is taken by the correction of anomalies of the top jaw which can be connected with a cross bite or the existence of inherent defect (gap) of a lip or the sky. Complex method is used for the treatment of the constriction of the upper jaw. This method provides surgical preparing of the orthodontic treatment (maxillary expansion). Various orthodontic device could be used for the expansion and constriction of the dental arch, particular orthodontic device Hyrax. Clinical observations show that the constructive features of the device for the maxillary expansion affect on the intensity and nature of the movement of the teeth and jaw bones. In this connection the research of the influence of a feature of the orthodontic device on the stress-strain state of a human skull is almost demanded. This work is devoted to the final element modeling of displacement of maxillary bones after promotion of various orthodontic devices Hyrax. Stereolithography (STL) model of the skull was obtained with the use of software for medical imaging MIMICS based on 210 images tomographic dried adult intact skull with well-preserved alveolar process and teeth. The finite element model is obtained after processing model STL-in module 3-matic package MIMICS. The development of a finite element model of orthodontic devices of the molar and the first permanent molar are manate at the Ansys Worbench package. The model of the device and teeth is added in final element model of a skull after importing into the Finite Element Modeler module. The boundary conditions, imposed on a skull, correspond to rigid support of the knots being in a neighbourhood of a foreman magnum. The displacement of each plate is 0.4 mm (it corresponds to work of the screw of the orthodontic device on a half-turn). The displacement of plates set only in the horizontal direction The distribution of equivalent stresses and displacements for skull obtained for three orthodontic appliance after the finite element calculation. The device are differ by the location of plates relative to the palate. In the first case, the rods and plates orthodontic device locate in the same plane, in the second and third cases, the orthodontic device and the plate located on the 6 and 8 mm higher (closer to the palate) to the horizontal position. Found that the direction and values of the total displacement significantly change while the plates of the orthodontic device are installed closer to the palate. In the case of horizontal displacement of rods and
plates device, the vectors of the displacement of the upper jaw are located above the occlusal plane, the maximum displacement is 0.2212 mm. When the plate device raised to 8 mm above with respect to the horizontal position, the total displacement vector directed almost down; largest displacement in this case is 0.4448 mm. This difference of the maximum total displacement can be explained by the appearance of the significant deformation of the nasal bone and lobintalledndy maxillary processes in the case of the third orthodontic device. At the same time, nature of distribution of displacements specifies that both considered designs of orthodontic devices aren’t optimum as maxillary expansion provides cross rather palatine suture shift of bones of a skull. Computer experiment showed that the best position of the device when they are located at the height approx 1/8 part of the distance between occlusal plane and upper palate.

Sergei M. Bosiakov, Nazavisimosti avenue, 4, Minsk, 220030, Belarus

2 DEG SPINFET MODEL
A. BOUDINE L. KALLA K. BENHIZIA M. ZAABAT
aboudine@hotmail.com
Beni.karima@laposte.net zaabat@hotmail.com

In this work we present the study of spin polarized transport in semiconductors as new type of current transmission in semiconductor devices, we built a 2deg model for so-called SPINFET transistor.

We chose the spinFET transistor or the transistor at spin rotation as a better implementation because it is a type of HEMT transistor in which we replace the source and drain by ferromagnetic contacts. The source contact acts as a spin polarizer for electrons injected into the conduction channel of the transistor and the drain contact is a spin analyzer to those (spins) which have reached the end of the canal. We establish the expression of drain current in function of orientations of the spin of electrons at the end of the canal and the magnetization of the drain contact, taking in account, the possibility to control the current through the grid voltage.

Boudine Azeddine, Route de Constantine, OUM EL BOUGHI, 4000, Algeria

CALCULATION OF THE CONTACT ANGLE AIR BUBBLE-PARTICLE
M. BOUHENGUEL S. KOUACHI A. BOUCHEMMA S. HAFSI
mbouhenguel@yahoo.fr sabrikouachi@yahoo.fr ahcene.bouchemma@gmail.com shafsi@yahoo.fr

Abstract A theoretical method for the calculation of contact angle of spherical particle in interaction with an air bubble in the flotation process was developed. The balance of forces acting on the instantaneous three phase contact perimeter in the radial direction could connect the central angle $\alpha$ and the contact angle $\theta$ in only one equation depending on the modified Bond number $Bo$. An another theoretical equation is developed which take into account the linear tension that depends on the both central angle $\alpha$ and the contact angle $\theta$. The application of the Newton’s mathematical method made it possible to couple this equation and obtained the desired contact angle for the particle size range between $[5 \ 100 \ \mu m]$. Some other theoretical results are presented in this study.

Bouhenguel Mustapha, University Of Oum El Bouaghi Algeria, Oum El Bouaghi, 04000, Algeria

EROSION-TYPE FRACTURE OF ASPHALT CONCRETE AS A RESULT OF AUTOMOBILE STUDS IMPACTS
V. BRATOV Y. PETROV
vladimir@bratov.com yp@yp1004.spb.edu

The paper will present a developed model in order to predict fracture of asphalt road surface impacted by an automobile tire stud. Two analytical approximations of the process will be studied. The first one is spall fracture of asphalt. The model is not very close to the real process, but the solution is simple and is providing a possibility to analyze effect of asphalt properties on critical impact speeds leading to asphalt fracture. The second analytical model is based on the known Hertz-type solution for a cylinder impacting half-space. This model is much closer to the real stud impact process and is providing a possibility to estimate the effect of asphalt elasticity modulus on critical stud velocity, leading to fracture of the asphalt surface. Fracture criterion for all the studied models is based on the incubation time theory for brittle fracture.

As a result of the analysis it is demonstrated that the critical automobile speed, leading to creation of fracture in asphalt does depend on asphalt elastic modulus. This dependency is received both qualitatively and quantitatively. It is shown that larger elastic moduli are resulting in smaller critical car velocities giving damage to asphalt. At the same time larger elastic moduli are providing better performance of asphalt layer undergoing quasistatic loading (slow heavy traffic). Practical solution to maximize durability of highways is to use different asphalt mixtures in right (slower) and left (faster) traffic lanes. This can be, for example, achieved by addition of plasticizers into asphalt mixture used to cover high-speed traffic lanes.

Vladimir Bratov, Bolsjov pr. V.O. 61, St.-Petersburg, 199178, Russia

VISCOSIMETRIC FLOW OF AN ELASTOVISCOPLASTIC MATERIAL UNDER THE PRESENCE OF A LUBRICANT ON THE RIGID CYLINDRICAL SURFACES
A. A. BURENIN L. V. KOVTANYUK A. S. USTINOV
ustinova@iacp.dvo.ru

In lubrication theory, the elasticity of a lubricating liquid is usually neglected. Therefore, the lubricant is modeled by a viscous or viscoplastic liquid and the rubbing parts are assumed to be
rigid. In that case, the wear and the fatigue strength of the materials joined by the lubricant layer are connected only with the direct contact of the rubbing parts due to extrusion of the lubricant layer; i.e., essentially, due to the defects in lubricant. In the case of considering the elastic properties of lubricant, long-term strength of material decreases because of deformation transfer through the lubricant layer. These processes affect significantly the fatigue strength of the parts and their long-term strength under operating loads of the type “load-uniform workload-unloading during braking and stopping”. Accounting for the elastic properties in the lubricant layer and the elastoplastic properties of the contacting bodies materials encounters considerable mathematical difficulties. Since, the deformations in the layer cannot be considered small, it is necessary to use the theory of large deformations of the bodies with elastic, plastic, and viscous properties.

In this paper, we used generalized model of large elastoplastic deformations taking into account the viscous properties of materials [1]. We obtained the analytical solutions of some quasistatic boundary value problems concerning the viscosimetric flows of an elastoviscoplastic material in the gap between the rigid coaxial cylindrical surfaces. In the neighborhood of one of the rigid cylinders (both internal and external), there is a layer of an elastic non-Newtonian lubricant. The slipping of a material is possible on the rigid cylinders. The conditions of origination of a flow are studied in the lubricant layer and in the basic material. The values of the maximum velocity of rotation were found when the flow does not exceeds the bounds of the lubricant layer. Reversible deformation, development and braking of a viscoplastic flow, unloading and deformation under rotation in the opposite direction were studied. The laws of the movement of the elastic-plastic flow boundaries were received.

REFERENCES


Aleksandra S. Ustinova, radio 5, Vladivostok, 690041, Russia

DYNAMICS OF THE FERROFLUID LAYER ON A LIQUID SUBSTRATE IN VERTICAL MAGNETIC FIELDS

C. A. BUSHUEVA K. G. KOSTAREV
bca@icmm.ru

We study the influence of an alternating magnetic field on the behavior of a new physical object - the ferrofluid layer with a stable rupture of the surface. This rupture is very sensitive to external influences due to the absence of the boundaries with solid phase. The presence of two easily deformable boundaries at the ferrofluid layer significantly reduce the value of the critical magnetic field at which the layer is destroyed, turning into an ordered system of drops or polygonal shapes that evolve with changes in the intensity, frequency and direction of the magnetic field.

Study the evolution of a horizontal layer of ferrofluid on a liquid substrate showed that the increase in strength of the non-uniform vertical axisymmetric magnetic field leads to the deformation of a continuous layer up to a rupture in the form of a perfect circle [1]. The critical strength is linearly dependent on the initial thickness of the ferrofluid. The emerged rupture remains after removal of the field in case the initial layer thickness does not exceed a certain value. In the case of relatively thick layers the appearance of the rupture is accompanied by the drop ordered structures.

The action of a uniform magnetic field directed perpendicular to the surface of the layer also causes the formation of an ordered system of drops which amount depends on the initial thickness of the layer, the presence of a stable rupture and its size as well as the rate of the field rise to the critical value [2]. The experiments show that the critical field strength increases with the initial layer thickness and decreases with increasing magnetic susceptibility of the ferrofluid. There were carried out the experiments on the deformation of the ferrofluid layer with alternating vertical magnetic field of low frequency acting in conjunction with a constant field.

This work was supported by RFBR grants No 12-01-31085, No 13-01-96041 and the Program of the Ural Branch of RAS (project No 12-T-1-1008).

REFERENCES


Christina A. Bushueva, Academic Korolev Str., Perm, 614013, Russia

THE ROLE OF TRIBOELECTRICITY IN POWDER BEHAVIOR

A. CASTELLANOS

castella@us.es

Triboelectricity is one of the oldest scientific subjects dating back to Thales de Miletus (600 hundred years B.C.). He made the observation that an amber rod attracts dust particles after it is rubbed with a cloth. Although the word triboelectricity comes from the Greek τρίβω for friction and ηλεκτρόν for amber, any two materials only need to come into contact and then separate for charge to be exchanged. Triboelectricity is an ubiquitous phenomenon in powders, since interparticle contacts are easily formed and destroyed.

Powders charge in all processes, in which the particles collide among themselves or against walls. Examples of triboelectrification in natural processes can be observed in sand storms, dust devils, and volcanic plumes. Triboelectricity also plays an important role in fluidization, pneumatic transport, silo storage, and pharmaceutical powder dispersion in devices such as dry powder inhalers. However, progress in its understanding has been very
slow because it involves temporal and spatial scales going from the atomic to the macroscopic level.

Tribocharging in metal-metal contacts in vacuum is thermodynamically driven by the difference of Fermi levels and was explained by Harper in the middle of last century. Tribocharging between metal-insulator and insulator-insulator contacts is believed to be a non-equilibrium kinetic process depending on the detailed mechanisms of charge transfer. Three different mechanisms have been proposed depending on the type of charge carrier: electron transfer, ion transfer and material transfer. We will discuss the actual state of knowledge on these transfer mechanisms.

Independently on the mechanisms of charge transfer, there is a limit to the maximum stable charge that a powder grain can sustain in ambient air (due to electrical breakdown). Engineers in the printing industry have developed charge control agents to charge the powder grains close to this limit. We will discuss the relative importance of van der Waals, capillary and triboelectrical forces for this limiting situation. It happens that van der Waals and maximal triboelectrical forces are of the same order for polymer particles of approximately 10 microns. Toners in the printing industry have sizes of this order, and it is no wonder that the controversy about whether van der Waals force or the triboelectrical force is dominant has raged in this industry until now.

The level of net charge depends on the impact energy that may vary widely from process to process. Apart from being an electrostatic hazard, it is known empirically that triboelectricity typically enhances powder cohesion, causes agglomeration, particle deposition on the walls, and worsens flowability. For this reason engineers have developed different means to reduce the level of tribocharging. Any optimal reduction technique has to be based on a sound understanding on which of the basic mechanisms of charge transfer is dominant. Examples will be presented to illustrate some of these reduction techniques, and its effect on packing.

Acknowledgements This research has been supported by IFPRI International Fine Particle Research Institute), the Spanish Government (project FIS2011-25161), Andalusian Government (FQM-253). I acknowledge very fruitful discussions with Dr. Elena Grekova.

Antonio Castellanos Mata, Calle Reina Mercedes s/n, Sevilla, 41012, Spain

POSITIVITY-PRESERVING NUMERICAL SCHEMES FOR CROSS-DIFFUSION MODELS IN BIOSCIENCES

M. Chapwanya J. Lubuma R. Mickens
mchapwanya@up.ac.za jean.lubuma@up.ac.za rmick23756@aol.com

Diffusion equations have been extensively studied for the modeling of biological processes such as animal dispersal and spread of disease. In contrast, for cross-diffusion equations, whereby the diffusion matrix is not strictly diagonal, the mathematical analysis is a challenging one which is largely undeveloped and they have received much less attention in biosciences. We consider a class of reaction-diffusion equations, including the Fisher equation, the solutions of which enjoy the positivity and boundedness properties. Furthermore, we consider two examples of cross-diffusion equations, which have positive solutions. The first example is a model for malignant invasion, which involves the concentrations of invasive cells, connective tissue and protease as dependent variables. The second example is a convective predator-prey pursuit and evasion model. For the class of reaction-diffusion equations, we design nonstandard finite difference (NSFD) schemes that are dynamically consistent with respect to the positivity and the boundedness of solutions. This is achieved by coupling Mickens’ rules (of complex denominator function of discrete derivatives and nonlocal approximation of nonlinear terms) with a suitable functional relation between the time and the space step sizes. When applied to the two cross diffusion models, it is shown that this approach leads to NSFD schemes which are not dynamically reliable. We then obtain dynamically consistent NSFD schemes for the cross-diffusion models by an alternative strategy which, apart from Mickens’ rules, consists in using a special nonlocal approximation of the diffusion terms, the step sizes varying independently from one another. We provide numerical experiments that support the reliability of the NSFD schemes for the relevant continuous models.

Jean M. Lubuma, Lynnwood Road, Pretoria, 0002, South Africa

THE INFLUENCE OF THERMAL DIFFUSION ON THE FORMATION OF THE TRANSITION ZONE BETWEEN THE COATING AND BASE

M. V. Chepak-Gizbrekht A. G. Knyazeva
mv2016@mail.ru anna-knyazeva@mail.ru

The analytical solution of the problem of the alloying elements redistribution between the coating and the base at the nonisothermal conditions was obtained taking into account the effects of thermal diffusion and the difference in element mobilities in various materials. The mathematical model is a one-dimensional conjugate problem with perfect contact between the materials. The heat flux of specify intensity acts on the coating surface. The heat and mass fluxes are absent at infinite distance from the contact of materials. At the initial time, alloying element presents only in the coating. Using the information on the concentration and temperature fields the stresses and strains were evaluated. In approaching of an elastic body the problem of mechanical equilibrium of sample is solved similar to the problems of thermoelasticity theory. For different viscoelastic bodies, the solution is found with the help of analogy method. It has been demonstrated that the thermal diffusion plays a basic role in the case when one of the materials has the low thermal conductivity.

Marija V. Chepak-Gizbrekht, Lenina, 30, Tomsk, 634050, Russia

THE MECHANICS OF LIQUID FOAMS

S. Cox
foams@aber.ac.uk

An aqueous foam consists of regions of gas enclosed by thin liquid lamellae, yet its properties encompass those of solids as well as liquids. Foams are elasto-visco-plastic materials. It is
this rich behaviour, which results largely from the local geometric structure, that leads to their use in a number of applications, including personal care products, the froth flotation process for ore separation, and enhanced oil recovery.

I will describe the detailed geometry of a foam, including Plateau’s laws and the Young-Laplace law. I will make the link between local structure and the static elastic shear modulus $G$, and show how bubble-scale simulations can be used to predict the dependence of $G$ on bubble volume dispersity and liquid content.

Moving from statics to dynamics, I will describe the way in which a foam evolves over time. This includes ageing mechanisms such as gas-diffusion through the films and liquid drainage through the structure, as well as the rheological response. A foam behaves as a shear-thinning fluid, and I will make the case that bubble-scale simulations of foam rheology are required to determine appropriate parameters for continuum modelling.

Simon Cox, IMAPS, Aberystwyth, SY23 3BZ, United Kingdom

SOME PROBLEMS ON KINETICS OF “DIFFUSION” CRACKS AND DELAMINATIONS

I. N. DASHEVSKIY
dash@ipmnet.ru

In the cracks contained in such materials as metals under the action of corrosive media, degrading polymers and ceramics (for example, HTSC-ceramics), gas-saturated rocks, etc., gas can be accumulated. For a penny-shaped crack in an unbounded elastic medium and for a thin penny-shaped delamination under the surface of a half-space, as well as for similar cracks-strips, in a new uniform way on the basis of the energy approach and with the use of Clapeyron theorem kinetic equations are derived describing the growth of specified defects under gas diffusion into them. The analysis of the reasons leading to identity of the equations named, allows (under some conditions) to extend the results obtained for these problems to a number of other important cases: cracks on the interface of an adhesive joint of two pliable half-spaces with different mechanical and diffusion properties (with the interface being permeable as well as impermeable), the account of anisotropy, etc. It is shown, that exactly the same reasons (and under the same restrictions) make it possible to extend to the same cases the results obtained earlier for growth laws of a penny-shaped crack in an unbounded elastic medium versus laws of gas inflow into it as well.

Keywords: crack, crack formation, fracture, bending, plate, wedge, model, indenter.

Ilya N. Dashevskiy, prosp. Vernadskogo 101, block 1, Moscow, 119526, Russia

SYMMETRIC CRACKING IN BENDING OF A PLATE AND A WEDGE

I. N. DASHEVSKIY
dash@ipmnet.ru

Introduction. The energy approach is used to develop a model of brittle fracture of a thin plate (and a wedge) under bending by a point indenter, which permits studying some possible mechanisms determining the number of sectors into which the plate breaks.

The model. We assume that: the plate is loaded by a point indenter; as the plate strength is exhausted, fracture occurs instantaneously with the formation of a symmetric system of radial cracks; one can neglect the irreversible losses and the possible dynamics; the main contribution to the energy balance equation is made by the energy of formation of new surfaces (cracks) and by the elastic bending energy of the arising sectors; the minimum-energy-consuming fracture scheme is realized. Since the energy necessary to form new cracks and the total elastic bending energy of the $n$ triangular sectorsbeams arising under bending vary in opposite directions with variation in both the crack length $L$ and $n$, it follows that the total energy required to form $n$ sectors has a minimum depending on $L$ and $n$, and it is this minimum that determines the number $n$ of the arising sectors.

Results. In the simplest scheme, the number of developing cracks turned out to be independent of the plate physical-mechanical characteristics and its thickness and varied from 2 to 4 as the wedge opening angle varied from 0 to $2\pi$ (on the charts $w(n, \varphi)$ is the reduced dimensionless function of energy costs for a wedge with an angle of $\varphi$ in the formation of $n$ sectors). An analysis was performed and a qualitative interpretation of the obtained results was given. Possible refinements of the proposed model in various directions were discussed. Some results for a circular plate of finite dimensions (clamped plate; freely supported plate; clamped annular plate) were given.

Keywords: crack, crack formation, fracture, bending, plate, wedge, model, indenter.

Ilya N. Dashevskiy, prosp. Vernadskogo 101, block 1, Moscow, 119526, Russia

ON THE FORMATION OF REGULAR CRACK NETWORKS AROUND OIL AND GAS WELLS UNDER UNIFORM COMPRESSION

I. N. DASHEVSKIY
dash@ipmnet.ru

The energy approach is used to propose a model of arising of regular systems of cracks, emerging the surface of a circular cavity, being observed, for example, around oil and gas wells under uniform compression. The cracks are supposed to arise due to the accumulation of elastic compression energy in the system. The limit compression (the exhaustion of strength) being achieved, a network of cracks is formed in the most stressed layer adjacent to the interior of the body, thus utilizing the accumulated elastic energy of this layer. In this case, of all the possible grids the least energy-consuming one is formed, that is, the system with such a number $n$ and length $L$ of the cracks, that the energy needed for its creation is minimal. In the simplest scheme the number $n$ of “petals”-wedges arising from the cracking turns out to be equal to 5 (which corresponds to $2n = 10$ cracks) and (contrary to limit compression pressure magnitude) be independent on geometrical and physical-mechanical parameters of the problem.

Ilya N. Dashevskiy, prosp. Vernadskogo 101, block 1, Moscow, 119526, Russia
MEASUREMENT AND MODELING OF THE UNLOADING FUNCTION OF LOWER LIMBS ORTHOSES

I. N. Dashevskiy  S. E. Nikitin
dash@ipmnet.ru

We study and simulate mechanisms and degree of unloading when applying orthoses on an affected lower extremity. This is important since the rate of bone regeneration depends on the intensity of loading the limb. The degree of unloading of lower limbs for two types of orthoses with varying magnitude of lateral compression was measured in vivo by means of “DiaSled” system for underplantal pressure field measurements. In experiment the coefficient of unloading turned out to vary from 1 to about 2.3 depending on specific conditions. The problem of its quantitative dependence on the degree of lateral orthosis compression requires further research. Based on comparison of structural stiffness of individual elements of the system, obtained either by direct estimate, or through a specially delivered experiment, or by solving the problem of axial shear of a tubular cylinder, a biomechanical model of limb unloading by orthoses was developed. The model predicted a linear decrease of the axial load on the orthosed limb with increasing orthosis lateral compression and gave a theoretical estimate of the coefficient of unloading from zero to 1.6–2.1 depending on the degree of compression. On the other hand, proposals were drafted for updating orthoses’ fabrication and application technique; they aim to facilitate the ability to control the degree of unloading (which significantly affects the rate of bone regeneration) by changing the lateral compression.

Keywords: biomechanics, orthoses, lower limbs, unloading, modeling, measurement

Ilya N. Dashevskiy, prosp. Vernadskogo 101, block 1, Moscow, 119526, Russia

COMPUTATION OF TEMPERATURE STRESSES IN THE PROCESS OF UNSTEADY HEATING WHEN ESTIMATING VISCOUS BEHAVIOR OF MATERIAL

E. P. Dats  A. G. Konstantinov  E. V. Murashkin
dats@dvo.ru murashkin@dvo.ru

Temperature stresses which are generated due to high temperature gradients, to a great extent determine behavior of a lot of modern constructions. Heat stresses by themselves and in combination with outside mechanical strains can cause cracks and further breach of hyper-fragile materials. Some materials, when under an immediate stress caused by a wild unsteady temperature field, grow fragile and can’t stand heat shock. The theory of thermoviscoelasticity studies the possibilities to find computational and analytical solutions to stress-deformed state of a quill cylinder in conditions of uneven steady-state heating of boundary surfaces. It’s a well known that some materials such as glass begin to develop viscous behavior at high temperature levels. Applying a classical model of a general one-dimensional body, we managed to find analytical solutions to temperature stresses and deformations caused by uneven thermal action assuming that the viscosity factor is constant. On the basis of the above solutions we examined the possibility to find a computational solution to the equilibrium equation of the thermoelasticity theory adjusted for viscous behavior of the material. This solution was used to determine distribution of parameters for a stress-deformed state taking into consideration the dependence of the viscosity factor on temperature.

This research was supported by the grant of the President of the Russian Federation (MK-776.2012.1) and the grant of the Russian Foundation for Basic Research (mol_a_ved 12-01-33064).

Evgenii V. Murashkin, Radio, 5, Vladivostok, 690041, Russia

GENERATING RESIDUAL STRESSES FIELDS OF A QUILL CYLINDER MADE OF THERMO-ELASTIC-PLASTIC MATERIAL

E. P. Dats  S. N. Mokrin  E. V. Murashkin
dats@dvo.ru msn_primat@mail.ru murashkin@dvo.ru

The level of residual stresses and strains can have a significant affect on exploitation parameters of materials. In case of high temperature gradients the influence of generating residual stresses and decreases in the yield stress of the material, could be the determining factor to launch a process of irreversible deformation. To calculate the condition of an elastic-plastic body, which has accumulated irreversible deformations and to evaluate the level of residual stresses in conditions of cooling the body to initial temperature in particular, one needs to estimate a displacement field. The problem of how to evaluate a displacement field was firstly considered by D. D. Ivlev within the framework of the theory of an ideal elastic-plastic body. He showed the way to compute displacement in statically determinate problems of a perfect plasticity theory and indicated the conditions when it is feasible. The above method of computing displacement is applied to solve the problem under our study. The research is devoted to the study of how the characteristics of stress-deformed state of material are developed under high temperature gradients and influence of residual deformations on the further process of temperature stress formation. We examined the generation of residual stresses of a quill cylinder in conditions of zero loading force accompanied by uneven steady-state heating of boundary surfaces. We detected the emerging zones of plastic yielding in the vicinity of the cylinder surfaces. Then residual deformations and stresses are calculated on cooling.

This research was supported by the grant of the President of the Russian Federation (MK-776.2012.1) and the grant of the Russian Foundation for Basic Research (mol_a_ved 12-01-33064).

Evgeniy P. Dats, Radio, 5, Vladivostok, 690041, Russia
A new model has been developed to simulate a woven textile composite layer with a polycrystalline matrix. Based on the numerical solution of the boundary-value problem by the finite-element method, the values of stress concentration caused by local processing defects (break in a fiber, closed internal pore) under two-axial transversal macrodeformation are obtained. It is shown that application of additional processing operations to fill the formed voids by matrix material can decrease stress concentration and increase the ability of a material to withstand external force loads. The mechanisms responsible for initiation of damages in a polycrystalline matrix are determined.

The authors acknowledge the support of the Russian Foundation for Basic Research (Grant RFBR–Urals No 11–01–96033).}

Denis Dedkov, 29, Komsomolsky Ave., Perm, 614990, Russia

THE INITIATION OF THE MARANGONI CONVECTION ON THE LIQUID-LIQUID INTERFACE
M.O. Denisova K.G. Kostarev R.V. Birikh
maria.denisova@icmm.ru

Experimental study of the solutal Marangoni convection showed that the capillary motion of water begins only when a threshold concentration gradient [1] is generated at the interface. The cause of the water surface rheology is the adsorbed film, which is formed of uncontrolled surface-active impurities. The chromatographic analysis shows that most of these contaminants are organic compounds, poorly soluble in water, which allows them to be accumulated on the surface, acting as surfactants. At the same time many of them are readily soluble in organic liquids, which should reduce sharply their concentration in water in the case of contact with one of these liquids. Due to a reduction of the surface concentration of impurities the value of the concentration threshold should decrease.

Experimental verification of this assumption made for a number of organic solvents showed that the threshold for initiating the capillary convection at the interface is preserved. It is important to note that, depending on the type of solvent, the value of the threshold may either decrease or increase. For some organic liquids water itself was a good solvent for uncontrolled surface-active impurities. Exceeding of the threshold concentration gradient gives rise to capillary flows, characterized by the symmetry with respect to the interface and a small penetration of the flow in the bulk of water, and in bulk of the solvent.

The obtained data are in qualitative agreement with the simulation results, in which the the liquid-liquid interface is presented as a separate phase with bingham properties.

The work was supported by the project of RFBR 12-01-00656, and the loint project of SB, UB and F-E B of RAS No12-C-1-1006

---

REFERENCES


Maria O. Denisova, street Acad. Koroleva, 1, Perm, 614013, Russia

THEORETICAL STUDY OF THE PROCESS OF SELF-SUSTAINING HIGH-TEMPERATURE SYNTHESIS OF Ni3Al UNDER INTENSIVE PLASTIC DEFORMATION
A. V. Dimaki S.V. Astafurov E. V. Shilko V.E. Ovcharenko S.G. Psakhie
dav@ispms.tsc.ru

Currently, methods of obtaining of nanostructured intermetallic compounds, based on the self-sustaining high-temperature synthesis with simultaneous intensive plastic deformation of the reaction mixture (SHS+IPD), develop intensively. At that, detail understanding of the processes, taking place in the reacting system, requires both experimental and theoretical studies. In this paper, we describe the mathematical model of the SHS+IPD for Ni3Al system, the results of model verification are shown. We also demonstrate the influence of the applied external pressure on the process of SHS.

The model of SHS+IPD process includes the following system of equations: 1) the heat transfer equation; 2) the equation of motion of the reaction mixture, and 3) the continuity equation and 4) the equation of chemical kinetics (or several of these equations, in case of modeling "staged" transformation of mixture of initial components into the reaction product). The initial and boundary conditions for these equations are determined by the problem under consideration. In order to adequately describe the temperature profile, the processes of melting and crystallization of reagents and reaction product are explicitly taken into the account in the model. The effect of mechanical stress on the synthesis effectively taken into account in the model by means of introducing a medium pressure (with the corresponding coefficient) into the exponent in the equation of chemical kinetics. Thus, the model assumes that the mechanical stress impact on the speed of overcome of potential barrier without changing its height. The system of equations is solved by the finite difference method on a uniform grid in the two-dimensional formulation.

The developed model has been verified by means of comparison of the dependencies of temperature on time during the synthesis reaction in thermal explosion mode, without the application of external stresses, obtained in experiments and in the simulation. Quantitative agreement between simulation results and experimental data has been demonstrated. The effect of intensive plastic deformation regime on the synthesis of intermetallic compound has been theoretically investigated. In particular, the influence of strain rate and the time interval between the start of the synthesis and application of mechanical stress has been studied. Obtained results can be applied for selection of regime of SHS+IPD process.
The model is universal and, by appropriate choice of parameters, can be modified to describe the synthesis of a wide class of intermetallic compounds in the SHS+IPD regime.

Andrey V. Dimaki, Academicheskii av. 2/4, Tomsk, 634021, Russia

THEORETICAL STUDY OF THE MECHANICAL RESPONSE OF FLUID-SATURATED MEDIUM WITH HYBRID CELLULAR AUTOMATON METHOD

A. V. Dimaki  E. V. Shilko  S. V. Astafurov  S. G. Psakhie
dav@ispms.tsc.ru

Study of the mechanical response of fluid-saturated porous media under mechanical loading represents one of the actual problems being on a joint of materials science, the theory of elasticity and plasticity, dynamics of liquids and gases. As analytical as numerical researches by means of traditional and widely known methods of simulation are complicated due to the absence of the advanced approaches allowing adequate description of interaction of components of medium, being in various aggregate states at different scales. In order to solve the abovementioned problem, the hybrid cellular automaton method has been developed. The main idea of this method is to join together particle method and net method. The hybrid cellular automaton method represents the combination of conventional and movable cellular automaton methods (CCA and MCA, correspondingly). The investigated medium is considered as the superposition of two interrelated media, one of which is described by a set of MCA and another by a mesh of CCA.

The step of calculation consists of two substeps. First of them is the step of the MCA model, called “mechanical”. In the framework of MCA method the simulated medium is described as an ensemble of finite-size interacting particles (Movable Cellular Automata). At the “mechanical” substep motion equations of movable automata are solved, processes of mass transfer and fracture of solid under mechanical loading are simulated. Next for the mechanical - “net” substep is performed on a mesh of CCA. At this substep the process of mass transfer of fluid (liquid or gaseous) in the pores and channels is considered, as well as the values of the forces acting to MCA from gas phase are calculated. The configuration of solid frame is projected to CCA mesh from MCA layer. Proposed approach allows one to join solutions of mechanical and gas (or liquid) dynamics problems to describe the multiphase heterogeneous medium.

Recently the developed approach has been applied to study the behaviour of samples of gas-saturated porous brown coal. It has been shown that the presence of gas in pores produces significant effect on mechanical properties of material, in particular, on its strength under uni-axial loading.

The method of hybrid cellular automaton is universal and can be applied to describe the behaviour of a wide class of media consisting of components in solid, liquid and gaseous phases, including ceramics, composites and biological materials.

Andrey V. Dimaki, Academicheskii av. 2/4, Tomsk, 634021, Russia

MODIFICATION OF AUTOMOTIVE BRAKE PAD-DISC INTERFACE IN ORDER TO PROVIDE SMOOTH SLIDING CONDITIONS. COMPARISON OF NANO-SCALE MODELING WITH EXPERIMENT

A. I. Dmitriev  W. Oesterle  H. Kloss  G. Orts-Gil
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. This is due to the mutual interaction of multi-scale mechanisms realized during the friction. In this work we have attempted to partly answer this question using computer simulations. Since the simulation allows us to consider various combinations of the structure of the system being simulated ceteris paribus, it becomes possible to understand the role of each constituent sequentially. The main attention is paid to structure and composition of the thin film that forms on the surface of both bodies as a result of compaction of wear product, its chemical composition and oxidation. This layer, also named a third body or friction film, differs in composition and microstructure from the two first bodies. We considered a single contact for the steady state sliding when the structure and composition of friction films already are formed. As a modeling tool we used the method of movable cellular automata (MCA), which has well proven itself in solving of such tasks. We investigated the influence of modification of the structure and composition of the third body on the features of system behavior at friction. The mechanical properties of inclusions, their concentration, the uniformity of distribution in the iron oxide matrix, and the structure of the oxide matrix itself was varied systematically. The results show the influence of the presence of soft inclusions on the frictional characteristics of the system. To assess the adequacy of the numerical model experimental studies with an artificial third body were also carried out. 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 are in good agreement with those experimental data.

Andrey I. Dmitriev, Akademicheski 2/4, Tomsk, 634055, Russia

NEW MODELLING OF EBG CARBON NANOTUBES STRUCTURE

C. Dridi  M. Zaabat  A. Boudine
dridichahrazed@yahoo.fr  zaabat@hotmail.com  a_boudine@hotmail.com

Since little is known isolate a sheet of carbon-graphite one atom thick. This crystal is two-dimensional graphene has remarkable electronic transport and mechanics properties, which are neither those of a metal nor those of a semiconductor. In this paper we have developed a novel structure electromagnetic band gap (EBG), with a periodic arrays of carbon nanotubes presented, by introducing a multiwalled carbon nanotubes like a metallic via holes. The electromagnetic band gap (EBG) surface, also referred to as a photonic band gap (PBG) surface, has attracted extensive
ON THE OCCURRENCE AND DISTRIBUTION OF SPHERICAL WAVES IN AN ELASTIC MULTIMODULUS MEDIUM

O. Dudko A. Lapteva
dudko@iacp.dvo.ru lanastal@mail.ru

The dynamic deformation of an elastic media with different resistance to tension and compression is considered. The model, which allows to move from problems with flat surfaces breaks to the case of spherical symmetry, is proposed. Properties of the generalized solutions of quasilinear equations of motion for the case of one-dimensional plane and spherical waves generated by transient action of the border of a multimodulus elastic medium are investigated within the framework of the chosen model. The obtained solutions of boundary value problems with one-dimensional plane and spherical waves showed a fundamental difference of propagation process of boundary disturbances in the piecewise linear multimodulus medium from the known results of the linear theory of elasticity. For the case of one-dimensional converging spherical waves in multimodulus medium the possibility of emergence of a spherical layer of constant density is shown. This layer which is a transitional area between the regions of stretched and compressed material is moving and expanding over time. It is obtained that the time of emergence the leading front of such a layer is later than the time of the changing nature of the boundary impact from a compressive force to the tensile (effect of “delay”).

Olga Dudko, Radio, 5, Vladivostok, 690041, Russia

DISPLACEMENT OF MISCEIBLE VISCOUS FLUIDS FROM THIN GAPS

V. Dushin V. Nikitin Yu. Philippov N. Smirnov
ebifsunl@mech.math.msu.su

The goal of the present study is to investigate numerically and experimentally the peculiarities of two-component viscous fluid flow in a thin plane channel, and to determine entrainment and flushing out one component by the other. Experiments on miscible displacement of fluids in Hele-Shaw cells were conducted under microgravity conditions. Extensive direct numerical simulations allowed to investigate the sensitivity of fluid flow to variation of values of the main governing parameters. Validation of the code was performed by comparing the results of model problems simulations with experiments.

Viscous fluids flow in gaps and blocked up space is relevant to problems of fluid flows in heat exchangers. Flows of multi-component fluids components possessing different properties (viscosities) have many peculiarities. In frontal displacement of a more dense and viscous fluid by a less dense and viscous one the Rayleigh-Taylor or Saffman-Taylor instability of the interface could bring to formation and growth of “fingers” of low viscosity component penetrating the bulk fluid.

The problem is also relevant to a hydrocarbon recovery. Entrainment of high viscosity fluid by the low viscosity fluid flow lowers down the quality of a hydrocarbon recovery leaving the most of viscous fluid entrapped thus decreasing the production rate.

The developed models and obtained results are applicable to description of liquid non-aqueous phase contaminants underground migration, their entrainment in the zones of inhomogeneity, and forecasting the results of remedial activities in the vicinities of waste storages and contaminated sites.

Nickolay N. Smirnov, Leninskie Gory 1, Moscow, 119991, Russia

INTRODUCTION TO MICROPOLAR MECHANICS

V. A. Eremeyev H. Altenbach
eremeyev.victor@gmail.com holm.altenbach@ovgu.de

The aim of the lecture consists of the presentation of basics of the micropolar continuum mechanics including a short but comprehensive introduction of stress measures, derivation of motion equations and discussion of the differences between Cosserat and classical (Cauchy) continua.

Mechanics of Micropolar Continua (or Cosserat Continua) was summarized in the famous book by the Cosserat brothers, Eugène and François, published the monograph “Théorie des corps déformables” in 1909. Since that time there were published tenth of books and thousands of papers in this field, see e.g. [1–8] where the state of the art in the field of the Cosserat theory is presented. In the Cosserat continuum translations and rotations of a material particle are kinematically independent. In other words, force and moment actions in the continuum are introduced independently as in dynamics of rigid body or mechanics of structures. In a micropolar medium, each material particle has six degrees of freedom, they are three translational and three rotational degrees of freedom. Besides ordinary stresses in the theory of there are introduced couple stresses. The micropolar continuum model closes the gap between the General Mechanics and the Strength of Materials. Such characteristic features of the Cosserat continuum model give a possibility to describe complex microstructured media, for example, micro-inhomogeneous materials, foams, cellular solids, lattices, masonry, particle assemblies, magnetic rheological fluids, liquid crystals, etc.

We briefly discuss some elements of rigid body dynamics to demonstrate that Cosserat’s description of continua fills up the gap between the Continuum Mechanics and Mechanics of rigid bodies. Here we formulate the Euler laws of motion and present the kinematics of a rigid body. Then we generalize the Cosserat approach to deformable media and derive from the Euler laws of motion the motion equations of micropolar continuum and
present Lagrangian and Eulerian statements of the boundary-

value problems. The content of the lecture is partially based on
[7, 8].

REFERENCES

[1] Nowacki, W. Theory of Asymmetric Elasticity. Pergamon-


[2] Eringen, A. C. Microcontinuum Field Theory. I. Founda-


[3] Eringen, A. C. Microcontinuum Field Theory. II. Fluent Me-


eralized Continua: One Hundred Years After the Cosserats.


Victor A. Eremeyev, Universitaetsplatz 2, Magdeburg, 39106, Germany

INTERACTION OF SOLITONS PROPAGATING IN A GRANULAR MEDIUM

V. I. Erofeev I. S. Pavlov V. V. Kazhaev

erf04@sinn.ru ispavlov@mail.ru

ipmvvk@mail.ru

A one-dimensional model of the granular medium is consid-

ered that represents a chain consisting of elastically interact-

ing particles, which possess translational and rotational degrees of freedom. In the long-wavelength approximation, the nonlinear differential equations have been derived that describe propaga-

tion of longitudinal, transverse and rotational waves in such a medium. Analytical dependences of the velocities of elastic waves and the nonlinearity coefficients on the sizes of particles and the parameters of interactions between them have been found. In the field of low frequencies, when the rotational degree of freedom of particles can be neglected, the obtained three-mode system reduces to a two-mode one. Numerical investigations of contradirectional and passing interactions of strongly nonlinear soliton-like subsonic and supersonic waves have been performed within the scope of the latest model. In particular, effects of splitting of supersonic solitary waves are demonstrated.

Vladimir I. Erofeev, Belinsky str., 85, Nizhny Novgorod, 603024, Russia

STRUCTURAL CHARACTERISTICS OF ENSEMBLES WITH RANDOMLY LOCATED INCLUSIONS

S. E. Evlampieva E. A. Parkaeva
ev1@cmm.ru

Real highly-filled structures demonstrate random structural features. To determine the micromechanical features occurring during the deformation of these composites, it is necessary to study the character of structural stresses and strains dependent on the geometric structure of a composite system, the properties of system components and the bond character between these components. This paper investigates the stress-strain state of the ensemble consisting of 91 equal-sized rigid inclusions randomly located in an infinite elastomeric matrix (plane strain) and loaded at infinity by a single tensile stress.

Mean stress fields and maximum principal strain fields are pre-

sented. The dependence of Young’s modulus on filler concen-

tration of composites is obtained. Comparison of the results of calculations for random and regular structure consisting of 91 inclusions is carried out. A software package COMPOSITE 2D is prepared and tested. The package is intended for calculation of microstresses and microstrains in the plane case (plane strain) and for determination of the effective properties of any structures.

The work was supported by grant RFBR 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.

Svetlana Evlampieva, 1, Ak. Korolov Str., Perm, 614013, Russia

MATHEMATICAL MODEL OF MICROPOLAR ELASTIC ORTHOTROPIC MULTILAYERED THIN BARS

A. Farmanyan

afarmanyan@yahoo.com

Micropolar theory of elasticity is a structural phenomeno-

logical model of rigid deformable bodies with strongly expressed internal structure. From this point of view the construction of mathematical models of micropolar anisotropic elastic multilayered thin bars, plates and shells is actual.

The main problem of the construction of models of micropolar elastic thin bars, plates and shells is in approximate, but adequate reduction of two-dimensional or three-dimensional boundary-

value problem to one-dimensional or two-dimensional problem.

In papers [1-3] general theories of micropolar elastic isotropic thin shells, plates and bars are constructed on the basis of asimptotically confirmed hypotheses method.

In the present paper hypotheses, accepted in paper [1], are generalized for the whole package of multilayered thin rectangle (plane boundary-value problem of micropolar theory of elasticity for orthotropic material is studied) and applied one-dimensional model of micropolar elastic orthotropic multilayered (with non-
symmetric structure) thin bars with free fields of diaspalements and rotations is constructed. Private models of micropolar orthotropic multilayered thin bars with constrained rotation and
“with small shear stiffness” are constructed. Models of two-layered and three-layered micropolar bars of symmetric structure are also studied.

REFERENCES


Anahit Farmanyan, Paruyr Sevak 4, Gyumri, 377501, Armenia

SPIN-ORBITAL MOTION: SYMMETRY, DYNAMICS, MULTIRESOLUTION

A. N. FEDOROVA     M. G. ZEITLIN
anton@math.ipme.ru zeitlin@math.ipme.ru

We present the results of a number of 2-D Surface Evolver simulations of the motion of a single foam lamella traversing an idealised rock pore. The film configuration in this quasi-static model satisfies Plateau’s equilibrium rules, and pressure difference is given via the Young-Laplace equation. Two parameters

CLASSIFICATION OF HYPERBOLIC EQUATIONS ARISING IN THE THEORY OF LONGITUDINAL VIBRATIONS

I. FEDOTOV     J. MARAIS     M. SHATALOV
fedotovi@tut.ac.za

Abstract Longitudinal vibration of bars are normally considered in mathematical physics in terms of classical model described by the wave equation under assumptions that the bar is thin and relatively long. More general theories have been formulated by taking into consideration the effects of the lateral motion by which the cross section of relatively long and thick bar (beam) are extended or contracted. A mathematical formulation of these models includes higher order derivatives in the equation of motion. Rayleigh did the simplest generalization of the classical model in 1894, by including the effects of lateral motion and neglecting the shear stress. Bishop developed the next generalization of the theory in 1952. The Rayleigh-Bishop model is described by a forth order partial differential equation not containing the fourth time derivative. He takes into account the effects of shear stress. The Rayleigh-Bishop’s model was generalized by Mindlin and Hermann. They considered the lateral displacement proportional to an independent function of time and longitudinal coordinate. This result is formulated as a system of two differential equations of second order, which could be replaced by a single equation of forth order resolved with respect to the highest order time derivative. The number of models is not restricted by the Mindlin-Hermann model. To obtain more general class of equations, the longitudinal and lateral displacements are expressed in the form of a power series expansion in the lateral coordinate. We consider all above mentioned equations in the frame of general theory of hyperbolic equations with the view of finding out to which kind of hyperbolic equations belongs one or another of them. We discuss the solvability of the corresponding problems.

Igor Fedotov, Nelson Mandela Dr., Pretoria, 0001, South Africa

MULTISCALE REPRESENTATION FOR SPACE-CHARGE DOMINATED BEAM TRANSPORT

A. N. FEDOROVA     M. G. ZEITLIN
anton@math.ipme.ru zeitlin@math.ipme.ru

We consider space-charge dominated beam transport systems, where space-charge forces have the same order as external focusing forces and dynamics of the corresponding emittance growth. We consider the coherent modes of oscillations and coherent instabilities both in the different nonlinear envelope models and in initial collective dynamics picture described by the Vlasov system. Our calculations are based on the variation approach and multiresolution analysis in the base of high-localized generalized (coherent) states. We control contributions to dynamical evolution from the underlying tower of hidden multiscales via invariant orbital nonlinear eigenmodes expansions in the base of compactly supported wavelets and wavelet packets bases.

Antonina Fedorova, V.O. Boshoj pr., 61, St. Petersburg, 199178, Russia
defining the shape of the pore were varied several thousand simulations, and the average pressure difference across the lamella recorded for each simulation. The results reveal four different types of motion, and an explanation based on geometric arguments is given as to how the shape influences which type of motion occurs. A plot of the average pressure difference across the lamella for all simulations shows two distinct bands across the parameter space where it is substantially higher, which occur when the lamella makes a jump in order to minimize its length and satisfy a volume constraint.

David Ferguson, Physical Sciences Building, Aberystwyth, SY23 3BZ, United Kingdom

**LONG-TERM FORECASTING OF CHANGES IN THE PERMAFROST OF THE WELLS AND THE DIFFERENT TECHNICAL SYSTEM**

M. Yu. Filimonov N. A. Vaganova

fmy@imm.uran.ru vna@imm.uran.ru

To model non-stationary temperature fields in permafrost from wells and other facilities have developed a new three-dimensional mathematical model, which takes into account not only the climatic (seasonal changes in temperature and solar radiation due to the geographical location of the field) and physical factors (different thermal characteristics of uniform ground which change over time), but also engineering design features and other wells of the technical systems [1-2]. Based on this model, a set of programs Wellfrost, for which a certificate of state registration of the computer. This set of programs has been tested on seven oil and gas fields located in the permafrost zone, which on the basis of numerical calculations have been developed Regulations (regulations), the last technical review and approved in Rostekhnadzor.

Comparison of numerical and experimental data for the field “Russkoe” has shown that the accuracy of the numerical results to determine the position of the boundary below the thawing influence of seasonal changes in temperature from the injection well was approximately 5% in the three years of its operation. This suggests that the developed algorithm and software package Wellfrost benchmark to test various tools and will be in demand in the oil and gas industry and construction, especially after the use of “cloud technology” in the organization of numerical computations on multi-processor computers with the integrated package of open climate databases and NASA development of an appropriate interface.

The study is supported by Program of UD RAS “Arktica”, project No 12–1–4–005.

**REFERENCES**


Mikhail Yu. Filimonov, N.A.. Vaganova, Institute of Mathematics and Mechanics UrB RAS, S.Kovalevskaya str., 16, Ekaterinburg, 620990, Russia

**FORMABILITY OF THE AUSTENITIC NICKEL-BASE SUPER ALLOY AMS 5596 SHEET IN COMPARISON WITH EXTRA DEEP DRAWING QUALITY STEEL SHEET**

W. Fracz T. Pieja F. Stachowicz T. Trzepieciński

stafel@prz.edu.pl

Formability of sheet metal is dependent on the mechanical properties. Some materials form better than others - moreover, a material that has the best formability for one stamping may behave very poorly in a stamping of another configuration. For these reasons, extensive test programs are often carried out in an attempt to correlate material formability with value of some mechanical properties. The formability of sheet metal has frequently been expressed by the value of strain hardening exponent and plastic anisotropy ratio. The stress-strain and hardening behaviour of a material is very important in determining its resistance to plastic instability. However experimental studies of formability of various materials have revealed basic differences in behaviour, such as the “brass-type” and the “steel-type”, exhibiting respectively, zero and positive dependence of forming limit on the strain ratio.

In this study mechanical properties and the Forming Limit Diagram of the AMS 5596 sheet metal were determined using uniaxial tensile test and Marciniak’s flat bottomed punch test respectively.

Feliks Stachowicz, al. Powstacw Warszawy 8, Rzeszw, 35-959, Poland

**CRITICAL RADIUS OF METASTABLE ZIRCONIA INCLUSIONS IN THE EFFECT OF TRANSFORMATION TOUGHENING OF CERAMICS**

A. B. Freidin R. A. Filippov E. N. Vilchevskaya I. Huusainova

rmnfilippov@gmail.com

Possible increase in fracture toughness of ceramics can be reached a result of stress induced martensite transformation from tetragonal to monoclinic polymorph of ZrO2 particles embedded into a bulk ceramic material. The incidence of transformations depends on zirconia particle size because of the energy input of the surface energy: too small particles remain overstabilized and do not experience transformation while too large particle may spontaneously transform at the technological stage of cooling. Thus, the size of metastable zirconia particles must belong to a certain range for effective transformation toughening. The critical sizes of the particles are usually estimated by comparing the Gibbs energy of ceramic with particles in the different phase
states taking into account changes of chemical, strain and surface energies. If the transformation criterion is just the equality of the Gibbs energies, as it is usually accepted, then two critical sizes are very close and the sizes range becomes too narrow and unrealizable practically. We additionally introduce into consideration an energy barrier that must be surmounted on the way of the transformation of the particles and may be related to formation of the new phase nucleus inside the particles. The energy barrier reduces the relative contribution of the chemical energy changes and increases the effects of stresses on the critical size of particle. As a result we obtain an adequate range of the critical sizes that is consistent with an experimental data. The barrier is estimated basing on the experimental data given in literature. Effect of elastic interaction of the particles on the critical radius is examined by a self-consistent approach. Then the range of particle sizes is defined in dependence on the energy barrier, operating temperatures, critical stresses and material parameters.

Roman A. Filippov, V.O., Bolshoj pr., 61, Saint-Petersburg, 199178, Russia

CHEMICAL AFFINITY TENSOR IN MECHANOCHEMISTRY OF DEFORMABLE SOLIDS
A. Freidin E. Vilchevskaya I. Korolev L. ShariPOVA
alexander.freidin@gmail.com vilchevskaya@gmail.com i.korolev82@gmail.com sleah07@gmail.com

We consider a stress-assist chemical reaction front propagation in a deformable solid undergoing a localized chemical reaction between solid and diffusing gas constituents. We introduce a chemical transformations strain tensor that relates two reference configurations of solid constituents and depends on reaction parameters. Then mass, momentum and energy balances are written down for the open system considered and the expression of the entropy production due to the reaction front propagation in a solid with arbitrary constitutive equations is derived. As a result, the expression of the chemical affinity tensor is obtained. In a quasi-static approach this expression looks like the expression of the classical chemical affinity if exchange scalar chemical potentials of solid constituents by the Eshehly stress tensors determined with respect to the reference configurations and divided by the reference mass densities. Additional terms appear in a dynamical case. A comparison of the chemical reaction front with the phase boundary in a case of martensite transformation is made. The kinetic equation for the reaction front propagation is formulated as a dependence of the reaction front velocity on the normal component of the chemical affinity tensor that acts as a configurational force. The influence of stresses including locking effects (blocking the reaction by stresses) are discussed. Analytical and numerical solutions of coupled problems of mechanochemistry are demonstrated.

Alexander B. Freidin, Bolshoy, 61, V.O, St. Petersburg, 199178, Russia

ATOMIC FORCE MICROSCOPY AS APPLIED TO MATERIALS WITH ANISOTROPIC NANOSTRUCTURE
O. K. Garishin S. N. LEBEDEV

gar@icmm.ru

Creation of new nanostructured materials is impossible without serious study of their internal structure at the nanoscale level (when it is necessary to consider the effects associated with the features of the molecular structure of substance, even though the material can still be considered as a continuous medium). Atomic force microscopy (AFM) is one of the most promising tools for such studies. Its main advantage over traditional electron microscopy is that the atomic force microscope allows to obtain information not only on the topology of the internal structure of the material, but also on its local physical properties (which may differ significantly from the macroscopic characteristics).

Standard software supplied to decrypt the atomic force scanning (AFM), based mainly on the models using a classical solution of the Hertz contact of two linearly elastic spheres (or a sphere and a flat half, if one of them has infinite radius). In most cases this is enough. However, there are situations where the Hertz solution should be used with great caution. For example: 1) a very “soft” materials, when the AFM probe is pressed into the sample to a greater depth, 2) the sample surface has microasperities commensurate probe tip radius, 3) the test material is anisotropic at nanoscopic level. This work is devoted to the theoretical study of last version.

Modeling processes in contact AFM probe, the surface was considered as a brittle elastic medium crumbling in the interaction with the probe (tooth enamel). It is known that the tooth enamel is a complex of heterogeneous media consisting of parallel long and fragile prisms with characteristic transverse dimension of the order of 2 to 8 mm. Typically, these prisms are perpendicular to the work surface of the tooth and quite firmly connected to each other at the sides. Such a material must have anisotropic properties. Enamel can be regarded in terms of mechanics as a transversely isotropic body, in which the stiffness in direction perpendicular to the surface is different from tangential stiffness.

The problem of repeated indentation of AFM probe into the same place the damaged brittle elastic transversely isotropic material has been solved. Is a growing hole remained in the sample after each contact (as a result of brittle fracture of the material). That is, changing the geometry of the sample surface occurred without permanent plastic deformation. Repeated indentation into the same place allows you to collect the necessary information about its true mechanical properties and modeling should help in adequate explanation of the data. Power dependences of the response of the AFM probe on the depth of its indentation and degree of anisotropy of material were obtained as a result. These data will be used in experimental studies of the nanostructure of enamel at different stages of tooth decay.

This work is executed at the financial support of RFBR and Perm Ministry of Industry of Innovations and Science (Grants 11-08-96001-r_ural_a, 13-08-00065), Perm Ministry of Education under agreement -26/627 (MIG)

Oleg K. Garishin, 1, Academic Korolyov st. , Perm, 614013, Russia
EXPERIMENTAL STUDIES OF POLYMER-SILICATE NANOCOMPOSITES STRUCTURE

O. K. Garishin  V. V. Shadrin  I. A. Morozov

shadrin@icmm.ru

Nanocomposites based on polyolefins and layered clay minerals (smectites) - is a promising new class of materials, which are currently the object of intensive fundamental and applied research. Polymer-silicate nanocomposites are widely used in industry, both as a structural material and for other purposes (heat insulation, fire resistance, preventing diffusion, etc.).

These systems are heterogeneous medium consisting of a polyolefin matrix (polyethylene, polypropylene, etc.), and embedded in it ultra-thin silica flakes (usually Na montmorillonite). Characteristic sizes of inclusions are a few nanometers in thickness and from 30 to 1000 nm in diameter. These particles may be randomly distributed over the volume of the material or form a packs of parallel plates. Matrix forming polyolefins are also partially crystallized polymers. Their structure can be divided into two parts with different mechanical properties: amorphous (a chaotic arrangement of the molecules) and crystallites (formations of regularly arranged molecular chains).

Creation of new nanostructured materials is impossible without serious study of their internal structure at the nanoscale. Atomic force microscopy (AFM) is one of the most promising tools for such studies. It allows to obtain information not only on the topology of the internal structure of the material, but also on its local physical properties (which may differ significantly from the macroscopic characteristics).

Studies were carried out on polyethylene PE 107-02K filled with modified clay Cloisite 20A (plate thickness of about 1-2 nm, in diameter 80-100 nm). Filler concentration varied from 0 to 15%-mass. PE-107-02C is partially crystallizable thermoplastic, the degree of crystallinity up to 50-60%.

The original technique of sample surface preparation to the AFM scan was developed. In the first place melting polyethylene crystallites, and then restore them (recrystallization) occurred in polyethylene by special heat treatment. Thus, the crystallite formations on the surface became more visible, and the micro damages caused in the sample manufacture disappeared.

Experiments were performed on atomic force microscopes Nano-DST and Bruker Icon in semicontact mode of nanomechanical mapping. As a result AFM scans of topography, hardness and adhesion to surface areas measuring 100×100 μm were built. It was found that the highest hardness (over 1000 MPa) and practically zero adhesion is characteristic of nanofiller particles. Amorphous phase was the least hard – 15-30 MPa, but had the greatest adhesion – about 15-20 nN. Stiffness and adhesion characteristics of the crystallites were somewhere in the middle: about 300 MPa and 7 respectively nN.

Crystallites, emerging the surface of the sample, represents formations of several packs of slightly curved parallel plates with a thickness of 30-60 nm with a soft amorphous phase in the gaps. The number of these layers varied from 10 to 20. Thus, using an atomic force microscope could estimate the mechanical properties of the elements of the composite nanostructure.

This work is executed at a financial support of RFBR and Perm Ministry of Industry of Innovations and Science (Grants 11-08-96001-p_ural_a, 13-08-00065), Program RAS 12--1-1004.

Vladimir V. Shadrin, 1, Academic Korolyov st., Perm, 614013, Russia

THRUST ALLOCATION FOR UNDERWATER ROBOTIC VEHICLES

J. Garus
j.garus@amw.gdynia.pl

Unmanned underwater vehicles (UUVs) have known an increasing interest in the last decades. The main benefits of usage of the UUVs can be removing human beings from the dangers of the underwater environment and reduction in cost of exploration of deep seas. There are various categories of the UUVs. The most often used ones are Underwater Robotic Vehicles (URVs). The URV is connected to a surface ship by a tether, which all communication is wired through, and equipped with a multi-thruster propulsion system.

Power distribution in the propulsion system is a key problem in control synthesis of the URV. Based on the analytic geometry, taking into account restrictions put on propelling forces and moments, some methods of finding of an optimal thrust allocation for desired values of propulsive forces and moments are described. Optimisation of thrust allocation is directed towards minimization of an energy expenditure necessary to obtain the required control. Special attention is paid to the unconstrained thrust allocation and techniques like the quadratic programming, the method of least squares and the method of matrix orthogonalization.

The work includes algorithms of the power distribution for both a faultless work of the propulsion system and a case of failure of the thruster.

Illustrative examples are inserted to demonstrate correctness and computational simplicity of the proposed thrust allocation strategies.

Jerzy Garus, Smidowicza 69, Gdynia, 81-577, Poland

A STRAIN-SOFTENING BAR REVISITED

S. N. Gavrilov  E. V. Shishkina
serge@pdmi.ras.ru shishkina_k@mail.ru

We discuss and improve from the standpoint of the modern theory of phase transitions the classical analytical solution by Z.P. Bažant et al. [1,2] describing the wave propagation in a strain-softening bar.

REFERENCES


Serge Gavrilov, Bolshoy 61, St.Petersburg, 199178, Russia
To this end, we have proposed in our early works the system of constitutive relations and kinetic equations for describing the mechanisms of intermolecular interaction effects on the character of deformation processes of semi-crystalline polymers on a phenomenological level. The capabilities of the proposed system have been verified in a number of numerical experiments on modeling the distinguishing features of deformation processes of semi-crystalline polymers at a certain temperature interval that includes temperature intervals of phase and relaxation transitions. To determine the material constants in the constitutive and kinetic equations, we have developed a program of experimental investigations with a Zwik universal testing complex and a setup NET-ZSH DMA 224C.

Based on this program, a cycle of thermomechanical experiments devoted to the investigation of deformation processes taking place in the semi-crystalline polymer (low-density PE) was carried out. The material was tested under a homogeneous stress-strain state on complex trajectories in the space “stress/strain/temperature time”. These experiments were focused on verifying the proposed system of constitutive physical relations and kinetic equations.

The study was supported by the RFBR (grant 12-08-00832).

Lyudmila A. Golotina, 1, Ak. Korolev str., Perm, 614013, Russia
Irina Goryacheva, Vernadskogo,101, Moscow, 119526, Russia

S.O.GLADKOV, R.G.RABADANOV ONSYNERGETIC OSCILLATIONS A THIN STRING.
S. O. GLADKOV R. G. RABADANOV
sglad@newmail.ru ramazan.1981@yandex.ru

Non-linear partial differential equation describing random motion of the free end of a string (fixed at one end) and supplemented with transversality condition for the moving - boundary problem has been obtained by means of synergetic principles. Account has been made of gravity and medium resistance forces, and their influence on the string motion has been analyzed. Some particular cases of the obtained system of non-linear equations have been studied.

Sergey Gladkov, Volokolamskoe shosse, 4, Moscow, 125997, Russia

ANALYSIS OF STRESSES IN THUMB CARPOMETACARPAL JOINT BASED ON THE TOMOGRAPHY DATA
I. G. GORYACHEVA G. M. ANFEROV
goryache@ipmnet.ru

The study of stress state in the thumb carpometacarpal joint was carried out using the methods of solid mechanics. The geometric model of the joint was constructed based on the computer tomography data in the position of extension of the thumb, obtained at the Department of Biomedical Engineering, National Cheng Kung University (Taiwan). The isotropic and anisotropic elastic bodies were used as the models of the cartilage and bones, respectively. The study of the contact interactions of bones in the joint was carried out numerically for a given geometry using ABAQU5 code. Based on the numerical solutions of the contact problem the comparative analysis of the stress distributions in bones and cartilage was carried out for various positions of bones. The dependences of the stresses on the cartilage thickness and bone porosity changed with the human age were also analyzed.

Irina Goryacheva, Vernadskogo,101, Moscow, 119526, Russia

MOTION OF BINARY FLUID IN A CRACK IN ELASTIC POROUS MEDIA
S. GOLOVIN V. ISAEV S. KALININ D. KUZNETSOV
golovin@hydro.nsc.ru visayev@slb.com
skalinin@slb.com dkuznetsov4@slb.com

We propose a model of planar crack propagation in isotropic...
porous elastic media. The crack is created due to injection of binary fluid containing liquid and solid components in the middle. The proposed model is an extension of known Kristianovich-Geertsmra-DeKlerk approach having the following features:

1. motion of liquid and solid components is described by a 2D model of binary fluid flow in Hele-Shaw cell;
2. fluid leak-off to the surrounding media is simulated using a piston-type mechanism;
3. oscillating concentration of injected components versus time at the inflow.

Numerical experiments allowed us to demonstrate a number of physical effects that the new model can capture:

1. instability of the fronts between binary fluid components;
2. influence of concentration oscillations on the crack propagation.

This work is focused on a development of the mathematical model and the algorithm for its numerical implementation.

Vadim I. Isaev, 1/10 Zelenaya Gorka, Novosibirsk, 630060, Russia

A THEORETICAL WAY TO CONSTRUCT MATERIALS WITH RESONANT FREQUENCIES, FORBIDDEN BANDS, AND APPARENT HISTORY DEPENDENCE

E. Grekova
elgreco@pdmi.ras.ru

We consider a linear elastic material with a complex particle (point body). Each particle is characterized by several generalized coordinates, scalar and vectorial. The elastic energy of the material depends on these coordinates and their gradients. We consider the case when there exists at least one coordinate, whose gradient does not influence any forces or couples in the material, but the elastic energy depends on the coordinate itself. In such a medium the following regime of motion is possible: all other coordinates are static, and this special coordinate is governed by an ordinary differential equation, which determines some resonance frequencies. We prove that if we cannot observe this coordinate, we will find an apparent history dependence in the material, though in some cases it may seem that the material objectivity is violated.

We construct materials with strain energy that does not depend on the gradient of such vectorial coordinate(s). In these materials we have non-propagating resonant motion in this/these coordinate(s) at some frequencies, which define limits for forbidden frequency bands, where the wave for other coordinates, coupled with them, does not propagate. Some researchers call media with such an apparent attenuation “acoustic metamaterials”. One example of them is the reduced Cosserat continuum.

I acknowledge the financial support from the Spanish National project FIS2011-25161 for attending APM2013.

Elena F. Grekova, Bolshoy pr. V.O., 61, St. Petersburg, 199178, Russia

MULTISCALE NUMERICAL STUDY OF MECHANICAL RESPONSE OF ZIRCONIA ALUMINA CONCRETE WITH PARTICLE-BASED MCA METHOD

A. S. Grigoriev  E. V. Shilko  V. A. Skripnyak  S. G. Psakhie
grigoriev@ispms.tsc.ru shilko@ispms.tsc.ru skrp@ftf.tsu.ru sp@ispms.tsc.ru

The majority of natural and technical materials have multiscale heterogeneous internal structure, which can be represented as a hierarchy of three principal structural scales: micro-, meso- and macroscopic scales. To model such materials at different structural/spatial 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.

In the present work the proposed 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.

Implemented multiscale approach is applied to construct a multiscale structural model of zirconia alumina concrete (ZAC) with reinforcing particles of electrofusion zirconia and barium-alumina cement binder. 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 against the spread of radioactive substances into the environment in case of severe accidents.

Nikolaevsky’s plasticity model with non-associated flow law was chosen as a rheological model for ZAC at the different structural scales. The main feature of Nikolaevsky’s model is the postulated linear relationship between the bulk and the shear components of plastic strain rate. Coefficient of this relationship is a function of both accumulated inelastic strain and strain rate.

When constructing the MCA-based multiscale model of ZAC the internal structure of the material on macroscopic and mesoscopic structural scales was taken into account. Each automaton at the macroscale was characterized by physical and mechanical parameters corresponding to the integral response of mesoscopic representative volume of ZAC. Samples of mesoscopic representative volume were designed with explicit consideration of irregularities of internal structure. Properties of cellular automata modeling components of mesostructure were determined using available experimental data in the literature.

Two types of mechanical tests were simulated: split (“Brazilian test”) and compression in a rigid jacket (to simulate modified Kolsky’s test). As a result of these tests the mechanical properties (including parameters of the rheological model and strength
values) of ZAC concrete were obtained for both macroscopic and mesoscopic scales. The influence of parameters of the internal structure of ZAC (including concentration of aggregates, porosity and strength of interfaces) on the mechanical properties of concrete was investigated.

The investigation has been carried out at partial financial support of the RFBR initiative grant No.12-01-00805-a.

Aleksandr S. Grigoriev, 2/4, pr. Akademicheskii, Tomsk, 634021, Russia

DEVELOPMENT OF ALGORITHMS FOR COMPUTING THE COLLISIONAL DYNAMICS OF GRAVITATING PARTICLES TO SIMULATE THE FORMATION OF THE EARTH-MOON SYSTEM THROUGH THE GRAVITATIONAL COLLAPSE OF A DUST CLOUD UNDER THE INFLUENCE OF SUN GRAVITY

P. Grigorieva  N. Markov  R. Lapin
nimfadoras@mail.ru m.k.s.f@list.ru lapruslan@mail.ru

One of the important questions of the modern science is the origin of the Moon. Investigations of Vernadsky Institute of Geochemistry and Analytical Chemistry of Russian Academy of Sciences and Keldysh Institute of Applied Mathematics showed that the Moon formation started from protoplanetary disk. Then this hypothesis was investigated within the method of particle dynamics by Prof. Krivtsov and Dr. Le-Zakharov and in particular the formation of two massive bodies was observed. The computer simulation was hold with rotating disk without considering gravitational field of the Sun. In this work this investigation is continued using the developed method: the influence of the Sun is taken into consideration and the parameters close to the real ones are used in the computer simulations. Our experiments prove the ability of origin of the Earth and Moon from a spinning protoplanetary cloud. Now we are working on improvement of computing method and finding initial parameters to approximate the results of the computer experiments to real situation.

Polina M. Grigorieva, Politechnical street,29, Saint-Petersburg, 195251, Russia

MISFIT DISLOCATION LOOPS IN CORE-SHELL NANOPARTICLES

m.y.gutkin@gmail.com, anna.kolesnikova.physics@gmail.com, krasnitckii@gmail.com, aer@mail.ioffe.ru

The core-shell nanoparticles (CSNPs) have attracted significant interest due to their vast applications in optoelectronics, photonics, spintronics, catalysis, sensors, solar cells, biomedicine, etc. [1-3]. As the core and shell materials have different crystal lattice parameters and thermal expansion coefficients, the formation of CSNPs is accompanied with appearance of residual (misfit) elastic strains and stresses which can relax by different mechanisms [4, 5]. One of the possible ways of the stress relaxation is the generation of circular misfit prismatic dislocation loops (CMPDLs) around the core. A first-approximation analysis of the case, when such a CMPDL lies in the equatorial section of a CSNP, was done in [5]. 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 in the CSNP with respect to the CMPDL generation.

Recently we have solved a boundary-value problem in the theory of elasticity for a circular prismatic dislocation loop placed coaxially in an elastic sphere [6]. This has allowed us to reconsider rigorously the problem of a CMPDL placed in an arbitrary plane around the core in an elastically homogeneous CSNP. We have calculated the energy change due to the CMPDL 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 CSNP sizes and the CMPDL position along the core axis. In the special case of a CMPDL lying in the CSNP equatorial plane, the exact diagram of structural stability in the CSNP, which is given by the dependence of the critical misfit on the ratio of the core and shell radii, well corresponds with the approximate diagram built in [5] if the CSNP radius is large enough. When this radius becomes smaller than roughly 6080 nm, the approximate diagram predicts underestimated values for the critical misfit, and the difference between the approximated and exact critical values increases with decreasing radius of the CSNP.

We have also considered a more general case, when the CMPDL occupies an arbitrary position along the axis of the CSNP, and built the corresponding diagrams of structural stability for the system. The most important result of these diagrams is that the critical misfit reaches its minimum value for a CMPDL lying in the CSNP equatorial plane. This means that the equatorial position of the CMPDL is the most energetically preferable in any CSNP.

REFERENCES


Stanislav Krasnitckii, 29 Polyteknicheskaya st., St. Petersburg, 195251, Russia

DYNAMICS OF EDGE DISLOCATIONS IN DISCLINATION STRESS FIELDS UNDER SHOCK COMPRESSION

M. Yu. Gutkin  E. A. Rzhavtsev
m.y.gutkin@gmail.com, egor.rzhavtsev@gmail.com

In recent decades, the micromechanics and physics of large
plastic deformations in metals and alloys have remained in focus of extended research [1-4]. A commonly accepted view is that the structural transformations, which accompany the large plastic deformations, are caused by coupled evolution of dislocation and disclination ensembles. An effective way for theoretical description of this evolution 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]. This paper represents our further results in this field.

The computer code is updated to take into account the coupled dynamics of dislocations of opposite signs which can annihilate if their spacing becomes smaller than a critical distance. As before [8], in view of highly nonequilibrium conditions of shock wave propagation, we assume that at the boundaries of the simulation box, which model the subgrain boundaries in a metallic grain under shock compression, there are some jumps of misorientation angles. For tilt boundaries, the jump points are effectively described in terms of partial wedge grain-boundary disclinations [1, 2]. These disclinations create elastic fields which strongly affect upon edge dislocations being generated and gliding within the simulation box under a shear stress. The stress level and dura-

ble are determined by the shock impulse characteristics. We take three model disclination configurations which are a dipole, a quadrupole, and a random multipole, and in every case we consider various dynamic dislocation structures forming under different stress levels ranging from 0 to 1 GPa, with the middle level 0.5 GPa corresponding to conditions of shock compression experiments with Al-based alloy D16 [9, 10]. The main result of this modeling is that in many cases, the dislocations form a number of stable walls which are in fact new low-angle boundaries within the pre-existing subgrain. This process represents the physical mechanism of the subgrain fragmentation under the shock compression. Using our computer code, we have shown that typical duration of the shock impulse 650 ns in experiments [9, 10] is much longer than the time necessary for the fragmentation. It is also important that thus formed dislocation structures remain stable after the shock compression.

REFERENCES


Egor Rzhavtsev, Polytechnic Street 29, Saint-Petersburg, 684312, Russia

GENERATION OF RECTANGULAR PRISMATIC DISLOCATION LOOPS IN SHELLS OF COMPOSITE CORE-SHELL NANOPARTICLES

M. Yu. Gutkin A. M. Smirnov
m.y.gutkin@gmail.com
blinoezhka.as@gmail.com

The composite nanoparticles (CNPs) have been among the hottest topics in modern materials science, solid state physics, chemistry and biomedicine [1-3]. Due to contacts of different materials, CNPs are the subject of residual (misfit) elastic strains and stresses which can relax through generation of various defects [4, 5]. These defects can lead to degradation of many properties (electronic, optical, etc.) of CNPs, which explains the great attention to this problem [2]. In particular, different mechanisms of misfit stress relaxation in core-shell CNPs were suggested in [4]. Recently they have been revisited with more details in [5]. One of the possible mechanisms discussed in [4, 5] is the generation of prismatic dislocation loops in the shell of a core-shell CNP. However, the authors [4, 5] did not specially analyze this case.

In the present work, we consider the energetics for generation of rectangular prismatic dislocation loops in the shell of a core-shell CNP which is assumed elastically isotropic and homogeneous. Further, we suppose that the shell thickness is much smaller than the core radius, in which case one can use a planar model of a thin layer on a semi-infinite substrate for correct calculation of the strain energy of the rectangular dislocation loop [6]. Within these approximations, we give strict analytical calculations of the energy changes accompanied the loop generation on either core-shell interface or outer shell surface, and compare these cases in terms of critical misfit parameters with account for the loop shape. We consider the following three characteristic shapes for the dislocation loops: (i) extended along the interface (AI-loop), (ii) square (S-loop), and (iii) extended normally to the interface (NI-loop). It is shown that for both the cases of loop generation from the shell free surface and core-shell interface, the AI-loops are the most preferable. On the other hand, the loop generation is more profitable from the core-shell interface than from the shell free surface for NI- and S-loops and vice versa for AI-loops. Thus, we can conclude that the generation of AI-loops from the shell free surface is the most preferable channel of misfit stress relaxation in the shell for prismatic dislocation loops. The critical misfit for AI-loop generation from the shell free surface increases when the shell thickness increases and the core radius decreases.

REFERENCES


A. HAKEM Y. BOUAFIA

ahakem1951@yahoo.fr
youcef.bouafia2012@yahoo.com

Elaboration and mechanical characterization of a material are of paramount importance because the engineer cannot calculate or determine the allowable loads of a room without knowing the mechanical properties of the material he intends to use. In addition, he must know from what part load begins to deform irreversibly (limits of elastic) resulting in a change of its geometry (residual elongation) and from which there is a risk of load failure (tensile strength).

The purpose of mechanical testing is to quantify the values of the characteristics that will be used in the calculation of strength of materials in service, prior to use in a given application, must fulfill their proper functioning in various embodiments in order to rationally exploit and avoid, in some cases, disaster leading to severe consequences.

The mechanical properties are closely related to the microstructure. To understand the behavior of materials in use and able to control their properties, it is necessary to describe and quantify their microstructure.

The choice of this material was dictated by the fact that it is widely used in various mechanical applications, while the addition of 7% mass. If (0.20 to 0.60)% Mg and its subsequent heat treatment to various industrial processes of sand casting and metal shell were chosen following the significant improvements in certain desired properties which gives it excellent if skills for casting combined with Mg which is the main agent for improving mechanical properties.

EXPERIMENTAL PROCEDURE:
To determine the behavior of the material deal with various stresses it may encounter during use, these solicitations are reproduced using static or dynamic tests, usually conducted on standard specimens in order to know the characteristics Figures of the material. Four techniques are used, namely traction to identify the various constraints, the Brinell hardness HB for the stress field, resilience Kcv us about the mode of fracture, fragility and resistance to shock and metallographic to identify structures.

Keywords: Al-Si, tempering, ripening, income, sand, shell.
optimum process parameters. During production series, the surface finishing process and strengthening treatment for granular test pieces are presented, about calculations results also approved industrially.

Hamouda Khaled, el alia bp 32 bab ezzouar, Algiers, 16042, Algeria

ELASTIC PROPERTIES ON THE ATOMIC SCALE
P. HANSSON M. JANSSON S. MELIN
per.hansson@mek.lth.se
solveig.melin@mek.lth.se

The elastic and plastic properties of a thin FCC copper film resting on a stiff substrate are investigated simulating displacement controlled nano-indentation through molecular dynamics calculations. The thickness of the film is down to a few nanometers, only, and the characteristics of the loading-unloading curve studied assuming the indenter to be stiff. The force-displacement curve is monitored during displacement controlled indentation and the precise conditions for the occurrence of so called pop-ins during loading are investigated. The influences from indenter size, coating thickness and crystallographic orientation are determined. Also conditions for dislocation formation initiation and the development of dislocation structures are studied.

Solveig Melin, Division of Mechanics, Lund University, P. O. Box 118, S-22100 Lund, Sweden

MATHEMATICAL MODELS OF ELASTIC DEFORMATION AND TEMPERATURE STRESSES OF MICROPOLAR ORTHOTROPIC THIN PLATES
G. S. HAYRAPETYAN N. S. ASLANYAN S. H. SARGSYAN
gayane_hayrapetyan@mail.ru
asnaira73@mail.ru slusin@yahoo.com

Micropolar theory of elasticity is a phenomenological theory of elastic bodies, where internal structure of material is taken into consideration. Effects of micropolarity of the material are significant for thin bodies as plates and shells [1,2].

In the present paper general mathematical models with free fields of displacements and rotations of elastic deformation and thermoelasticity of micropolar orthotropic elastic plates are constructed. In the basis of the above mentioned models general hypotheses are put, which are the qualitative properties of the solution of corresponding three-dimensional boundary-value problem, obtained with the help of asymptotic integration in thin domain of the plate.

Following private models of elastic deformation and thermoelasticity of micropolar orthotropic thin plates are constructed: a) with constrained rotation; b) with “small shear stiffness”.

Concrete problems of determination of stress-strain state and temperature stresses of general plane stress state and bending of micropolar orthotropic thin plates are studied. Effective properties from the point of view of strength and stiffness of micropolar material are revealed on the basis of numerical analysis.

REFERENCES

Samvel Sargsyan, Paruyr Sevak 4, Gyumri, 377501, Armenia

VIBRATIONS OF AN ELASTIC PLATE FLOATING ATOP A TWO-LAYERED FLUID AT LOW FREQUENCIES
D. A. INDEITSEV D. P. KOZOV M. G. ZHUCHKOVA
m.zhuchkova@list.ru

We consider low-frequency vibrations of an infinite elastic plate floating upon a two-layered fluid of finite and constant depth. To describe wave motion in the upper layer shallow water approximation is used. Dispersion curves obtained from this approximate theory are compared with exact ones.

Marina G. Zhuchkova, V.O., Bolshoj pr., 61, St. Petersburg, 199178, Russia

TEMPERATURE MODELS IN SOLID MECHANICS. PROBLEMS OF INTERACTION BETWEEN LASER RADIATION AND CRYSTAL LATTICES
D. A. INDEITSEV
Dmitry.Indeitsev@gmail.com

The present work deals with a dynamic problem of thermoelectricity. The problem arises from experimental data on the parameters of thermoelastic response in dielectrics and metals. The theoretical study is motivated with a dramatic difference in the behavior of heat-conducting and non-heat-conducting materials under microsecond laser heating. The difference can’t be explained in terms of classical model. In order to find an adequate description, another two-component model which takes into consideration the interaction between lattice and electron gas is presented. Each component is assumed to have its own temperature. In order to analyze the suggested model we discuss the possibility of solving the initial-value problem by applying the Galerkin procedure on a variable interval. The method is based on the assumption that almost all perturbations of some physical value are concentrated in the finite interval. The length of the interval depends on time and isn’t known in advance.

Dmitry A. Indeitsev, V.O., Bolshoj pr., 61, St. Petersburg, 199178, Russia
STATIC DEFORMATION OF A TWO-COMPONENT MEDIUM WITH NONLINEAR INTERACTION FORCE

D. A. INDEITSEV    D. YU. SKUBOV    D. S. VAVILOV

Dmitry.Indeitsev@gmail.com
skubov.dsk@yandex.ru londr@yandex.ru

Usually phase transitions in solids are described by using the assumption about unstable constitutive law, containing a decreasing segment. The present paper investigates the possibility of obtaining such stress-strain relation through considering two-component medium with nonlinear interaction force. The problem is formulated for one dimension in space. Numerical solution is compared with results, obtained by applying the Galerkin procedure.

Dmitry S. Vavilov, V.O., Bolshoj pr., 61, St. Petersburg, 199178, Russia

SCREEN SEPARATION: COMPUTATIONAL MODEL BUILDING EXPERIENCE

K. S. IVANOVA    L. A. VAISBERG

ivanoff.k.s@gmail.com

The work is revealing authors’ experience in developing of computational resource-effective algorithm for modeling of vibrational screen separation of granular materials. It is shown that numerical interpretation of several analytical models could lead to a new approach which is not as resource-intensive as widespread multifunctional computational methods (including DEM) are. Being based on the problem-oriented classical models the algorithm presented here appears to demand for little deployment time compared with universal approaches for it doesn’t require vast calibration and adjustment procedures to precede its application. Another significant advantage of the algorithm is the fact that providing precise enough results simulations could be performed with no extensive computational resources. Fast simulations allow performing automatic estimation of optimal screening devices design and technological parameters provided that search area and goal function are given.

The algorithm allows parcelwise improvements which were illustrated with advanced openings passing and vibrational separation submodels.

Kirill S. Ivanov, V.O., Bolshoy pr., 61, St. Petersburg, 199178, Russia

ON NUMERICAL SIMULATION OF CONDUCTOR GALLOPING USING VORTEX ELEMENT METHOD

O. A. IVANOVA

ivanovaolga1@mail.ru

A conductor is considered to be absolutely flexible (its flexural and torsional rigidities are equal to zero) and linearly elastic. Its motion is described by the following set of equations:

\[
\frac{\partial}{\partial \xi} \left( \frac{Q}{1 + Q/\alpha} \frac{\partial x_i}{\partial \xi} \right) + \left(1 + \frac{Q}{\alpha}\right) q_i^a + \delta_{i3} - \frac{\partial^2 x_i}{\partial \tau^2} = 0,
\]

\[
i = 1, 2, 3,
\]

\[
\frac{\partial^2 x_1}{\partial \xi^2} + \left(\frac{\partial x_2}{\partial \xi}\right)^2 + \left(\frac{\partial x_3}{\partial \xi}\right)^2 = (1 + \frac{Q}{\alpha})^2.
\]

Here \(\xi \in [-0.5, 0.5]\) is a natural coordinate, \(\tau\) is time; \(Q(\xi, \tau)\) is the tension; \(x_i(\xi, \tau), i = 1, 2, 3\), are cartesian coordinates of conductor; \(q_i^a(\xi, \tau), i = 1, 2, 3\), are aerodynamic loads; \(\alpha = \text{const}\) is the longitudinal stiffness; \(\delta_{ij}\) — Kronecker delta. Boundary conditions are

\[
x_1(\pm1/2, \tau) = \pm t/2, \quad x_2(\pm1/2, \tau) = 0, \quad x_3(\pm1/2, \tau) = 0,
\]

where \(t\) is dimensionless length of the span.

These equations are transformed to a set of nonlinear differential-algebraic equations using Galerkin method. The system of basis functions for Galerkin method consists of preliminarily computed eigenmodes of the conductor small free oscillations and some additional functions needed to satisfy boundary conditions and to describe the conductor equilibrium form.

Starting from time \(\tau = 0\) the conductor is exposed to an air flow with constant velocity \(V_\infty\). Aerodynamic loads are calculated using flat cross-section method, i.e. for \(N\) separate conductor cross-sections under the assumption that the flow around them is plane-parallel. Thereby the 3-dimensional problem of the flow around the conductor simulation is transformed to a set of \(N\) 2-dimensional problems. To simulate the flow around the conductor cross-sections the vortex element method is used.

The program using MPI technology is developed, which enables to execute computations effectively on various multiprocessor systems. All parallel processes divided into equal groups; each group (which consists in the simplest case of one process) provides simulation the flow around one cross-section. Aerodynamic loads calculated in particular cross-sections are sent to the ‘main’ process, which integrates the conductor motion equations on the next time step. New positions of cross-sections and their velocities are broadcasted to all processes which continue the flow around cross-sections simulation. The opportunity of stationary aerodynamic coefficients usage instead of direct load computation, like the majority of investigators do, is also available.

Several test computations were executed. For some cases the galloping phenomenon was observed. The results were compared with those known from literature. The influence of the way of aerodynamic loads calculating and the influence of some mathematical model modifications on the parameters of galloping were investigated.

Olga A. Ivanova, 2-n P. Baumanskaya, 5, FN-2 dep., Moscow, 105005, Russia
NUMERICAL MODELING OF EXTEND AND COMPRESSION INTERFACE AIRCRAFT-RUNWAY BY MARTINGALE FOR PREDICTION ACCIDENTS

L. Kabeya Mukeba Yakasham
km_kabeya@hotmail.com

This paper presents a stochastic analysis by martingale with the growing complexity hazardous situations during aircraft accidents. The multiparameters are not identified completely for explaining the phenomenal condition of state steady. The aircraft and runway has a geometric 3-D volume interface “Solid-fluid-Solid”, simulated by extension during takeoff and compression during landing phase. The original objective of simulation is to train people to emergency procedures and devices during potential crisis situations. We identify some parameters influencing accidents and her suitable mathematical model for prevent the indicator of risk. The new approach method of martingale in Aviation safety and security used here, provides to reach the objective of our communication. The difficulty is, in every incident or accident of aviation which are subjects of a new survey that implies others.

Léonard Kabeya Mukeba Yakasham, P.O Box 6534 Kinshasa 31 Ndolo, Kinshasa, 243, Democratic Republic of Congo

DYNAMICS OF AN ELLIPSOID ON THE HORIZONTAL PLANE WITH FRICTION

A. V. Karapetyan  M. A. Munitsyna
avkarapetyan@yandex.ru munitsyna@gmail.com

The problem of motion of homogeneous ellipsoid of rotations on a horizontal plane is considered. It is supposed, that the mass centre of ellipsoids does not coincide with its geometrical centre, but lays on a symmetry axis of ellipsoid. It is considered also, that in a point of contact with a plane there is a friction with the following property: in case of absence of sliding (speed of a point of contact is equal to zero) the value of force of a friction also is equal to zero; at presence of sliding work of force of a friction. For considered system there are stationary motions and their stability is investigated. Results are represented in the form of classical Smale diagrams.

The case when of ellipsoid of rotations is close to a sphere is considered too. In this case it is shown, that at ellipsoid motion the value of its kinetic moment varies slowly, that allows to construct generalized Smale diagrams on the basis of diagrams of generating system.

For the cases of classical model of a viscous friction the received results of numerical experiment are produced. Besides, cases of the connected models of the friction considering both a sliding friction, and a friction of spinning and rolling are numerically considered.

This work is supported by Russian Foundation for Basic Research (projects 11-01-00354, 12-08-00591, 12-01-31059, 13-01-00230).

Alexander V. Karapetyan, Leninskie Gory, 1, Moscow, 119991, Russia

ON THE INFLUENCE OF INTERNAL STRESSES CAUSED BY THE ISOLATED DEFECTS ON THE STABILITY OF ELASTIC CYLINDER UNDER COMPRESSION AND TENSION

M. I. Karyakin  I. V. Pozdnyakov  N. Shubchinskaya
m.karyakin@gmail.com
natalieshubchinskaya@gmail.com

Initial stresses caused by the defects of crystal lattice draws attention by the reason of a big impact to actual mechanical behavior such as plasticity, creep, destruction etc. In the context of finite deformation elasticity theory much motivation for the research of initial stresses, more especially internal stresses, comes from soft tissue biomechanics, and for a recent discussion of internal stresses in artery walls. So one can say there are a lot of experimental presuppositions and theoretical grounds to take to account the nonlinear terms and influences in the internal stresses theory. In present work in terms of nonlinear theory of elasticity a lot of issues of effects internal stresses on the equilibrium and stability of elastic specimens were studied.

We present results on the two kinds of isolated defects: the wedge disclination and screw dislocation. To describe the mechanical properties of a cylinder constitutive models for compressible elastic solid were used such as John material and Blatz & Ko material. The analysis of length changing of an unloaded cylinder due to the defect formation was done. It was shown that length changing is a nonlinear effect and the elongation or contraction depends on material parameters of the mechanical models. To verify the numerical results the asymptotic formula were obtained within the limits of the second-order effects theory.

To analyze the stability of a cylinder with isolated defect under tension and compression the bifurcation approach was used based on linearization of the equilibrium equations in the neighborhood of the solutions obtained by means of the semi-inverse method of nonlinear theory of elasticity. Search of the bifurcation points is based on the analysis of the homogeneous linear boundary value problem of a six order, whose coefficients depend on radial displacements of the points of the cylinder found in the first stage. The bifurcation point is treated as such value of the parameter of the defect or any deformation characteristic for which the linearized problem has a nontrivial solution.

The problem of compression of a cylinder was studied primarily as a mean of verification of the developed software system. In the case of extension it was shown, in particular, that the value of Poisson’s ratio has a significant effect on the stability of the cylinder containing the isolated defect.

This work was supported by the Russian Foundation for Basic Research (Project 12-01-00038-a)

Nataliya Shubchinskaya, Milchakova street, 8a, Rostov on Don, 344090, Russia

58
COUPLING LATTICE BOLTZMANN MODEL AND ATOMICISTIC MODEL FOR FLUIDS

O. Khromov  W. Shan  U. Nackenhorst

A hybrid atomistic-continuum method for multiscale simulation of fluid flow is presented. For description of atomistic part, molecular dynamics (MD) method is used. A mesoscale Lattice Boltzmann method is governing the behavior of continuum part. Time scale is decoupled by Schwarz decomposition algorithm. It allows one to conduct several MD timesteps assuming that mesoscale solution is steady in the meantime. The subdomains communicate via the exchange of velocities in the intersection region and mass balance across the interface. Velocity extraction from atomistic region is performed through coarse-grain averaging. The backward exchange is governed by correction term of velocity relaxation towards desired value. Mass balance is ensured by particle insertion and removal. The efficiency of hybrid method is shown via comparison between fully-atomistic and hybrid simulations of a fluid flow.

Oleg A. Khromov, Appelstr 9a, Hannover, 30167, Germany

TIME-DEPENDENT GREEN TENSOR FOR A HOMOGENEOUS, ISOTROPIC, ELASTIC MEDIUM. A PARADOX

A. P. Kiselev  A. M. Tagirdzhanov

Closed-form solution for arbitrarily-time-dependent Green tensor for a homogeneous, isotropic, elastic medium, was first presented by Stokes in 1851. However, the result still looks surprising. Let the source time-dependence be \( \delta(t) \). The wavefield is then a sum of two delta-shaped spherical waves and a certain wavefield \( U(x, y, z, t) \), which linearly grows with time at each point between the aforementioned spheres. This result is discussed.

A support from RFBR grant 11-01-00407-a is acknowledged.

Aleksei Kiselev, Bolshoi VO 61, St.Petersburg, 111111, Russia

MATHEMATICAL MODELING OF CELL GROWTH IN ACTIVE BIODEGRADABLE SCAFFOLDS FOR TISSUE ENGINEERING

N. Kizilova

Cell cultivation in the biodegradable scaffolds at active mechanical conditions is one of the most promising techniques in tissue engineering. The scaffolds are regular porous structures possessing biocompatibility and lightweight design with appropriate pore size for the growing cells, extracellular structures and vascular vessels. Active treatment of the seeded scaffold by periodic external loading and saline flows ensure the tissue growth in nonvanishing inconstant stress field as in the live bodies. A novel mathematical model of the tissue growth in the actibe biodegradable scaffold is presented in the paper. Biological material is considered as a multiphase multicomponent medium consisting of different cells, extracellular substances and growth mediated chemicals (growth factors, glucose, etc). The balance equations for masses, momentums and energy takes into account the phase exchange, external forces (mechanical load, gravity, microgravity, centrifugal, electromagnetic fields) and interactions between the phases and scaffold. Internal variables describing the microstructure are introduced in the model. The entropy balance equation is obtained and the relationships between the fluxes and forces are analyzed. Basing on the obtained relations the 2D-problem of the multicellular growth in the scaffolds with different geometry is studied. A homogeneity index describing cell distribution in the filled scaffold is proposed.

Natalya Kizilova, Svobody sq., 4, room 7-32, Kharkov, 61022, Ukraine

A MODEL OF IMPERFECT INTERFACE AND DELAMINATION DETECTION BY NORMAL WAVES

N. V. Klyueva  I. N. Soldatov

Lamination testing of multilayer plates and pipes is a very important task of ultrasound nondestructive evaluation. To describe phenomena that occur in the multi-layered materials with imperfect contacts between elastic layers was proposed a few models. An area-extensive delamination, parallel to the layer surfaces, can be modelled as a "loosely-bonded interface" by allowing slip. The boundary conditions of this model require that tangential and normal components of the stress and the normal component of the displacement be continuous at the interface, but there is a local discontinuity of the tangential component of the displacement. The detailed study of propagation of guided waves in this model is performed. It is found that some normal modes are sensitive to the interface conditions. Changes of dispersion curves for the normal waves are studied for various depths of delaminations. We also propose an extension of imperfect interface model of Rokhlin S.I., Wang YJ. In this report, we discuss some simple properties of the extended model.

Natalya V. Klyueva, 85, Belinskogo Str., Nizhny Novgorod, 603024, Russia

MODELING OF PHASES AND CHEMICAL COMPOUNDS FORMATION

A. G. Knyazeva  S. A. Shanin  M. V. Kripakova

Modern methods of material synthesis, surface treatment, coating deposition and materials cutting and welding connect with the transformation of various energy forms to the heat energy. There are many physical and chemical phenomena accompanying the technology stages and favoring to composition
and properties change of materials. Surface layers structure and properties formation is effect of various irreversible physical and chemical processes which are not taken into consideration in traditional mathematical models. If the final state could be investigated experimentally, so, as a rule, the staging of the processes accompanying the treatment belongs to discussion questions. Practically, the processes going during the treatment in irreversible conditions represent the content of black box. It is very significant to understand, what level of blackness of black box? Is it possible to retrieve the information from mathematical modeling of technology processes stages?

In our works the approach to the technology processes stages modeling was suggested. That is based on experimental results, takes into consideration the irreversible nature of the processes and allows predicting the composition change and some mechanical properties change due to treatment conditions variations. The models of multi component and heterogeneous deformable media, chemical kinetics and various parts of thermodynamics, the information on reaction kinetics, chemical thermodynamics, and physical and mechanical properties form the basis for our models.

Using the information on initial reagents, specimen geometry, technology conditions, the dependencies of the properties on the temperature etc., we formulate the mathematical problems with initial and boundary conditions, write down kinetic equations, state equations and the relations for the fluxes, choose numerical methods, develop the algorithms, make the analytical estimations and then we carry out numerical experiment allowing to obtain the information on the physical and chemical processes during technology and for finally state. All models are coupling. As examples, the models of the coating growth on the specimen surface and the models of surface treatment using particle beams are discussed.

Anna Knyazeva, Lenin Street, 30, Tomsk, 634050, Russia

PURE BENDING OF PRESSURIZED CURVED TUBE
A. M. KOLESNIKOV A. V. POPOV
Alexey.M.Kolesnikov@gmail.com a_v_popov@mail.ru

This research treats the pure bending of curved tube subjected by internal pressure. We call a curved tube a sector of toroidal shell. The material of tube is incompressible, isotropic and hyperelastic. The bending stiffness of tube wall is neglected due to its small thickness. The problem is solved into framework of non-linear membrane theory of Kirchhoff-Love. Using semi-inverse method [1,2] the deformation of the tube is decomposed into two parts: an in-plane deformation of meridional cross section, plus a rigid rotation of each of these meridional planes about some axis by linearly varying angles. This approach reduces the problem to the ordinary differential equations. The boundary-value problem is solved numerically using a shooting method together with a Runge-Kutta integration process. We analyze the tubes of circular and elliptical cross section. We study the dependence between the bending moment and curvature of pressurized tube under large deformation and the influence of the cross section on the behavior of curved tube.

This research was supported by the Russian Foundation for Basic Research (grants 12-01-31431, 12-01-00038, 11-08-01152) and by the Ministry of Education and Science of the Russian Federation (contract 14.A18.21.0389).

REFERENCES


Alexey M. Kolesnikov, ul. Milchakova 8a, Rostov-on-Don, 344090, Russia

CIRCULAR PRISMATIC DISLOCATION LOOPS IN SPHERICALLY SYMMETRIC ELASTIC SOLIDS WITH FREE SURFACES
A. L. KOLESNIKOVA M. Yu. GUTKIN
S. A. KRASNITCKII A. E. ROMANOV
anna.kolesnikova.physics@gmail.com m.y.gutkin@gmail.com krasnitckii@gmail.com aer@mail.ioffe.ru

Dislocation loops are typical elements of solid structures and they play an important role in the physics and mechanics of materials [1]. The majority of modeling applications of dislocation loops is based on the knowledge of their elastic fields and strain energies. In particular, the elastic properties of circular dislocation loops in isotropic elastic solids have been analyzed in large details for the situations when the solids are either infinite or bounded by planar interfaces. However, for the case of spherical free surfaces or interfaces, the list of strict solutions for elastic fields of circular dislocation loops is rather short [2-4].

This paper presents a solution to the boundary-value problem in the classical theory of elasticity for a circular prismatic dislocation loop (CPDL) in an elastic body with one or two spherical free surfaces such as a spherical particle, an infinite body with a spherical cavity, and a spherical shell of finite thickness. The axisymmetric position of the CPDL with respect to the spherical surfaces is assumed. Elastic stresses, dilatation and strain energy of the loop are presented in a concise and transparent form of the series with the Legendre polynomials, numerically calculated and illustrated by corresponding maps, and discussed in detail. It is shown that the stress and dilatation fields are strongly screened and distorted by the internal and external free surfaces of the systems under consideration as compared with the case of an infinite medium. Moreover, the exact solutions of the boundary-value problems have revealed some interesting qualitative peculiarities in the distribution of the elastic fields. This mainly concerns the CPDL dilatation which can change its sign in the subsurface layers of the particle, near the cavity and in the shell. For an interstitial CPDL, this creates the conditions favorable for surface nucleation of vacancies which are stimulated to migrate towards the loop, accommodate the compression near it and annihilate with the loop interstitials, thus leading to a kinetic instability of the loop in the systems.
The strain energies of CPDLs strongly depend on their radii and positions in particles and shells, or near cavities. In particles and shells, the strain energy reaches its maximum when a CPDL lies in the equatorial planes and has the radius of roughly 0.8 of the particle radius or outer radius of the shell, if the latter is several times larger than the inner radius of the shell. For a cavity, the strain energy of a CPDL increases with its radius and its shift from the equatorial plane.

The solutions obtained can be used in theoretical modeling of deformation and fracture processes in particles, shells and porous materials of any scale level, from nano- to macroscopic solids.

REFERENCES


Mikhail Y. Gutkin, Bolshoj 61, Vasil. Ostrov, St. Petersburg, 199178, Russia

WAVE ESTIMATION OF VOLUME OF THE LIQUID, GRANULAR AND MIXED COMPOSITIONS IN CYLINDRICAL TANKS

V. Kolykhalin
cap-07@mail.ru

The acoustic measurement of volume of the liquid, granular and mixed compositions in cylindrical tanks are considered. The knock acoustic source of sound vibrations is installed on the outside surface of the vertical cylindrical tank with the impedance bottom, the rigid walls and the rigid roof. The results of the mathematical and physical simulations of sound transmission are shown. The sound intensity measurements of free air volumes into tank are controlled with a per of microphones and corresponded to the different substance volumes. The intensity diagrams considerably differed from each other in low frequency band are analyzed.

Vitaly Kolykhalin, Leninsky prospekt, 95, korpus 2, St. Petersburg, 198302, Russia

STUDY OF MECHANICAL BEHAVIOR OF CERAMIC COMPOSITES WITH VARIOUS FRACTION OF PORE FILLED BY PLASTIC INCLUSIONS

IG. S. KONOVALENKO IV. S. KONOVALENKO
CH. O. TOKTOHOEV A. YU. SMOLIN S. G. PSAKHI

igkon@ispms.tsc.ru ivkon@ispms.tsc.ru asmolin@ispms.tsc.ru

Using the method of movable cellular automata the 2D model of mechanical behavior of ZrO2-based ceramic composites with the pore size greater then the average grain size and plastic filler in pores was constructed. Deformation, fracture, and the dependence of the strength and elastic properties of the composite on fraction of pore filled by plastic inclusions in a wide range of porosity were investigated.

This study was supported by the Russian Foundation for Basic Research project No. 12-08-33099-mol-a-ved.

Igor S. Konovalenko, 2/4, pr. Akademicheskii, Tomsk, 634021, Russia

ANALYTICAL AND NUMERICAL INVESTIGATIONS OF THE CHARACTER OF STRESSES IN THE VICINITY OF SINGULAR POINTS IN THE FRAMEWORK OF THE CLASSICAL AND ASSYMETROC THEORY OF ELASTYSITY

T. KOREPANOVA V. KOREPANOV N. SEVODINA
ton@icmm.ru kvv@icmm.ru natsev@icmm.ru

In the theory of elasticity, the possibility of singular solutions is related to the existence of infinite stresses at singular points of the examined regions, at which a disturbance of surface smoothness, a change in the type of boundary conditions or contact of dissimilar materials take place. The study is concerned with the analysis of stresses in the vicinity of singular points in the context of 2D and 3D problems of the elasticity theory. The obtained results contribute to the knowledge acquired from the numerous relevant investigations.

To analyze the behavior of stresses in the vicinity of singular points, it is necessary to construct eigensolutions for plane wedges in 2D problems and for polyhedral wedges and cones in 3D problems. The spectrum of the above configurations covers practically all variants of singular points.

A new analytical solution for circular cones has been constructed. In contrast to the results available in the literature, we managed to obtain the solutions for homogeneous circular cones under different boundary conditions on the lateral surface, for a hollow cone with two lateral surfaces and also for a cone composed of two or more materials, the contact points of which lie on the conical surfaces.

The behavior of stresses in the vicinity of singular points is analyzed by making use of a new variant of the numerical method, which can be applied both to two- and three-dimensional problems. The basic ideas behind the proposed method are illustrated by solving an example three-dimensional problem for conical bodies.

Using the method of numerical simulation, the eigensolutions have been obtained for trihedral wedges under different boundary conditions on the lateral surfaces, for circular and non-circular homogeneous cones, for homogeneous cones with two lateral surfaces and for cones composed of two dissimilar materials, the contact points of which lie on the lateral surfaces. The proposed method has been applied to conical bodies, whose lateral surface has ribs, disturbing its smoothness. The obtained solutions allowed us to determine the character of the stress behavior at the tip of a plane wedge crack and at the tip of two crossing wedge cracks located in different planes.
The investigations of stress behavior in the vicinity of singular points made in the framework of the classical theory of elasticity have been carried out in parallel with the investigations, in which eigensolutions for homogeneous plane wedges are constructed based on the asymmetric theory of elasticity. In addition to analytical investigation we present the results of numerical estimation of the asymptotic relation for stresses in the vicinity of singular points for 2D problems of the asymmetric theory of elasticity obtained on the basis of the finite element method.

The work were supported by grant of the Russian Foundation for Basic Research (projects 12-01-31007, 12-01-33042, 11-01-96022).

Anna A. Koroleva, Nezavisimosti 4, Minsk, 220030, Belarus

DIFFUSION-INDUCED OSCILLATIONS OF EXTENDED DEFECTS

A. L. KORZHENEVSKII

alekorzh@mail.ru

The interface equation of motion is derived from a bulk phase-field model of a solidified binary alloy. It is shown that in the regime of a rapid solidification the equation can be reduced to a nonlinear oscillator one with a negative friction force. The force provides the appearance of a stable limit cycle. Its existence explains universal aspects of zonal structures in the final solid products.

Alexander L. Korzhenevskii, Basseynaya 67, 82, St. Petersburg, 196211, Russia

SEMI-ANALYTICAL METHOD FOR SOLVING BOUNDARY VALUE PROBLEMS FOR MULTI-WEDGE BODY CONTAINING A DOMAIN WITH INTERNAL STRUCTURE.

V. F. KOSHELEV

vadimkoshelev@yandex.ru

Composite solid formed from a large number of edge-bonded dissimilar wedges are under consideration. One of the wedges contains an arbitrary set of heterogeneities: inclusions, pores or/and cracks. We focus on the problems of 2D potential flow of fluid, heat or electricity as well the anti-plane elasticity. Besides, the results could be transferred to 2D elasticity. We deal with the BEM (boundary element method) based on the complex variable boundary integral equation serving for solving harmonic problem for the general 2D inhomogeneous blocky structure. Specific feature of a distinct homogeneous wedge is existence of analytical solution yielding a linear dependence between the potential function and the flux (in the terms of finite Mellin transformers) at the opposite wedge boundaries. Employing this result we can express the integrals over the all of the edge boundaries by the integral terms referring to the “main” wedge (containing the set of heterogeneities). Thereby, one comes to drastic reduction of the number of unknowns in the computational procedure of the BEM: all of the collocation points locate at the boundaries of the “main” wedge. More interesting for applications is the case of multi-layered system bonded with half-plane, containing heterogeneous. It also falls into the approach discussed. This approach seems to be especially productive in 3D problems concerning heterogeneous structures.
THEORETICAL STUDY OF THE FLUID FLOW AND
BUBBLE VELOCITY EFFECT ON THE FLOTATION
RATE CONSTANT AT THE APPLICATION OF THE
INERTIALESS COLLISION EFFICIENCY MODELS
MODELS
S. KOUACHI    M. BOUHENGUEL
sabrikouachi@yahoo.fr mbouhenguek@yahoo.fr

A theoretical study showing the effect of fluid flow and bubble velocity using the general flotation kinetic model developed under turbulent condition and with including the efficiency of collision using the inertial generalized Sutherland equation (GSE) for collision model, the attachment efficiency using modified DobbyFinch model, and stability of bubble-particle aggregate includes the various forces acting between the bubble and the attached particle, is illustrated by the incorporation of the inertial collision efficiency models. Some results are obtained revealing the positive and negative inertial effect using galena particles under defined flotation data conditions by incorporating in the flotation rate constant both of the collision efficiency models such as of YoonLuttrell and Nguyen developed for potential flow condition with assuming that the bubble surface is completely mobile. The results show the influence of turbulence and the increasing of the bubble velocity to determine the particle size range between the models considering the inertial effect and those who ignored the particle Inertia.

Kouachi Sabri, 26 Rue Mohamed Ben Belgacem, Ain Beida, 04200, Algeria

FLOW PATTERNS AT THE RAMAT HOVAV DISPOSAL
SITE, ISRAEL
M. KOZNETSOV    A. YAKIREVICH    S. SOREK
kmikhail@bgu.ac.il

The Ramat Hovav area serves as a national waste disposal site for hazardous materials conveyed from chemical industries. The rational of choosing this site is based on the believe that the local chalk formations, with high porosity of (22-44%) and low permeability, should provide natural hydrogeological repository to protect deeper aquifers from hazardous leakage. However, these chalks are associated with a number of fracture systems that diverts groundwater flow and transports contaminants that may discharge into upstream exploited fresh water aquifers. The current uncertainty in understanding flow patterns affected by heterogeneity, may preclude practical and useful prediction of the anticipated hydraulics of the regional flow channels as well as the orientation and location of these channels relative to the recharge location from the disposal reservoirs. Quantitative analysis of the regional flow pattern (e.g. identification of preferential flow paths) as a first step followed by prediction of temporal and spatial distribution of contaminants plumes, will enable engineering protocols to further control of aquifers contamination. The aim of this research is to construct a novel approach such that with scarcity of field data will still enable the build of a flow model to predict flow pattern throughout the local fractured system.

A Lumped Parameter Model (LPM) of steady state groundwater flow through a fractured media was developed and applied to the Ramat Hovav industrial area. To construct the LPM in the modeling domain, two fractures sets (more than 2.107 fractures for each set) were statistically generated and mapped in the study area. On the basis of the generated random fracture network, a procedure was developed to assess a Representative Elementary Area (REA) each of which holds characteristic segments of the random fractures converted into representative fractures network, thus reducing considerably the number of fractures. The LPM flow equations were associated with the representative fractures network and for which boundary conditions were prescribed.

The model was calibrated against observed groundwater levels of the years 2007-2008 to asses the hydraulic parameters characterizing individual random fracture transmissivity, the annual groundwater recharge for six selected polygons, and the values of hydraulic head at the Dirichlet boundary. The inverse problem was solved by combination of the Marquard-Levenberg least square optimization and a “trial-and-error” procedure. Results indicate that the developed model predictions are is consistently with minor deviation from observed hydraulic heads.

Simulations predict that recharge rate at the investigated area is of minor influence. This means that the annual rainwater infiltration is compensated by the evaporation process. Significant rate of infiltration and groundwater recharge was assessed under the Makhteshim plant, the waste landfill, and the evaporation ponds.

Three hypothetical scenarios of groundwater pumping were simulated, aiming at prediction of flow pattern changes and the significance in decreasing migration of contaminated groundwater out of the study area of Ramat.

Mikhail Kouznetsov, -, Sede-Boker Campus, 84990, Israel

WAVE THERMORELAXATION EFFECTS IN
MATERIALS WITH LARGE AMOUNT OF GAS-FILLED
CRACKS
YU. F. KOVALenko    R. L. SALGANIK
K. B. USTINov    A. A. FEDOTov
perfolinkgeo@yandex.ru salganik@ipmnet.ru
ustinoff127@mail.ru afed83@gmail.com

A problem of propagation of temperature waves in materials with large amount of gas-filled cracks is considered. The cracks are supposed small enough comparing to the wave length so that the waves might be considered propagating in an equivalent continuum with the effective characteristics determined by the presence of these cracks. The relative distances between the cracks are supposed to be large enough so that while considering any of them the influence of the other cracks to mechanical behavior be negligible (small concentration approach). It is also supposed that the mechanical impact on the cracks is not sufficient to cause their growth.

Effective deformation behavior of the medium in question (contrary to metals, rocks and ceramics) appeared linear viscoelastic with essential rate dependence of the volumetric deformation, determined by compression of the gas contained in the cracks, especially noticeable at not too high and not too law
rates. Therefore the connectivity parameter in equations of thermoelasticity appeared much higher comparing to the case of usually considered media without the gas-field cracks. Hence in case in question the connectivity effect in the thermoelasticity equations may not any longer be neglected and have to be accounted, which is done in the current work. The obtained results related to propagation of thermoelastic waves in the described media are discussed from the point of view of their application to diagnostics of formation of the this type of cracks inherent to gas-field rocks and steels under conditions of appearance and growth of hydrogen saturation and hydrogen cracking.

The results of quasi-static investigation similar in other ways to the described one [1] carried for studying a gas-field material were used. This work has been supported by the Russian Foundation for Basic Research (project 11-01-00801).

REFERENCES

Alexandr A. Fedotov, Orshanskaya, 3, Moscow, 111111, Russia

POSITIONING OF A SPHERE IN A ROTATING CYLINDER UNDER CONDITION OF VIBRATIONAL HYDRODYNAMIC TOP

V. G. KOZLOV S. V. SUBBOTIN
kozlov@pspu.ru subbozza@mail.ru

The dynamics of a light centrifuged sphere in a rotating inclined cylinder filled with liquid under transversal vibrations is experimentally investigated. The sphere and the cavity rotate at different angular velocities, and in the absence of vibration the cavity velocity is always greater than the spheres one. This phenomenon was called the vibrational hydrodynamic top [1].

The intensification of the lagging motion of a sphere and the excitation of the outstripping differential rotation are possible under transversal vibrations. It occurs in the resonant areas where the frequency of vibrations equals to the fundamental frequency of the system. The resonant areas are determined by the ratio of the frequency of vibrations to the angular velocity of the cavity rotation \( n \equiv \Omega_{\text{rot}}/\Omega_{\text{cav}} \). The position of the centrifuged sphere in the center of the cylinder is unstable [2]. In the threshold of outstripping motion excitation the sphere is shifted from the center to the one of the end-walls and is settled at definite distance from it. The position of the sphere is determined by the dimensionless frequency of vibrations \( n \) and depends on the intensity and structure of the averaged fluid flow.

In inclined rotating cylinder the axial component of the gravity force appears however a light sphere does not float to the end-wall but saves the quasi-stationary position at a definite distance from it. It makes possible to create a vibration suspension of a light sphere in a vertical rotating cavity under transversal vibrations. It is found that in the wide range of angles of the cavity inclination the sphere position is determined by dimensionless rotation rate.

Acknowledgements. The work was done in the frame of Strategic Development Program of PSHPU (Project 030-F) with partial support of Ministry of Education and Science of RF (task 1.2783.2011).

REFERENCES

Stanislav V. Subbotin, Sibiskaya, 24, Perm, 614990, Russia

ANALYTICAL AND COMPUTER MODELLING IN MECHANICS OF DISCRETE MEDIA

A. M. KRIVTsov
akrivtsov@bk.ru

Description of the physical and mechanical processes resulting in breakage of the continuity of the media is presented. The reason for the continuity violation is either the discreteness of the material structure (nanosystems, granular materials, astrophysical systems) or the peculiarities of the processes (fracture, agglomeration, structure and phase transitions). It is shown that an effective description of such media requires both the creation of powerful analytical tools, and the development of modern methods of supercomputing. In the lecture it is demonstrated how to use the developed approaches to solve problems in various areas of mechanics and related sciences: mechanics of carbon nanostructures; deformation, structural transformation and fracture of crystalline solids; obtaining an analytical relation between the parameters of discrete microsystems and thermomechanical properties of continuous macrosystems; the dynamics of granular media, the evolutionary dynamics of gravitating systems.

Anton M. Krivtsov, V.O., Bol’shoy pr., 61, St. Petersburg, 199178, Russia

PROPPANT TRANSPORT IN HYDRAULIC FRACTURES: COMPUTER SIMULATION OF EFFECTIVE PROPERTIES AND MOVEMENT OF THE SUSPENSION

A. M. KRIVTsov V. A. KUZKIN
akrivtsov@bk.ru kuzkinva@gmail.com

Hydraulic fracturing is a widespread technology used since the late 1940’s for stimulation of oil and natural gas production. A key process accompanying hydraulic fracturing is transport of proppant (small particles suspended in the fluid). It is used to prevent the closure of a crack. The lecture aims to review and develop approaches serving for adequate simulation of the proppant transport. It is stated that prescribing proper rheology of the suspension at different proppant concentrations is of key significance.
We comment on the difficulties arising when using physical experiments to find the rheology. An attempt to replace expensive and time consuming physical measurements by numerical experiments is carried out. Two distinct computational methods, the particle dynamics (PD) and the smoothed particle hydrodynamics (SPH), are employed to complement each other and to verify the numerical results. We discuss theoretical rationale of the methods and the choice of appropriate input parameters for the problem under consideration. The calculations performed gave us the dependence of the suspension rheology on the proppant concentration. We could see, that when the number of degrees of freedom is high enough, the both methods provided close results. It is shown that in the case of the proppant suspended in a Newtonian fluid, the profile of the suspension velocity is parabolic in the range of volumetric proppant concentrations from 0 to 0.3. This implies that the suspension may be considered as a Newtonian fluid with the effective dynamic viscosity depending on the concentration. It appears that the dependence of the effective viscosity on the concentration becomes strongly non-linear when the concentration exceeds 0.15. A simple analytical equation approximating the dependence in the studied range of proppant concentrations is derived. Application of the obtained results to the analytical and computational modeling of the hydraulic fracturing is discussed. Conclusions on further work are drawn.

Vitaly Kuzkin, Bolshoy pr. V.O. 61, Saint Petersburg, 197198, Russia

**INFLUENCE OF PARTICLE MIXING IN THE MELT ON THE CHARACTERISTICS OF ELECTRON-BEAM TREATMENT PROCESS OF METAL SURFACE**

O. N. Kryukova  A. G. Knyazeva

okruk@ispms.tsc.ru  anna@ispms.tsc.ru

Macroscopic regularities of structure and properties formation of the surface layers in various technologies are characterized by some equivalent parameters. But depending on the types and properties of basic material and modifying particles, the physicochemical processes determining the properties of the coating are quite various. General action of high energy sources are reduced to the formation of melt bath, where physical and chemical processes occur and lead to certain structure of material. The dissolution ones materials in others; the melting of the base and particles; the crystallization of the solution or suspension play a significant role in the coating structure formation. Dissolution process can be described on the base of the conception, which was developed for the processes of chemical engineering that suitable for macroscopic approach.

If the particles are able to dissolve, the properties of surface and coatings obtained during electron-beam treatment are defined by the composition and structure of the particles and depend on treatment regimes. When the temperature is much then melting temperature of the base, the turbulent mixing in the melt bath could be essential. We take into account that this process has a random character. The investigation of the problem had shown that melt turbulent mixing influences the particles dissolution kinetics in the melt bath. The mixing leads to more fast particles dissolution in the melt bath and to more homogeneous composition.

Olga N. Kryukova, pr. Akademicheskii, 2/4, Tomsk, 634021, Russia

**PECULIARITIES OF ATOMIC CASCADE DISPLACEMENT DEVELOPMENT IN VANADIUM ALLOYS**

D. S. Kryzhevich  A. V. Korychuganov

K. P. Zolnikov

kryzhev@ispms.tsc.ru

Investigation of evolution of atomic cascade displacements in metal alloys on the base vanadium under radiation loading was carried out. Calculations were fulfilled in the frame of molecular dynamics method using many body interatomic potentials. Main characteristics of atomic cascade evolution (number of generated structural defects on the different stages of atomic cascade development; volumes of radiation damage; pick time at which number of radiation defects reaches maximum value and etc.) on dependency of impulse value of primary knocked atom were determined. The values of threshold displacement energies (minimal value of primary knocked atom energy for generation of single stable Frenkel pair) on dependence of crystallographic orientation simulated lattice were calculated.

This work was supported by grant RFBR #11-08-00423-a.

Dmitrij S. Kryzhevich, pr. Akademicheskij 2/4, Tomsk, 634021, Russia

**INVESTIGATION OF FREE CONVECTION OF FLUID BY DIGITAL HOLOGRAPHIC INTERFEROMETRY**

D. A. Kucher  B. G. Manuhin  O. V. Andreeva

S. A. Chivilikhin

infermol392@mail.ru

When a liquid is heated there is an effect of natural convection, which is characterized by a thermal field. Field parameters of temperature are great importance in the field of hydrothermal synthesis. A team of authors has at its disposal a unique autoclave with sapphire windows for the study of the synthesis of nanoparticles using optical radiation, but the techniques for studying such systems and processes by optical methods is not currently developed.

The paper proposed to use to estimate the temperature field in the cavity with optical access method of holographic interferometry. To demonstrate the technique to create a layout interferometer and performed experiments on model objects, a mathematical interpretation of the flow in the test object, and a comparison of experimental and theoretical studies of the temperature field in layers of varying thickness. A satisfactory agreement between theory and experiment and make recommendations for experiments related to the study of the process of hydrothermal synthesis of nanoparticles.

Dmitry A. Kucher, Kronverkskiy pr., 49, Saint Petersburg, 197101, Russia
A NEW METHOD FOR THE SYNTHESIS OF EPITAXIAL LAYERS OF SILICON CARBIDE ON SILICON Owing to FORMATION OF DILATATION DIOPOLES

S. A. KUKUSHKIN    A. V. OSIPOV
sergey.a.kukushkin@gmail.com

A new method is developed for the solid-phase synthesis of epitaxial layers when the substrate itself is involved into a chemical reaction and the reaction product grows in the interior of substrate layer. It opens up new possibilities for the relaxation of the elastic energy due to attraction of point defects formed during the chemical reaction in anisotropic media. In the same time the attracting point dilatation centers compose relatively stable formations dilatation dipoles, named by analogy with electric dipoles, providing significant reduction of the total elastic energy. The correspondent theory of point dilatation centers in anisotropic crystals is developed. It is eliminated that the most advantageous location of the dipoles is the direction (111) in crystals with cubic symmetry. In order to confirm the theory the single-crystal silicon carbide, SiC, films with the thickness up to 200 nm have been grown on silicon substrates Si(111) owing to the chemical reaction with carbon monoxide, CO. Grown high-quality single-crystal SiC films do not contain misfit dislocations despite the huge lattice mismatch value 20%. Also the possibility of growing of thick wide-gap semiconductor films on such templates SiC/Si(111) and, accordingly, its integration into silicon electronics, is demonstrated. In particular, a working LED structure based on GaN has been produced. Finally, the thermodynamic theory of new phase nucleation due to a chemical reaction has been developed and it was shown that in the case under consideration the chemical equilibrium constant generalizes the concentration of adatoms exploited in a one-component nucleation theory.

Sergey A. Kukushkin, Institute of Problems of Mechanical Engineering, V.O., Bolshoj pr., St. Petersburg, 199178, Russia

INVESTIGATION OF THE PROBLEM OF MOTION OF A HEAVY DYNAMICALLY SYMMETRIC BODY ON A PERFECTLY ROUGH PLANE BY THE KOVACIC ALGORITHM

A. S. KULESHOV    G. A. CHAPLYGIN
kuleshov@mech.math.msu.su gchern@gmail.com

The problem of motion of a heavy dynamically symmetric body, bounded by a surface of revolution, on a fixed perfectly rough horizontal plane is a classical problem in nonholonomic mechanics. In 1897 S. A. Chaplygin proved that this problem is integrable and its integration is reduced to solving of second order linear differential equation. However the general solution of this differential equation is known only for a few particular cases, when the moving body is a dynamically symmetric ball or a circular disk. In 1986 J. Kovacic proposed the algorithm for solving second order linear differential equation in terms of liouvillian functions. In our presentation we discuss new results obtained in the problem of motion of a heavy dynamically symmetric body on a perfectly rough plane by application of the Kovacic algorithm to this problem. In particular, we present the complete solution of the problem in the case when the moving body is a dynamically symmetric paraboloid.

Gleb A. Chernyakob, GSP-1, Leninskiye Gory, Moscow, 119991, Russia

MOTION OF A RIGID BODY CONSISTING OF TWO SYMMETRIC LAMINAE ON A HORIZONTAL PLANE

A. S. KULESHOV    M. O. ITSKOVICH
kuleshov@mech.math.msu.su mlshok7@mail.ru

Let us consider the rigid body of the following form: it comprises of two equal symmetric laminae whose planes of symmetry make a right angle between each other. The laminae are connected along the common axis of symmetry. When this body moves along the fixed horizontal plane it touches the plane at two points.

We study the problem of existence and stability of equilibria of such a body on a horizontal plane. Results obtained for the general case are used in the particular case of the body consisting of two interlocked elliptical disks. In this particular case it is possible to find also the trajectories of the ground contact points of the body with the supporting plane.

This investigation is partially supported by the Russian Foundation for Basic Researches (Grant No. 13-01-00230).

Alexander S. Kuleshov, Leninskie Gory, Moscow, 119991, Russia

MOTION OF A RIGID ROD ON A CONVEX SURFACE

A. S. KULESHOV    S. V. IFRAIMOV
IfrSergey@gmail.com

Motion of a rigid rod on a fixed surface is investigated. The rod is assumed to move on a surface without sliding. Equations of motion of the rod are derived in the Gibbs – Appell form. Condition of existence of an invariant measure for these equations is obtained. In particular, this condition is valid when the supporting surface is a cylinder, a sphere, a paraboloid, an ellipsoid.

All equilibria positions of the rod on a surface are found and described. We prove that the rod will be in equilibrium position on a surface when it touches the surface by its center of mass. Another possible equilibrium of the rod is the position when the rod is directed along the gravitational vertical. The center of mass of the rod will be below (stable equilibrium) or above (unstable equilibrium) the point of contact with the supporting surface.

The last possible case of equilibrium of the rod on a surface exists when the normal section of the surface through the direction of the rod is a straight line. In equilibrium position the rod touches the surface along this straight line. In this case we have the multipoint contact of the rod with the surface.

Sergey V. Ifraimov, Vavilov st. 40, Moscow, 119333, Russia
**MICROMECHANICAL MODEL OF INTERFACE DAMAGE ACCUMULATION IN FIBROUS COMPOSITE**

V. I. Kushch

vkushch@bigmir.net

Two micromechanical, representative unit cell type models of fibrous composite are applied to simulate explicitly an onset and development of scattered local damage in the form of matrix-to-fiber interface debonding. The first one is based on the analytical, multipole expansion type solution of the problem for multiple interacting inclusions with interface arcs cracks by means of complex potentials. The second, finite element model employs cohesive zone model of interface. Computer simulation of interface damage accumulation by means of these models has been performed. It has been shown that the developed models provide detailed analysis of the progressive debonding phenomena including the interface crack cluster formation, overall stiffness reduction and induced anisotropy of the effective elastic moduli of composite. Application of the statistical theory of extreme values to the progressive damage description has been discussed. Based on observation that the statistics of peak interface stress in disordered fibrous composite follows a Fréchet-type asymptotic rule, the macro level model of initial stage of damage accumulation in fibrous composite is suggested.

Volodymyr I. Kushch, 2, Autovazovskaya St., Kiev, 04074, Ukraine

**EFFECT OF CRACK DENSITY, ORIENTATION AND CLUSTERING ON SIF STATISTICS AND ANISOTROPY OF RANDOMLY CRACKED SOLID**

V. I. Kushch I. Sevostianov

vkushch@bigmir.net igor@nmsu.edu

The paper addresses the problem of stress intensity factors (SIFs) statistics and effective elastic moduli of randomly cracked solid with prescribed crack orientation statistics. The representative unit cell approach has been used. The geometry of a micro-cracked solid is modeled by a periodic structure with a unit cell containing a number of cracks sufficient to account for the microstructure statistics. The method combines the superposition principle, the technique of complex potentials and new results in the theory of special functions. By a proper choice of potentials, the boundary value problem is reduced to an ordinary, well-posed set of linear algebraic equations. The method is applied to obtain the exact series solution for the local stress field and SIFs for each separate crack. By analytical averaging the strain and stress fields, the exact finite form expression of the effective stiffness tensor has been obtained. A series of computational experiments has been performed and the statistically meaningful results have been obtained discovering the way and extent to which the SIF statistics and effective stiffness are affected by the microstructure parameters, namely, the crack density, their angular scattering and cluster formation. It is found that SIF distribution follows the GnedenkoGumbel asymptotic rule. An analytical expression is suggested for the SIF statistics in a microcracked material and a simple meso mechanical model of the cluster of cracks is proposed. Comparison has been made with the selected simple micromechanical models. Among these models, the differential scheme provides the best fit of the numerical data.

Volodymyr Ivanovych Kushch, 2, Autovazovskaya St., 04074, Kiev, Ukraine

**NUMERICAL STUDY OF STRESS-STRAIN STATE OF THE STEEL SURFACE UNDER NANO-STRUCTURED BURNISHING**

V. P. Kuznetsov I. Yu. Smolin A. I. Dmitriev

smolin@ispms.tsc.ru dmitr@ispms.tsc.ru

In this paper the theoretical study of the problem of stress-strain state of the surface of the steel at burnishing is solved within the framework of computer simulation. A dynamic formulation of the problem, which allows more accurate to describe the details of the process, is used. The following loading conditions to implement burnishing of a thin surface layer of steel sample are used: a constant normal force and then constant velocity applied on the indenter. The finite element method in the approximation of plane strain condition is used. Indenter was modeled by an absolutely rigid body, and for model sample the model of elastic-plastic body with isotropic hardening on the experimentally defined law was adopted. The patterns of stress-strain state of material near the treated surface and mechanisms for the formation of nanocrystalline layer were investigated. Modeling results allow one to suggest the distribution of field of stresses intensity and plastic deformation in area of the contact of hard indenter with surface being treated. According to obtained results during dynamic loading large plastic deformations arise and accumulate under the moving indenter. Their values in a narrow surface layer of thickness about 10 microns can reach values of 100%. We also analyzed the influence of the size, shape of the indenter and the coefficient of friction in the contacting pair. The modeling results are in good agreement with experimental data.

Andrey I. Dmitriev, Akademicheski 2/4, Tomsk, 634055, Russia

**PECULIARITIES OF CONVECTIVE MOTIONS IN THE FLUID WITH THE QUADRATIC DENSITY-TEMPERATURE DEPENDENCE**

D. V. Kuznetsova I. N. Sibgatullin

morven9@yandex.ru sibgat@imec.msu.ru

A horizontal layer of fluid with the quadratic density-temperature dependence is studied (in this example water is considered). The horizontal boundaries are isothermal and stress-free. The position of the maximum of density is determined by temperature at the boundaries. The layer in the static state can be separated into two parts: the sublayer which can be unstable under the certain circumstances and the sublayer which is stable. The arising convective motions lead to the interaction of these sublayers and to the development of the motions in the whole layer. The problem is modeled by the Navier-Stokes equations in the Boussinesq approximation. The solution is supposed to be spatially periodic. The height of the layer is fixed so the increasing
The measurements were made in the temperature range 25-325 °C towards the synthesis of new macromolecules. In recent years, nanocomposites reinforced with carbon fibers, thermally expanded graphite and nanotubes have been studied for their interesting physical properties. These properties for this new class of materials, were significantly improved in areas such as mechanical engineering, electrical engineering and others.

In this work, we used dilatometry and DSC to study the fluoroplastic rod form in which we have introduced carbon nanotubes. The measurements were made in the temperature range 25-325 °C with the same heating rate of 10 °C/min. Test samples were taken in two directions one radial (X) and the other in a direction perpendicular to the previous (Z).

Dilatometric measurements gave the results below. We noted that the dilatometric behavior of the two curves obtained in both directions X and Z are different. They do not have the same form. There is a strong anisotropy.

The evolution of the regimes and the transition to chaotic motions is studied at the length of the computational domain chosen by means of the additional simulations. Different cases are considered for this problem characterized by the different ratios of the heights of the statically unstable and the statically stable sublayers. Effects of hysteresis and the sequence of bifurcations leading to chaos are shown, with the existence of the subcritical Neimark-Sacker bifurcation for the case when the point of the density maximum is in the middle of the layer in the static state. The solutions obtained for different ratios of the heights of the statically unstable and the statically stable sublayers are compared and their properties are analyzed. The diagram of regimes is obtained which shows the dependence of the solution on two parameters: the ratio of the heights of the sublayers and the temperature difference at the boundaries.

Daria V. Kuznetsova, Michurinsky, 1, Moscow, 119192, Russia

DILATOMETRIC STUDY OF FLUOROPLASTIC CONTAINING CARBON NANOTUBES
T. Labi I. Zerrouk A. Zahaf A. Boubertakhi S. Hamamda
labii_toufik@yahoo.fr i54@yahoo.fr

The development of polymer blends to produce materials with new properties appears increasingly as an attractive alternative towards the synthesis of new macromolecules. In recent years, nanocomposites reinforced with carbon fibers, thermally expanded graphite and nanotubes have been studied for their interesting physical properties. These properties for this new class of materials, were significantly improved in areas such as mechanical engineering, electrical engineering and others.

In the temperature range 25-170 °C, the coefficients α_x(T) and α_z(T) have nearly the same values and substantially the same speed. From 180 °C, curves α_x(T) and α_z(T) move away from each other and both contain two distinct dilatometric abnormalities. In α_x(T) the first abnormality appears at 210 °C and the second at 260 °C.

In α_z(T) the intensity of the first anomaly located 220 °C is very low compared to that of α_x(T), while the second dilatometric anomaly located around 250 °C, the roles are reversed, the intensity α_z(T) is greater relative to that of α_x(T). Beyond 250 °C, the behavior of α_x(T) becomes monotonous. Therefore, both sides of the anomaly, α_x(T) is linear and has the same intensity. For cons, the shape of α_z(T) has completely changed. Intensity remains high.

Curves ΔL/L confirm the presence of two anomalies α_x(T) while on α_z(T), the first anomaly is virtually nonexistent. DSC measurements confirmed the presence of the anomaly located at a temperature slightly above 280 °C.

Keywords: Fluoroplastic, nanomaterial, nanotube, dilatometry, DSC

Hamamda Smail, Route Ain El Bey, Constantine, 25000, Algeria

NONLINEAR DYNAMICS OF THE REDUCED COSSERAT CONTINUUM. CONDITIONS AT THE SURFACE OF DISCONTINUITY.
V. Lalín E. Zdanchuk
zelizaveta@yandex.ru

We present equations of nonlinear dynamics of the reduced Cosserat continuum in Lagrange variables. Previously, we had already submitted equations in Euler variables. These equations are derived in divergence form. Conditions of discontinuity were obtained for a plane-wave.

Elizaveta Zdanchuk, Polytechnicheskaya, 29, Saint Petersburg, 195251, Russia

GRAPHENE-COATED ATOMIC FORCE MICROSCOPE TIPS FOR RELIABLE NANOSCALE ELECTRICAL CHARACTERIZATION
M. Lanza H. Duan
mlanza@pku.edu.cn hiduan@pku.edu.cn

Electrical characterization at the nanoscale is an essential procedure for analyzing the performance of many materials used at both industry and academia. In this field, one of the most powerful tools is the Conductive Atomic Force Microscope (CAFM), which can characterize the electrical properties of both conductive and thin insulating materials at very small areas. The main challenge associated with this technique is the poor reliability of the tips, which metallic varnish can wear out very fast due to high current densities and frictions when scanning the surface of the sample under test. Therefore, finding a new method to avoid fast tip wearing is essential for cheap and reliable nanoscale electrical characterization. In this work, the properties of commercially available CAFM tips are modified by coating them with CVD-grown graphene. The resulting graphene-coated tip proved to be extremely stable and resistant in terms of mechanical durability and electrical characterization, such as high frictions and elevated current densities, respectively. The tips can also inhibit the sample interaction with the conductive tip coating, which is a source for false imaging.

Huilong Duan, No 5 Yi He Yuan, Beijing, 100871, China
THE THRESHOLD EXTENT OF SOFTENING AND THE INCIPIENCE OF FRACTURE IN THE TRESCA-TYPE MATERIALS

T. B. Lavrova
lavr@samsu.ru

The initial diffuse microfracturing of a solid within the limits when it is still can be considered as a continuum, is expressed phenomenologically by a law of plasticity with softening, the latter in principle enabling to describe initial stages of fracturing within the framework and using the methods of solid mechanics. In the work there are studied the bounds of stable processes of diffuse microfracturing, i.e. of the deformation processes under softening for the Tresca-type elastic-plastic materials. It is known that the bounds of stable deformation are established by the Hadamard inequality for the moduli tensor of plastic response: within the range of validity of the inequality deformation is stable (under certain additional conditions), whereas violation of the inequality is surely followed by the onset of instability in the form of localized instability. The latter is treated as the incipiency of macroscopic fracture in a solid. Hardening of the material means that all its true moduli are positive, and softening means that at least one is negative. Thus, hardening is equivalent to positive definiteness of Drucker's quadratic form, and softening means that it can take negative values. The analysis presented here is based upon the assumption that initial stresses are negligibly small as compared to the elastic moduli. In that case the Hadamard inequality reduces to positive semi-definiteness of Drucker's quadratic form on the set of symmetrized dyads, the latter being the part of the whole set of symmetric second order tensors. Hence, the Hadamard inequality can be valid even in the case when Drucker's quadratic form takes negative values, but not on the symmetrized dyads. In other words, softening within certain bounds is compatible with the Hadamard inequality. In determining such bounds of admissible softening for the Tresca-type elastic-plastic materials it is of principle significance to take into account that the yield surface possesses edges. The normals to the faces of yield surface (in the strain space) are symmetrized dyads, as for the faces adjacent to an edge, corresponding normals are the co-axial symmetrized dyads. On the edges there are four regimes of constitutive response: elastic unloading, two regimes of partial plastic loading and that of complete plastic loading. It is shown in the work that both on the faces of yield surface and on the edges for regimes of partial loading the onset of softening coincides with violation of the Hadamard inequality, that is just the condition for origin of the localized instability, which is treated as the incipiency of macroscopic fracture in a solid. It is proved also that in the regime of complete plastic loading there exists certain finite achievable extent of softening, that being threshold softening for origin of the localized instability and for incipiency of fracture. It is developed an algorithm of determination of the both the threshold value of softening and the mode of incremental strains in the zones of localization together with spatial orientation of the zones themselves. The latter are just future displacement discontinuities in embryo.

AN EQUILIBRIUM PROBLEM FOR THE TIMOSHENKO-TYPE PLATE CONTAINING A CRACK ON THE BOUNDARY OF A RIGID INCLUSION

N. Lazarev
nyurgun@ngs.ru

An equilibrium problem for an elastic Timoshenko type plate containing a rigid inclusion is considered. On the interface between the elastic plate and the rigid inclusion, there is a vertical crack. It is assumed that at both crack faces, boundary conditions of inequality type are considered describing a mutual non-penetration of the faces. A solvability of the problem is proved, and a complete system of boundary conditions is found. It is also shown that the problem is the limit one for a family of other problems posed for a wider region and describing an equilibrium of elastic plates with a vertical crack as the rigidity parameter goes to infinity.

Nyurgun P. Lazarev, Belinsky, Yakutsk, 677000, Russia

SHAPE SENSITIVITY ANALYSIS OF TIMOSHENKO’S PLATE WITH A CRACK UNDER THE NONPENETRATION CONDITION

N. P. Lazarev   E. M. Rudoy
nyurgun@ngs.ru rem@hydro.nsc.ru

An equilibrium problem for an elastic transversely isotropic Timoshenko’s plate with a curvilinear crack is considered. On the crack faces, the nonpenetration conditions, which have the form of inequalities (conditions of the Signorini type), are given. By using a sufficiently smooth perturbation determined in the middle plate plane, the variation of plate geometry is specified. The formula of the derivative of the plate energy functional with respect to the perturbation parameter is deduced.

Evgeny M. Rudoy, pr. Lavrent’eva, Novosibirsk, 630090, Russia

CALCULATION OF RESIDUAL DEFORMATIONS AT ROTARY MOTION OF THE ELASTIC CREEP MATERIAL

A. O. Lemza   E. V. Murashkin
al-fencer@mail.ru murashkin@dvo.ru

At present research of effects stipulated by elastic properties of medium and nonlinear rheological properties of materials is important interest. This paper is about viscometric flow of elastic creep material between two rigid cylindrical surfaces. The solution is constructed using the large deformations’ model generalized to the case of account of viscous properties on the step of reversible deformation.

One characteristic of a class of considered boundary value problems is the ability to calculate rheological parameters of the unloading process and appearing and relaxing residual stresses. Creep problem at fixed level of external loading, problem of stress
relaxation at constant displacement field and problem of the plastic flow and unloading at rotary motion of a elastic creep material between two coaxial cylinders at turn of one of them were set and solved. The implicit finite-difference scheme is constructed for solving obtained system of equations with partial derivatives. Fields of residual stresses, deformations and were constructed as a result of numerical calculation.

The authors were supported by the Grant of the President of the Russian Federation (project no. MK-776.2012.1) and the Grant of the Russian Foundation for Basic Research (mol_a_yed 12-01-33064).

Aleksandr O. Lemza, Suhanova, 8, Vladivostok, 690091, Russia

NUMERICAL SIMULATION OF UNSTEADY COUPLED HEAT TRANSFER IN MINE AIR AND MASSIF FOR ARBITRARY MINE VENTILATION NETWORKS

L. Yu. Levin M. A. Semin
aerolog,lev@mail.ru mishkasemin@gmail.com

In this research we formulate mathematical model and numerical method for unsteady coupled heat exchange between mine air and massif for arbitrary mine ventilation network. Real ventilation networks consist of many airways interconnected in complicated way, therefore in most cases numerical analysis of air and heat distribution is required.

Understanding of thermophysical processes is very important for maintaining thermal comfort in mines through the provision of adequate air temperature and velocity. Airflow fields and massif thermal properties defines behavior of temperature fields in mine air. In some problems (emergency modes of ventilation systems, such as fires) feedback coupling is essential and therefore airflow field is sufficiently depends on temperature field of mine air. Also massif thermal field changes in time due to heat exchange between massif and mine air.

The aim of this investigation is to give an adequate prediction of thermal fields in mine air and massif in order to control thermal regimes in mine in regular and emergency modes of ventilation systems.

Mikhail A. Semin, 78A Sibirskaya Str., Perm, 614007, Russia

ON MODELLING HYDRAULIC FRACTURES IN INHOMOGENEOUS MEDIA

A. Linkov L. Rybarska-Rusinek E. Rejwer
D. Jaworski
dawidj.poczta@gmail.com

Hydraulic fracturing is commonly performed in rock stratum composed of layers and structural blocks and containing other inhomogeneities like inclusions, pores and cracks. The purpose of the work is to develop methods facilitating accurate, stable and robust evaluation of the stresses in strongly inhomogeneous medium with propagating hydraulic fracture. To reach the goal we use: (i) special forms of boundary integral equations and boundary element methods (BEM), (ii) higher order approximations of boundaries and density functions, (iii) special tip and (multi-) wedge elements, (iv) combination of the BEM with the fast multipole method, and (v) recurrent analytical evaluation of all the influence coefficients and all the multipoles on the basis of derived quadrature rules. The paper presents authors findings in implementing these approaches. Both 2D and 3D problems are considered. The exposition is illustrated by the results of numerical tests, which confirm efficiency of the methods developed.

The authors gratefully acknowledge the support of the European Research Agency (FP7-PEOPLE-2009-IAPP Marie Curie IAPP transfer of knowledge programme, Project Reference 251475).

Dawid Jaworski, al. Powstancow Warszawy 12, Rzeszow, 35-959, Poland

PLASTIC DEFORMATION OF SOLIDS WITH STRESS STATE DEPENDENT PROPERTIES UNDER PLANE STRESS CONDITIONS

E. V. Lomakin A. M. Mel’nikov Y.-R. Jeng
lomakin@mech.math.msu.su m_andrew_m@mail.ru imeyrj@ccu.edu.tw

Plasticity characteristics of many materials depend on the form of the stress state created in the body under the action of external loads. The diagrams of stress intensity versus strain intensity for different types of loading are different, and hence the single curve hypothesis of plastic strain cant be used. Here the plastic strain mechanism includes not only the dislocation
sliding mechanism but also the displacements of structure elements such as inclusions and filler particles and the development of existing and formation of new microcracks, pores, and other structural defects. These variations are usually accompanied with irreversible changes of the material volume. Therefore, the assumption of plastic incompressibility of such materials can’t be used. Moreover, in such materials, an interconnection between the bulk and shear strain processes is often observed, although such materials can behave as linearly elastic bodies under the conditions of uniform compression. These effects manifest themselves in the study of the deformation characteristics, plastic and strength properties of rocks, cast iron, structural graphite, fireproof ceramic materials, concrete, composite materials reinforced by filler particles, etc.

The plastic strain of the media under consideration is investigated with the use of plasticity condition represented in the corresponding generalized form with the use of the parameter of the stress state type. The plasticity constitutive relations are formulated based on the plastic flow law associated with the accepted plasticity condition. For the conditions of plane stress state in the framework of the material rigid-plastic model, a system of partial differential equations is obtained and conditions for its hyperbolicity are determined. The relations for determining the stress fields and velocity fields in plastic domains are obtained, and their properties are investigated. The problems of tension of the strips with symmetric edge angular notches are analytically solved, where the stress fields are determined and the continuous displacement rate field is constructed. The problem of uniform symmetric tension of a plane with a circular hole is considered. The stress fields in a strip with symmetric circular notches are examined, too. A comparison with solutions for plastically incompressible media whose properties are invariant with respect to the stress state type is performed. It is shown that the values of limit loads significantly depend on the parameters characterizing the sensitivity of material plastic properties to the variation of the stress state type. The obtained analytical results are compared and verified using finite element elastic-plastic model. It is found a good correlation between analytical and numerical results in the case of the tension of a plane with the angular notch but in the case of a stripe, the limit load for continuous solution obtained on the base of rigid-plastic model is greater than that for elastic-plastic model.

This work was supported by Russian Foundation for Basic Research and National Science Council, Taiwan (Grants 12-01-31184, 11-01-92001).

REFERENCES


Evgeny V. Lomakin, Leninskie Gory, Moscow, 119991, Russia

SHAPE OPTIMIZATION OF COVERS AND HOOPS OF PACKAGING METAL BOXES

R. LOMBARKIA B. BARKAT M. S. CHEBBAH
lombarkia_redhouane@yahoo.fr
barkat-bel05@yahoo.fr chebbah_mss@yahoo.fr

This paper presents an optimization study of the geometrical parameters of covers and hoops of packaging metal boxes designed by the company BENPACK which its headquarters and factory are in the city of Batna in Algeria Country.
The main objective was to find the optimal combination of geometrical parameters of contact between the cover and the hoop at a given internal pressure, to avoid opening the cover.

Three types of test boxes, the most marketed by the company BENPACK was selected, the box of diameter 56, 83 and 108.5 mm. First we found an approximation of the objective function, which is the contact pressure at the last increment before opening cover, using Box-Behnken design and ABAQUS finite elements code. Second, we applied the response surface methodology coupled with the SQP optimization algorithm to find the ideal dimensions for each type of boxes.

Redhouane Lombarkia, bp 154 Batna Benboulaid 05003 Batna Algeria, Batna, 05003, Algeria

THE PRINCIPLE OF SYMMETRY AND SIMPLE GRADIENT THEORY

S. LURIE A. GUSEV N. TUCHKOVA
lurie@ccas.ru tuchkova@ccas.ru

Relying on the fundamental symmetry considerations and using Lagrange’s variational formalism, we derive the governing relations of linear anisotropic strain gradient elasticity. We demonstrate that to avoid spurious solutions, one should necessarily impose some certain symmetry restrictions on the operational strain gradient elastic constants. We argue that in the previous related works this necessity has been unnoticed and that as an unwanted consequence, the resulting theories may suffer from spurious solutions. By imposing the symmetry condition, we refine the widely used simplified strain gradient elasticity theory. By enforcing the “strain gradient” symmetry condition, we simplify the rich Mindlin’s theory of isotropic strain gradient elasticity. The derived symmetric theory has only two strain gradient coefficients. To access the possibility of further simplifications, we use this theory to some simple problems. We compared the resulting size-dependent solutions with those obtained using simplified strain gradient theories with a single strain gradient coefficient and indicated that in general such simplified theories are not necessarily quantitatively accurate.

On the other hand, for the use in some preliminary, exploratory studies we present a simple, completely symmetric isotropic strain gradient elasticity theory with a single strain gradient coefficient.

As an example we considered composite with nano spheres and estimated its effective properties using simplest symmetrical model and self-consistent Eshelby method. We shown the dignity of simplest model and proposed some assessment for the application.
ON MATHEMATICAL MODELING OF GAS COOLING OF AXISYMMETRIC POROUS HEAT-EVOLUTIONAL OBJECTS WITH PARTIAL CLOSURE OF THE OBJECT’S OUTLET

N. A. LUTSENKO
NickL@inbox.ru

A lot of catastrophes result in appearance of heat sources, such centres of heat often arise in porous media. The obstructions of the ruined buildings, rocks, soils, peat are porous media in terms of mechanics. The centres of heat evolution in porous media arise, for example, during the explosions at atomic and industrial facilities, in underground explosions and fires in places of the extraction of natural resources. The example of the exploded unit of the Chernobyl NPP showed that the gas (air) cooling of such heat sources may be the only available counteraction method of the disaster [1].

This work is devoted to the mathematical modelling of the gas cooling of the porous objects with heat sources when the object’s outlet is partially closed. The gas flows through the solid motionless porous heat-evolutional object, which is bounded of impermeable non-heat-conducting side walls, opened at the bottom and partially opened at the top. Mathematical model is constructed within the framework of the model of two interactive interpenetrative continua [2] and includes the continuity equations, the momentum conservation equations, the energy equations and the equations of state for each phase (solid and gas). The distinctive feature of the concerned model is that the flow rate and the gas velocity at the porous object inlet and outlet are unknown and must be calculated by solving. The original numerical method have been developed, which is based on a combination of explicit and implicit finite-difference schemes, for investigating unsteady regimes of the gas cooling of the porous objects with heat sources. Modification of this method has been successfully used in modelling the combustion of porous media [3].

Axisymmetric unsteady problems of the gas cooling of porous heat-evolutional objects with partial closure of the object’s outlet have been solved. It is shown that the cover on the outlet of the porous object significantly reduces the object cooling, the greatest heating occurs in the vicinity of the cover. When the size of the cover increases, the outflow of heat from its vicinity decreases and the temperature significantly increases in this area. It can lead to local melting and destruction of an object when temperature in the rest of the object isn’t high. The gas dynamics within the porous object is shown to be complex. For example, two peaks of vertical gas filtration velocity can arise. The work was supported financially by the Ministry of education and science of Russia (project 14.A18.21.0383), the Russian Foundation for Basic Research (grants No. 11-01-98510-r_vostok_a, No. 12-01-31064-mol_a), the Far-Eastern Branch of the Russian Academy of Sciences.

REFERENCES


SHAPE OPTIMIZATION OF A BIAXIALY LOADED SPECIMEN

K. A. LYADOVA V. V. SHADRIN L. V. KOVTANYUK A. S. USTINOVA
lyakovaka@icmm.ru shadrin@icmm.ru

We performed experiments on several specimens to find an optimized specimen shape for biaxial testing using a Zwik testing machine. The basic goal is to achieve uniform strain and stress fields in the area of interest under biaxial stretch conditions. Finite element simulations were carried out for different shapes of cruciform specimens. The obtained numerical results were tested experimentally, and the optimal shape of specimens made of elastic materials was found. The nonuniformity of the strain field in the elastic specimen of the chosen shape was studied during the tensile test. First the specimen was stretched along one axis and then, in the presence of induced anisotropy, along the other axis. The nonuniformity of the strain field on the boundary of the examined area did not exceed 5%, which fell inside the experimental error range. It is shown that the selected specimen shape is versatile enough to test both elastic and inelastic materials with complex mechanical properties.

The study is supported by the RFBR (grant 12-08-00740-a), the RAS program 12-C-1-1015 and the Ministry of Education of Perm Kray (agreement C-26/627).

Kseniya A. Lyadova, Academica Koroleva, 1, Perm, 614013, Russia

NONSTATIONARY VIBRATIONS OF A GROWING THERMOELASTIC PARALLELEPIPED

S. A. LYCHEV A. V. MANZHIROV I. FEDOTOV
lychevsa@mail.ru manzh@inbox.ru fedotovi@tut.ac.za

The thermomechanics of growing bodies studies the distributions of mechanical and thermal fields in quasistatic and dynamic processes that occur in the bodies whose composition varies in the process of deformation and heating. These types of accretion are often realized in technological processes such as laser surfacing, gas-dynamic deposition, and vapor phase deposition. Mathematical modeling of the deformations and temperature fields arising in these processes allows one to optimize the technological
The boundary value problems for thermoelastic growing solids have their own peculiarities. The constitutive equations are formulated with respect to the temperature field and total distortion field. The latter can be represented as the composition of assembly distortion (plastic distortion analogue used in the theory of dislocations) and the deformation gradient of assembled solid. It is assumed that the growth process can be described as a process of continuous deposition of pre-stressed and pre-heated material surfaces. The assembly distortion induces the linear connection on the material manifold which becomes a flat space of affine connectivity with nontrivial Cartan torsion. The Cartan torsion of this connection describes locally the deviation from homogeneity. One can obtain values of the initial distortion tensor field and therefore the values of torsion as the solutions of boundary-value problem for the motion and heat conduction of growing boundary.

The linear equations of motion and heat conduction as well as boundary conditions for growing infinitesimal deformed solid are formulated. The solutions of corresponding initial boundary value problems are obtained in the form of spectral expansion over eigenfunctions of mutual conjugate pairs of differential operators.

As an illustrative example an initial boundary-valued problem for thermoelastic parallelepiped is studied. Full coupling of mechanical and thermal fields is taken into account. A closed-form solution is constructed for a body under “smoothly rigid” heat-insulated fixation conditions for the stationary faces and the growing load-free face. The temperature field on the growing face is analyzed numerically for various accretion scenarios. An analysis of the temperature behavior on the growth boundary shows that, depending on the accretion rate, the boundary can be considered as an isothermal (for high values of the accretion rate) boundary or a boundary with variable “effective” temperature determined in the process of solving the problem.

Sergei A. Lychev, Vernadsky Ave 101 Bldg 1, Moscow, 119526, Russia

PROPERTIES INVESTIGATION OF THE CEMENT COMPOSITES CONTAINING NANOSTRUCTURED MINERAL FIBERS

N. V. Makarova  A. S. Lipovoy
maknat@bk.ru

Nanotechnology is one of the active research areas that encompass a number of disciplines including civil engineering and building materials. Results of investigations of the concrete surface, reinforced with nanostructured mineral fibers by using atomic force microscopy and dynamic ultra-micro hardness tester of the specific areas of surface are presented. For comparison plain concrete and concrete with addition of single mineral fibers investigated as well. The analysis of the obtained data has shown that as a result of the directed microdisperse structurization provided by nanoinitiators on a surface of fibers, increase strength and deformation characteristics of a material.

Natalya V. Makarova, 5, Radio Str., Vladivostok, 690041, Russia

INVESTIGATION OF MECHANICAL DEFORMATION OF POLYMER SAMPLES USING HOLOGRAPHIC METHOD

B. G. Manukhin  M. A. Shumova
O. V. Andreeva  S. A. Chivilikhin
manuhin.ifmo@gmail.com

The results of experiments and mathematic modeling of changing environmental parameters on the characteristics of volume holograms registered in polymer material. At the disposal of the author is an experimental technique which allows consider the effect on the parameters of recorded hologram changes in humidity, which change from typical value (30 - 60 %) to maximum possible condition when sample is in closed room with open water surface (80 - 90 %). The described experiments were performed using a volume recording media manufacturing in laboratory.

Boris G. Manukhin, Kadetskaya liniya st. 3, Saint-Petersburg, 190033, Russia

GEOMETRICAL METHODS IN MECHANICS OF GROWING SOLIDS

A. V. Manzhirov  S. A. Lychev
manzh@inbox.ru  lychevsa@mail.ru

A vast majority of objects around us arise from some growth processes. Many natural phenomena such as growth of biological tissues, glaciers, blocks of sedimentary and volcanic rocks, and space objects may serve as an example. Similar processes determine the specific features of many industrial technologies including well-known crystal growth, laser deposition, melt solidification, electrolytic formation, pyrolytic deposition, polymerization, and concreting technologies. Recent research indicates that growing solids exhibit properties dramatically different from those of conventional solids, so that classical solid mechanics cannot be used to model their behavior. It is essential that in growing bodies the residual stresses occur. It is impossible in general to avoid them that lead to undesirable consequences, such as distortion of its geometry, local discontinuity, loss of stability. In particular, the estimation (and minimization) of possible distortions in stereolithography, the analysis of stability of epitaxial thin-walled structures applicable in micro-electromechanical systems (MEMS) are significant.

The growing body can be considered as a special class of inhomogeneous body, in which inhomogeneity arises because of nonholonomic distortion, caused by the joining of incompatible stressed parts. From this point of view the mechanics of growing solids have much in common with the theory of defects, in particular with the geometric theory of continuously distributed dislocations. In this context geometric concepts such as connection, curvature, torsion, and parallelism are among the basic concepts of the general theory of inhomogeneous solids.

The theory of fiber bundles of differentiable manifolds is taken as the geometric foundation of mathematical theory of growing solids. Analytic properties of differentiable manifolds are determined without utilization of prescribed connection. This allow
to formulate a boundary value problem in terms of quiet general geometrical properties and determine the particular type of connectivity a posteriori taking into account specific kinematic and static characteristics of the accretion process. Above all the geometrical concept of a fiber bundle corresponds to key features of the growing solid whose growth is modeled as a continuous adhesion of deformed material areas. Such an assembly generates a nontrivial fiber bundle of material manifold. The structure of this bundle is completely determined by the scenario of accretion.

The mentioned above considerations permit to obtain the complete system of equations and boundary conditions that determine the deformation of growing solid with taking into account of implantation strain state of fibers. In the framework of continuum mechanics “artificial” inhomogeneity caused by implantation may be treated as a bundle with non-Euclidean material connection. The torsion of this connection plays the role of the measure of such inhomogeneity. It depends on implant distortion that may be found by solving the boundary-value problem for the solid with the material boundary. In some special cases (particularly for incompressible material) it can be done analytically.

A special variant of two-dimensional boundary-valued problems for growing thin-walled structures are also obtained. This model is intended for simulation of such technological processes as multilayer lamination, stereolithography, laser deposition, etc.

Alexander V. Manzhirov, Vernadsky Ave 101 Bldg 1, Moscow, 119526, Russia

**FLAT AUTOMODEL PROBLEM UNLOADING ELASTOPLASTIC HALF-SPACE**

A. A. MANZUBORA M. M. RUSANOV

manzubor@iacp.dvo.ru maxprimat@mail.ru

We solve a problem unloading elastoplastic half-space. Before the unloading process space was loaded so that it acquired some level elastic and plastic deformation. In practice, the unloading process cannot be done immediately; instant stress relief on the entire surface of the material is not possible. Anyway, even when we try to make unloading quickly enough, somewhere will delay, instead immediate changer we observe some process. In our case the loading force is removed so that the boundary point of the step load is moving at a constant over -seismic velocity of the border half, so this problem is self-similar.

Note that we consider the case with large plastic deformation, to describe the elastoplastic space, we use the model proposed in [1]. In the solution was found that in the process of unloading the elastic strain can spread through the two waves, the speed of one of them close to the speed of the irrotational shock wave, and another closer to speed of the transverse. In general, the first wave may be just a simple Riman wave, and the second can be as simple or shock. To clarify the wave pattern used evolution condition and thermodynamic consistency condition breaks. In the solutions for different initial conditions obtained solutions with two simple waves, and also a simple and a subsequent shock.

The problem was solved numerically. In the solutions obtained graphs of stress at each wave, and the dependence of the wave velocity on the rate of stress relief and preliminary deformation.

**REFERENCES**


Maxim M. Rusanov, Radio, 5, Vladivostok, 690041, Russia

**ON FAST MULTIPLE ALGORITHMS OF VELOCITY COMPUTATION IN VORTEX ELEMENT METHOD FOR 2D AND 3D FLOWS**

I. K. MARCHEVSKY

iliamarchevsky@mail.ru

Numerical simulation of 2D and 3D flows and unsteady aerodynamic loads computation is a very complicated problem. In case of external flows with low subsonic velocities, meshless Lagrangian methods (discrete vortex method, vortex blobs/vortex particles method, vortex element method) sometimes are the most efficient from computational point of view. The main value in these methods is vorticity carried by vortex elements (VE), while velocity and pressure are computed using Biot-Savart law and Cauchy-Lagrange integral analogue. VE motion equations solution is based on VE pair interactions computation, which makes this problem similar to gravitational N-body problem. If we need to increase the accuracy of simulation, number of VE should be increased while computational complexity increases proportionally to the square of VE number.

There are two main approaches to computations acceleration in vortex element method. The first approach is connected with parallel algorithms usage; for example, it allows to reduce the computation time by 9-10 times for 16-core cluster. Computation time remains acceptable for cases when VE number doesn’t exceed 10-20 thousand for 3D and rather more for 2D problems. However, to improve the accuracy of simulation it is necessary to increase VE number while computation time should not increase significantly.

In order to achieve this aim we can use the second approach which assumes usage of fast multipole algorithms, similar to ones for N-body problem. An effective fast multipole method for the approximate solution of N-body problem was proposed by J.Barnes & P.Hut, its modification for 2D vortex element method developed by G.Ya.Dynnikova. This method is based on a tree construction and approximate calculation of the influence of VE located in tree cells, far enough away from each other. This method computational complexity is proportional to N lg N against N² for direct method. Fast multipole method usage allows to increase VE number to several million. It should be noted that computational cost of one operation of VE influence calculation in 3D case is approximately 100 times bigger than in 2D case, so fast multipole method developing for 3D flows is a very actual problem.

There exist asymptotically more efficient methods, which computational complexity is the order of N, but they are effective only for extremely large N values (order of millions), while the actual problem is the computations acceleration for cases when N is order of thousands or tens of thousands.

For 3D flows in order to simulate VE motion we should compute not only velocity vector for each VE, but also its tensor of deformation, and the ‘optimal’ tree should be constructed so that
at the last level each cell contains only one VE. For 2D flows we need only VE velocities, and it allows to reduce the computational complexity of the algorithm significantly. An effective and sufficiently accurate estimation is suggested for optimal tree depth.

The results of 2D and 3D flow simulation and obtained values of computations acceleration are presented for some problems connected to vortex structures evolution simulation.

Ilia K. Marchevsky, 2-nd Baumanskaya, 5, FN-2 dep., Moscow, 105005, Russia

NUMERICAL SIMULATION OF DEFORMATION OF MATERIAL WITH DIFFERENT COATING THICKNESS

S. Martynov R. Balokhonov
martins88@sibmail.com rusy@ispms.tsc.ru

Investigated in the paper are the mechanisms of deformation and fracture of a material with coatings of different thicknesses. Boundary-value problem in the plane-strain formulation is solved numerically by the finite-difference method. Microstructure of the composite is taken into account explicitly in calculations. The value of stress concentration near the “coating-base material” interface is found to increase non-linearly with decreasing the thickness for thin coatings, and the value changes but only slightly for different thicknesses of thick coatings. This effect is observed at the elastic stage of composite deformation, intensifies as plastic deformation develops in the base material, and amounts to 25% at the prefracture stage.

Sergey Martynov, pr. Akademicheskii,2/4, Tomsk, 634012, Russia

BONE REMODELING BASED ON SURFACE GROWTH

G. Maurice J. F. Ganghoffer
gerard.maurice@ensem.inpl-nancy.fr jfgangho@hotmail.com

Growth of biological tissues has attracted the attention of several researchers in continuum mechanics the last two decades [1-9]. The most advanced works treat the interactions between the mechanical equilibrium and the transport phenomena leading to growth, see [10], [11] using the theory of mixtures, or [12] highlighting the coupling between reaction-transport of solutes and mechanics. While most of the efforts have been spent on the modeling of volumetric growth, fewer works deal with surface growth, which from a conceptual point of view introduces the additional difficulty of a changing number of particles, in comparison to volumetric growth (an assumption of constant particle numbers is made there, considering that either the density or local volume do change instead). A unifying framework for the treatment of both bulk and surface growth phenomena has been proposed in [13], relying on the introduction of configurational forces as the internal driving forces for growth. Configurational forces for surface growth have been identified in [14, 15], with application to bone remodeling.

The main objective and novelty of this contribution is to set up surface growth models for hard tissues, with bone chosen as a representative example. Surface growth shall be expressed in an algorithmic format from a variational formulation of the strong form of the field equations, leading to numerical implementation in 2D situations.

Models for the surface growth of solid bodies are developed in the framework of the thermodynamics of irreversible processes. The growing surface is endowed by a specific mechanical behavior elaborated from a surface potential, depending upon an elastic surface strain and the normal to the growing surface. Mechanical equilibrium is written in terms of a surface Eshelby stress and involves the surface curvature tensor, while the surface velocity is related to the driving force for growth identified as the surface divergence of this Eshelby stress weighted by the surface density. A closed form solution of a one dimensional surface growth model of a bar is obtained. The developed formalism is next applied to simulate bone external remodeling for 2D geometries, showing the influence of external mechanical stimuli on the evolution of the external shape of bone. Simulations of the growth of the trabeculae of cancellous bone are lastly performed, relying on a micromechanical analysis of a representative unit cell, accounting for a size gradient of the trabecular microstructure.

REFERENCES

Localization of plastic flow often takes place at dynamic deformation and it influence on the resulting strength of the material. From classical viewpoint it is connected with thermal softening, which leads to a combined increase of temperature and deformation resulting in the formation of the adiabatic shear bands. But this scenario is inapplicable in the case of thermal strengthening of material against shear, which is experimentally observed at least in pure metals at high strain rates. The plastic relaxation rate is restricted by the number of dislocations and by their velocity; at the high strain rate it leads to a strain softening, which can be another reason for the localization of plastic flow in dynamical conditions.

We numerically investigate an influence of initial perturbations of temperature or dislocation density and of the stress concentrators on the localization of plastic flow. High-rate simple shear of micro-sample was simulated as well as the shock compression of the perturbed sample. Two-dimensional case was considered with use of the continuum mechanics and the dislocation plasticity model, which accounts dynamics and kinetics of dislocations.

At the high-rate simple shear, the perturbations of temperature or dislocation density lead to restricted localization of plastic deformation, but they can not initiate instability of the plastic flow as a self-sustained and increasing process. Noneuniformity of acting stresses is the main factor of the localization of the plastic deformation. Therefore, the process of localization must substantially depend on the loading conditions and on the internal structure of the material (on the presence of inhomogeneities, pores, inclusions and of the other stress concentrators). Interesting results were obtained from the shock loading of samples with randomly perturbed dislocation density field. Formation of clear shear planes behind the plastic shock wave front was observed; these planes are inclined on approximately 45 degrees to the shock wave propagation direction.

The study was supported by The Ministry of education and science of Russian Federation, project 14.B37.21.0384, and by The Russian Foundation of Basic Research, project 12-02-31375/12.

Alexander E. Mayer, Bratyev Kashirinykh str., 129, Chelyabinsk, 454001, Russia

FRACTURE AND FRAGMENTATION OF METAL SURFACE LAYER UNDER INTENSIVE ELECTRON IRRADIATION

P. N. MAYER A. E. MAYER
polina.nik@mail.ru mayer@csu.ru

Action of the high-current electron beam leads to intensive heating of surface layer of the irradiated metal. Rapid temperature increase can cause melting of the surface layer and generate intensive stresses in it. Release of these stresses induces fast expansion of the molten metal and, on the contrary, results in tension. Tension of the melt activates nucleation, growth and coalescence of vapor bubbles, it means, fracture and fragmentation of the metallic melt through nonequilibrium phase transition.

Here we numerically investigate the kinetics of the liquid metal fracture and fragmentation under the dynamic tension initiated by the powerful electron irradiation. Metal is treated as a two-phase medium consisting of vapor bubbles in liquid metal at the first stage of the evolution and of liquid drops in vapor at the second stage. Two-level approach is used: on the macroscopic level, the irradiated metal is treated as the two-phase heterogeneous medium in the one-velocity approximation, while on the microscopic level, the exchange of energy, mass and volume between both phases are described including grow or decrease of size of the vapor bubbles or liquid drops. Nonequilibrium phase transition in this cavitation zone leads to formation of ultra-dispersed particles with sizes from hundreds of nanometers up to several micrometers.

Between the cavitation zone and the metal surface there is a foremost flat layer of continuous metal without any cavities. It is similar to the spalled layer near the solid surface after the shock wave reflection. As opposed to the solid spalled layer, the liquid layer can be unstable due to its accelerated motion, as well, as due to the surface tension. The linear analysis of the liquid layer stability was performed. The Richtmyer-Meshkov instability of the free surface destructs the spalled liquid layer on times of about ten microseconds and higher after the irradiation. It is accompanied by formation of the wide spectrum of drops — from several micrometers up to several tens of micrometers in diameter.

The study was supported and by the Young Scientists Support Foundation of the Chelyabinsk State University, by The Ministry of education and science of Russian Federation, project 14.B37.21.0384, and by The Russian Foundation of Basic Research, project 12-02-31375/12.

Polina N. Mayer, Br. Kashirinikh str., 129, Chelyabinsk, 454001, Russia


RESPONSE OF A STRATIFIED VISCOUS HALF-SPACE TO A PERTURBATION OF THE FREE SURFACE

I. F. Melikhov A. S. Amosov S. A. Chivilikhin

ivan.melikhov@gmail.com
alexey.amosov@gmail.com
sergey.chivilikhin@gmail.com

The flow of highly viscous liquid in a half-space due to deformation of the free surface is investigated. The viscosity of the layer adjoining to the free surface is different from the viscosity of the remaining half-space. In the framework of small perturbation theory, the relationship between deformation of free surface and deformation of the layer/half-space interface is obtained. It was demonstrated that the volume and geometrical center of the perturbation on the interface and on the free surface are the same. The dependence of the perturbation amplitude and width on layer thickness was investigated. The results of numerical and analytical calculations are close for moderate free surface perturbations.

Sergey A. Chivilikhin, Kronverkskiy pr., 49, Saint Petersburg, 197101, Russia

EXPERIMENTAL FOUNDATION AND CONSTITUTIVE EQUATIONS OF MULTI-SURFACE THEORY OF PLASTICITY WITH ONE ACTIVE SURFACE

B. E. Melnikov I. N. Izotov A. S. Semenov
S. G. Semenov S. V. Petinov

kafedra@ksm.spbstu.ru kafedra@ksm.spbstu.ru
semenov.artem@gmail.com
semenov.serg@ksm.spbstu.ru
sergei.petinov@gmail.com

The multi-surface theory of plasticity with one active surface of equal plastic compliances is aimed to describe the elastic-plastic deformation under complex passive loading paths. Tensor and vector forms of constitutive equations are proposed. The conditions of thermodynamical consistency of the theory are obtained. A generalizations of the theory for the case of arbitrary shape of surfaces with equal compliances and of the anisotropy of elastic properties were carried out. Surfaces of equal compliances for the multilink loading paths and for the complex cyclic loading with total and partial unloading are experimentally studied. Comparison of experimental data and theory predictions was carried out.

Boris E. Melnikov, Polytechnicheskaya, 29, St. Petersburg, 195251, Russia

SQUEEZING OUT OF MATTER BETWEEN CRYSTALLINE SUBSTRATES

L. V. Mirantsev

miran@mail.ru

Using molecular dynamics (MD) simulations a squeezing out of nanoscopic layers of the matter confined between crystalline substrates has been investigated. It has been shown that such squeezing occurs through a series of discrete transitions nature of which is determined by the crystalline structure of substrates and parameters of intermolecular interactions. These transitions are accompanied by a step - like squeezing out of a certain number of particles followed by either changes in a structure of solid - like molecular layers induced by the crystalline substrates or step - like decrease in the number of such layers. It has been found that, depending on the parameters of intermolecular interactions, two types of behavior of the nanoscopic layer of the matter between crystalline substrates are observed. In some cases, a complete squeezing out of this layer is possible. In other cases, the last one or two molecular layers of the matter are found to be rigidly pinned to the substrates, and a complete squeezing out of this (these) layer (layers) is impossible.

Leonid V. Mirantsev, Institute of Problems of Mechanical Engineering, RAS, V.O. Bolsoi 61, St. Petersburg, 199178, Russia

THE GAS OUTFLOW FROM UNDERGROUND STORAGE UNDER HIGH PRESSURE GRADIENT

T. Miroshnichenko
tmi@dvo.ru

Study of gases flow into the porous media has a high priority for many of human activity areas. For example it is needed for rationalization of gas and coal mining, in the geophysical studies, etc. Some important problems of natural gas flowing into underground layers were detailed studied quite far. But investigations of shock-wave processes in such media are stay urgent nowadays because of high scientific and practical meaning in spite of marked progress in the area.

In the present work the gas outflow process through the layer of ground, appearing due to high pressure gradient, is considered. Let’s imagine that in underground storage filled by gas the pressure much increases immediately. It may happen as a result of different natural, technical or chemical processes. As a consequence the filtration gas process gets off through the ground into the open air. Then a model of the process could be defined as the model of gas explosion into underground storage. It is interesting to know the speed of change and behavior of main gas variables depending on initial gas and porous layer parameters. And how much of gas flowed out during unstedy process.

We will consider the process as one-dimensional and construct the mathematical model in terms of inhomogeneous media theory [1, 2]. The feature of the problem is that the flow rate is unknown function on the boundaries. It is necessary to define during calculation. Method based on finite difference schemes is used for calculation. High pressure gradient and the possibility of gas flow in wide velocity range add essential difficulties for calculations. The flow profile could be or shock wave or it is quite smooth with low velocity. Due to these aspects the use of most standard schemes leads to unwanted oscillations in numerical solution. To calculate the problem the flux-corrected transport method is taken as a basis [3]. Constructed numerical method allows calculate the problem appropriately with different initial conditions.

Two types of the problem are analyzed: isothermal and non-isothermal. They are compared for different input data. The at-
tention pays on the conditions when the shock wave arises into porous medium. It is shown that the temperature jump, taking place with pressure jump, influence on the solution essentially. Stability conditions of the shock waves into porous media with different permeability are analyzed. The rate of stationary state in relation to initial conditions is defined. Changes of the mass gas in the storage versus time is examined.

REFERENCES


ON VARIOUS STRATEGIES OF NUMERICAL SIMULATION OF HYDRAULIC FRACTURING

G. Mishuris M. Wrobel

ggm@aber.ac.uk miw15@aber.ac.uk

Numerical modeling of hydraulic fracturing is a challenging task from the computational point of view because of the main features of the problem, among which one can mention: (i) strong nonlinearity resulting from the coupling between the solid and fluid phases, (ii) moving boundaries of the fluid front and the fracture contour, (iii) singularity of the gradients of the physical fields near the crack tip, (iv) degeneration of the governing equations at the singular points of domain, (v) multiscaling and others (see [1,2]).

Although the problem has been analyzed for decades and many papers on the theoretical and practical aspects of its numerical modeling have been published, several difficulties are still to be overcome to make the numerical simulations more effective. In this work, we discuss and compare various numerical algorithms to model the problem. Different approaches related to the practical implementations are highlighted, among them: the choice of proper variables, proper ways to implement the boundary conditions, the methods for fracture front tracking and appropriate organisation of the numerical procedures. Direct and indirect schemes are analyzed for various leak-off regimes on the examples of the classical models.

This research has been supported by FP7 PEOPLE IAPP Project HYDROFRAC under number 251475.

REFERENCES


EXPERIMENTAL STUDY OF PULSED GAS DISCHARGE DYNAMICS IN A SOLENOIDAL MAGNETIC FIELD

N. A. MONAHOV  P. A. POPOV  S. V. BOBASHEV
V. A. SAKHAROV  N. P. MENDE

nm1988@mail.ru

An electric discharge is implemented in a gas at the end of a non-conducting cylinder between the central electrode coaxial with the cylinder and the ring electrode located on the cylinder surface near the cylinder end. The cylinder axis coincides with the axis of a magnetic coil wound on the lateral cylinder surface. The shape of the gas discharge and the distribution of thermal emission centers on the surface of the ring electrode when varying the discharge current and the magnetic induction are investigated. In addition, the dynamics of the gas discharge in a solenoidal magnetic field at the outlet of a supersonic conical nozzle is also investigated. In this case, the discharge is ignited between the nozzle sidewall and a rod located along the nozzle axis.

Nikolay A. Monahov, Polytechnicheskaya str. 26, Saint-Petersburg, 194021, Russia

ON SIMULATION OF THE FLOW AROUND AN AIRFOIL USING DIFFERENT NUMERICAL SCHEMES OF VORTEX ELEMENT METHOD

V. S. MOREVA

morevavs@rambler.ru

The problem of numerical flow simulation around an airfoil is considered. The flow assumed to be viscous and incompressible, so it is possible to use Lagrangian vortex element method. Well-known numerical scheme which often called ‘Discrete vortex method’ has several advantages, especially in terms of its simplicity, but it can lead to significant errors and even qualitatively wrong solution near the sharp edges and angle points of the airfoil. The classical scheme is also unsuitable if the of polygon legs approximating the airfoil differ in length significantly.

This (classical) approach is based on no-through boundary condition satisfaction according to which the limit value of the tangential component of the velocity on the airfoil is equal to zero:

\[ \mathbf{v}^*(r) \cdot \mathbf{n}(r) = 0, \quad r \in K. \]

Here \( \mathbf{n} \) is unit normal vector to the airfoil. Corresponding integral equation describing the intensity distribution of the vortex layer on the airfoil has the following form

\[ \oint_K Q(r, \xi)\gamma(\xi)dl_\xi = f(r), \quad r \in K. \]

This equation is similar to Fredholm equation of the first kind, but it has unbounded kernel. The kernel \( Q(r, \xi) \) is Hilbert type and it has \( |r - \xi|^{-1} \) type non-integrable singularity, so the integral is computed in the Cauchy principal value sense. For its correct computation special quadrature formulae and corresponding numerical schemes should be used.

To overcome the mentioned drawbacks of the classical method, another approach can be used, which is based on the boundary condition satisfaction according to which the limit value of the tangential component of the velocity on the airfoil is equal to zero:

\[ \mathbf{v}^*(r) \cdot \mathbf{\tau}(r) = 0, \quad r \in K. \]

It should be noted that both approaches are equivalent from an analytical point of view, but the proposed approach leads to Fredholm integral equation of the second kind:

\[ \gamma(\xi) + \oint_K Q^*(r, \xi)\gamma(\xi)dl_\xi = f^*(r), \quad r \in K. \]

It is easy to show that the kernel of this equation is bounded with the value \( \kappa/4\pi, \) where \( \kappa \) is the airfoil curvature.

In terms of these approaches several numerical schemes for vortex element method are developed. For the model problems results obtained with these numerical schemes are compared with exact solutions, which can be found using conformal mappings technique. The second approach (with the tangential component of the velocity) allows to obtain much more accurate results in comparison with the classical approach. A series of numerical schemes with different computational complexity is developed for various classes of problems.

Analytical expressions for the coefficients of linear equations approximating corresponding integral equation are obtained for all developed numerical schemes. The results of flow simulation for some simple cases are presented.

Victoriya S. Moreva, 2-nd Baumanskaya, 5, FN-2 dep., Moscow, 105005, Russia

THE MODEL OF ELASTOMERIC COMPOSITE BASED ON THE FILLER CLUSTER NETWORK AND SPECIAL INTERFACIAL POLYMER LAYERS

I. A. MOROZOV  L. A. KOMAR  S. N. LEBEDEV

ilya.morozov@gmail.com komar@icmm.ru lebedev@icmm.ru

Rubber reinforcement by filler is due to the continuous filler network and strong interfacial interactions.

It is assumed that the polymer, at a distance of 2 nm from the surface of inclusions, is in a glassy state, then its elastic modulus decreases, and at a distance of 10 nm it converts into a binder state.

The model is represented by a volume filled with fractal clusters. These clusters of spheres-inclusions are connected by elastic bonds, whose properties are dependent on the gap between inclusions.

Structural parameters are obtained from the analysis of microimages of filled rubbers. The force response of bonds to loading is determined by solving the pair interaction problems by the finite element method.

The behavior of the model “samples” under uniaxial loading conditions is studied taking into consideration bond failure criteria.

The study is supported by the RFBR (grant 11-08-00178-a) and the Ministry of Education of Perm Kray (agreement S-26/627).
We present an overview of key theoretical representations and experimental data on crack growth and its stoppage in nanocrystalline materials. The focuses are placed on micromechanisms for improvement of fracture toughness in such materials. Special attention is devoted to theoretical models describing various modes of nanoscale plastic deformation that enhance the fracture toughness of nanocrystalline materials. In particular, we consider lattice dislocation emission from crack tips, rotational deformation, nanoscale deformation twinning, grain boundary migration and grain boundary sliding as plastic flow modes strongly influencing crack growth in nanomaterials.

The lattice dislocation emission from crack tips the dominant toughening micromechanism in conventional coarse-grained polycrystals shows its specific features in nanomaterials due to the nanoscale and grain boundary effects. So, dislocations emitted from crack tips are effectively arrested at the neighboring grain boundaries and induce crack blunting. Crack blunting and dislocation stress fields hinder subsequent dislocation emission from crack tips and thereby promote crack growth. We have calculated the critical stress intensity factors in Al and Fe and demonstrated that a decrease of grain size from 300 to 10 nm in Al and Fe leads to a decrease of the critical stress intensity factor by a factor of 2 to 3 and thus reduces the fracture toughness of nanomaterials. Therefore, in nanocrystalline materials (in contrast to their coarse-grained counterparts), lattice dislocation emission is not effective in suppression of crack growth. This aspect explains low fracture toughness exhibited by most nanocrystalline materials.

At the same time, there are several experimentally documented examples of nanomaterials showing enhanced fracture toughness. These non-typical examples are well described within the concept of specific toughening micromechanisms operating in nanomaterials due to their specific structural features under certain conditions. The specific toughening micromechanisms are realized through such plastic deformation modes as grain boundary sliding, grain boundary migration, rotational deformation and twinning. Within theoretical models, these nanoscale deformation processes occur under the action of high shear stresses acting near crack tips and are accompanied by the formation of dipoles or quadrupoles of wedge disclinations, defects of rotational type. The discussed plastic deformation processes release in part high stresses near crack tips, thus increasing the fracture toughness of nanocrystalline materials.

Also, within the reviewed models, nanoscale rotational deformation and deformation twinning occur near crack tips of nanocrystalline materials through the formation and growth of nanodisturbances that represent nanoscale regions of ideal plastic shear. It is shown that these processes can occur near crack tips without the need to overcome an energy barrier.

In considering the effects of various alternative plastic deformation mechanisms on fracture toughness, we have shown that grain boundary migration, rotational deformation and twinning exert moderate influence on the fracture toughness of nanocrystalline materials. In contrast, grain boundary sliding in certain conditions can dramatically (several times compared to the case of brittle fracture) enhance the fracture toughness of nanocrystalline materials. This explains the experimental observations of good toughness exhibited by nanomaterials in several examples.

This work was supported by the Russian Ministry of Education and Science (Contract 8025 and grant MD-164.2012.1) and the Russian Foundation of Basic Research (grants 12-01-00291-a and 12-02-31642-mol-a).

Alexander G. Sheinerman, Bolshoj 61, Basil. Ostrov, St. Petersburg, 199178, Russia

BOUNDARY CONDITIONS AT THE LIQUID FIBROUS POROUS MEDIUM INTERFACE

E. V. Mosina A. A. Koltunov S. A. Ustinov katefrkate@mail.ru

The viscous incompressible flow in the vicinity of the boundary of a model porous medium is investigated. The system of the Stokes equations is solved for the flat channel partially filled with a set of square rods (prisms) arranged regularly in a square, hexagonal and staggered arrays across the flow. Two types of flow are considered: a shear flow due to the plane-parallel motion of the upper wall of the channel and a gradient flow due to the presence of a pressure gradient along the channel. The microscopic hydrodynamic fields of velocity and pressure are numerically found. The approximations for the permeability coefficient, the effective viscosity of the rods set and slip velocity and stress on the porous medium boundary, are obtained by averaging of the microscopic hydrodynamic fields. Three macroscopic models are considered: the Stokes Darcy model with the Beavers Joseph slip boundary condition, the Stokes Brinkman model with the boundary condition of velocity and stress continuity, and Stokes Brinkman model with the boundary condition of velocity continuity and stress jump. The proposed approximate formulas for the parameters in the liquid porous medium boundary conditions are useful for adequate description of the surface hydrodynamics of natural and synthetic fibrous filters, to obtain accurate estimations for the hydraulic flow characteristics and mean velocity profiles.

Ekaterina V. Mosina, prospect Universitetsky, 100, Volgograd, 400062, Russia

FE-IMPLEMENTATION OF HIGHER GRADIENT THEORIES AND ITS USE FOR EXPERIMENTAL ANALYSIS

W. H. Mueller C. Liebold wolfgang.h.mueller@tu-berlin.de

For the reason that the material behavior at the micro- and more at the nano-scale is shown to be size dependent e.g. re-
flected in a stiffer elastic response, finite element (FE) simulations of micro- and nanoelectromechanical systems should be enabled to incorporate such dependency meticulously. Our research project deals with various higher-order mechanical theories since the classical Boltzmann continuum fails to reproduce the size effect. Special attention is put on non-local theories such as the couple stress and micropolar theory for linear elasticity, based on the ideas of E. and F. Cosserat (1909) by introducing an independent degree of freedom of the subject matter, named rotation. In this work we make use of the Cosserat pseudocontinuum model by connecting the rotation vector to the mathematical rotation of the displacement gradients requiring only one additional length scale parameter as a consequence. We interpret the material points of a body as rigid particles. In contrast to existing works on the implementation of the superior strain gradient theory the crucial differential equation here is consistently based on the balance of linear momentum and on the uncoupled balance of angular momentum. From these balances the deformation energy density of the couple stress theory is derived by taking advantage of singularities on surfaces to identify the jump condition for the element interfaces. The developed variational formulation without body-forces or -couples is implemented into an open-source finite element code, FEniCS®, using equidistantly distributed tetrahedral dis- and continuous Lagrange elements with a polynomial degree of two in observance to the rank of the resulting elliptical partial differential equation. This novel open-source FE-software provides a collection of open-source packages for automated, efficient solutions of various differential equations. Beam bending simulations with decreasing beam thicknesses were performed following the corresponding method of size effect of Lakes (1995). The material data and the geometries are chosen to be in a good agreement to the experimental data of Lam et al. (2003) in order to allow a comparison of our numerical results to some experimental data. For testing the numerical effectiveness an analytical solution for the one dimensional Euler-Bernoulli beam theory is derived from the deformation energy density of the Cosserat pseudocontinuum model. We present bending rigidities, strains in $x$-direction, effective strains, $y$-components of the vector of rotation, $yx$-components of the rotation gradient and effective couple stresses calculated by post processing of the numerical outcomes. Bending rigidities and effective strains will be measurable in our labs with the help of atomic force microscopy and Raman spectroscopy, respectively. The latter objective of our research project is to measure the additionally occurring coefficient(s) called material length scale parameter(s) of non-local theories. The topics that will be discussed within this work deal with the problem of the boundary conditions for the additional derivations of the displacement gradients and will involve a description of the strong correlation between the characteristic size of the finite elements and the intrinsic material length scale parameter, as indicated in Noels and Radovitzky (2005).

THE DESTRUCTION OF INTERFACE OF SILICONS HETEROGENEOUS STRUCTURES AS A RESULT THE HYDROGEN DIFFUSION

E. E. Mukhin A. M. Polyanskiy
V. A. Polyanskiy Yu. A. Yakovlev
vapol@mail.ru

One of the most actual problems of modern microelectronics is reliability of semiconductor products. The solution this problem is important to creation of the electronic components for space communication systems, control systems of nuclear and thermonuclear reactions.

The modern sensors are usually thin-film structures on the silicon substrate. Reliability this sensor under condition thermo-mechanical stresses and radiation fields depends on strength of substrate and film. In the many causes occur destruction films and sensors and it does not relate witch properties of interface. Stronger films, with better adhesion, can be destroyed faster, than more crumbly.

In the paper are described results of research work study the reasons exfoliation of films system -Si-Ox, where Ox-is oxide Al2O3 or ZrO2. This type of sensor use in ITER project for data transfer about plasma to sensors located behind biological shielding. Body of sensors-mirrors form the system works like periscope. The mirror surfaces are under thermo-mechanical loading and it is rayed neutrons.

The silicon plates 10300.3 mm with dielectric layers on both sides were saturated with deuterium. The energy ions of deuterium were 50 eV. Inside the planes were found a little sphere using transmission electron microscopy. The size of spheres is about 10 nm.

Research work has done with hydrogen analyzer AV-1. We’ve shown, that hydrogen diffusion from silicon to interface can lead to destruction of interface under thermo-mechanical loading. Large hydrogen flow from silicon may be explained by redistribution the hydrogen on the energy level. The hydrogen inside silicon change bond energy under loading and it turn to diffusion state.

In the paper also has result of modeling diffusion of hydrogen. New method is offer for production of sensor resistant to external loadings.

Vladimir A. Polyanskiy, V.O., Bolshoj pr., 61 , St. Petersburg, 199178 , Russia

CRITICAL BEHAVIOR IN HIGH-VELOCITY IMPACT FRAGMENTATION

N. N. Myagkov M. V. Shul'tev
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

Wolfgang Mueller, Einsteinufer 5, Berlin, 10587, Germany

81
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.

In present work the numerical simulation of the high-velocity impact fragmentation is carry out by a gridless smoothed-particle-hydrodynamics (SPH) method in the program LSDYNA. 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 perform series of 3D simulations of the interaction of a spherical aluminum projectile with mesh targets at different impact velocities. The behavior of the materials is described by the MieGruneisen equation of state and Johnson-Cook model of plasticity.

The evolution of the fragments after the impact is considered and the fragment mass distribution are found at different impact velocities. For the steady states of fragment mass distributions the control parameter of problem can be identified with the impact velocity. With a study of the fragment mass distribution near to the transition point and its dependence on the system size we show that transition to the fragmentation behaves as a critical point attributable to a phase transition. The mass-size relation estimating the typical size of fragments at the steady-state stage of the fragmentation is considered. We also consider energy dependence of steady-state cumulative mass distributions.

REFERENCES


Nikolay N. Myagkov, Institute of Applied Mechanics, Russian Academy of Sciences, Leningradskiy prosp. 7, Moscow, 125040, Russia

COMPUTATIONAL BIOMECHANICS OF BONES

U. Nackenhorst  G. von Lewinski
nackenhorst@ibnm.uni-hannover.de

Bone remodeling has been recognized as an important issue in bone surgery, e.g. in artificial joint replacement. Computational mechanics techniques for the prediction of the bio-mechanical behavior of bone tissue under changed mechanical loading conditions have been developed since more than two centuries. This presentation aims for a state of the art review on modeling techniques for the prediction of bone surgery success and an outline of recent research activities.

A brief review on the development of continuum based theories for stress adaptive bone remodeling and the current state of the art on modeling techniques with emphasis to computational reliability and robustness will be presented. With the aim for a better understanding of the bio-physical processes as well micro-mechanical investigations down to the cellular level as sophisticated meso-scale computational models for the bio-physical behavior of living bone tissue will be discussed. Results from recent developments for the prediction of the osseointegration of bone implants will be compared with clinical observations.

Finally, we will give an outline on our current activities for patient individual treatment based on patient specific data basis.

Udo Nackenhorst, Appelstrasse 9A, Hannover, 30167, Germany

MODELING OF A WAVE DISTURBANCE CAUSED BY THE SHOCK-WAVE MOVING ABOVE A LIQUID SURFACE

L. V. Nadkrinichny
lmuten@iacp.dvo.ru

The generation and propagation of the shock-wave above the liquid surface \( z = \eta(x,t) \) are considered. An explosion may be the source of the shock-wave in gas [1, 2, 3]. A numerical simulation in such problems is a natural practice, but, as it turns out, in particular configuration of the pressure field the analytical solution is possible. In this case the pressure field \( P(x,t) \) represents the "step" with constant values behind and in front of the shock-wave moving with the constant velocity \( F \):

\[
P(x,t) = \begin{cases} 
  P_1 \text{ const, } x \leq F \cdot t, \\
  P_0 \text{ const, } x > F \cdot t,
\end{cases} \quad P_1 \geq P_0.
\]

The problem is solved under the assumption that the deformation of the liquid surface does not affect the parameters of the gas flow behind the shock-wave.

In the approach of the shallow water theory both the numerical and analytical solutions were obtained. The numerical calculations are carried out using a simplified Harten’s numerical scheme [4]. An important feature of the solution is that the water wave moves with the shock-wave: their fronts are the same. Criteria for existence and uniqueness of the solution were obtained in the form of relations for the parameters. In violation of the criterion the analytical solution does not exist. The relations between parameters of the shock-wave and the wave at the water surface were derived analytically. The values of the parameters allowing the shoaling of the bottom were revealed.

This work was supported by the grants from RFBR (project 11-01-98510r_vostok_a), FEB RAS (projects 13-III-V-03-027, 12-I-P15-04, 12-I-P18-03, 12-I-P23-02).

REFERENCES

[4] Nadkrinichny, L. V. Numerical investigation of surface wave generation and wave passing over the underwater obstacle //

Leonid A. Nazarov, Krasny Prospekt 54, Novosibirsk, 630091, Russia

DIRECT AND INVERSE PROBLEMS OF MASS TRANSFER IN COAL-ROCK MASSIVE: A NEW APPROACH TO GAS CONTENT DETERMINATION

L. A. NAZAROVA L. A. NAZAROV R. I. RODIN
larisa@misd.nsc.ru naz@misd.nsc.ru rodinri@mail.ru

Coal deposit prior degassing is an integral part of development mining process intended to reduce the hazard of dynamic phenomena such as instantaneous outbursts and bounces. In order to project degassing boreholes optimal arrangement and evaluate the degassing time it is necessary to determine: 1) productive capacity of the single hole; 2) gas content in intact coal seam.

1. The coal seams possess natural jointing hence we designed two level geomechanical model of degassing borehole vicinity, which takes into account: block structure and stress-strain state of coal massive, filtration parameters of joints, initial gas content of seam, diffusion coefficient etc. The methane emission from each block was described by 2D diffusion model with non-linear boundary conditions at block-joint interface. The gas transfer in cleat pattern was simulated by a set of connected 1D filtration models in curvilinear coordinate system. As a result the dependence of borehole gas discharge on natural stresses, seam depth, initial gas content, density of fractures and its geometrical parameters, as well as gas properties was established.

2. The well-known method for methane content determination - “canister test” - consists of pressure variation recording in a sealed measuring flask (MF) with just extracted coal sample. The data interpretation is fulfilled by simple integral approach [1] disregarding, in particular, by grain-size composition of sample as well as coal and gas physical properties. The new method of MF data processing based on mixed coefficient-boundary inverse problem solution is proposed. It permits to determine the initial gas content and coal substance diffusion parameters simultaneously.

In order to obtain input data for inverse problem, it is necessary to place two equi-volume parts of the same coal sample in the separate MF at different time moments and to record the corresponding pressure variations. The objective function G is constructed by time integration of standard error between homographic function of these variations and similar theoretical values. The conjugate gradient method [2] was used to find the minimum of G. Numerical experiments have shown that inverse problem is stable and uniquely solvable. As a result the initial gas content, diffusion coefficient and “gas-air” exchange coefficient can be determined.

This work 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. 99.

REFERENCES


Leonid V. Nadkrinichnyi, Radio, 5, Vladivostok, 690041, Russia

USING OF SPACE AND UNDERGROUND GEODETIC DATA FOR EVALUATION OF NATURAL STRESS FIELD COMPONENTS AND PROPERTIES OF MINING TECHNOLOGY BEARING ELEMENTS

L. A. NAZAROV L. A. NAZAROV A. V. PANOV
naz@misd.nsc.ru larisa@misd.nsc.ru anton-700@yandex.ru

Stress field variation monitoring is the important element of the every mineral geotechnology. The majority in situ stress measurement methods are labor-consuming and costly [1]. Realization of these methods assume induced perturbation in stress field with following recording and interpretation of rock mass response. At the same time changes in mined-out space configuration due to underground working also vary rock mass geomechanical fields up to the daylight surface, where the displacements - “image” of mining - can be recorded by means space geodesy. Nowadays this information is mainly used for monitoring of working areas or seismoactive territories. Meanwhile these data include information on Earth crust geodynamic and techogeneous processes, and this information is still inaccessible because of incongruous interpretation methods.

We proposed an approach for evaluation the natural stress field horizontal components and deformation parameters of geotechnology bearing elements by the geodetic recording on daylight surface or mined-out space contour, based on solving a mixed inverse problem.

A typical underground space configuration of shallow deposit mined by room-and-pillar method (model prototype is Upper Kama potash deposit) was considered: alternation of chambers and pillars elastic parameters (Young modulus and Poisson ratio) of which as well as lateral thrust coefficient L (ratio of horizontal stresses to vertical stress in intact rock mass) have to be determined. The vertical displacements on daylight surface and convergence of chamber walls were input data for inverse problems.

Numerical experiments revealed:

- objective function (root-mean-square difference of measured and theoretical displacements or wall convergence) has a pronounced ravine structure, so value of L can be determined in one level; 
- even at thirty-percent noise level in input data the inverse problem solution can be found within accuracy of 5%.

The investigations were partially supported by the Russian Foundation for Basic Researches, project no. 12-05-00843 and the Siberian Branch of the Russian Academy of Sciences, integration project no. 13.

REFERENCES

Russia

Larisa A. Nazarova, Krasny Prospekt 54, Novosibirsk, 630091, Russia

ON MODELING HETEROGENEOUS RESIDUAL STRESS

R. D. NEDIN A. O. VATULYAN
rdn90@bk.ru vatulyan@math.rsu.ru

Investigations of solid mechanics problems for bodies containing residual stress are of great importance from the point of view of assessment of strength and stability of structures. The development of three-dimensional linearized theory of deformable bodies with residual stress began in the early XX century. In 1913 Southwell was the first who derived the equations of linearized theory of stability in case of homogeneous subcritical state with small subcritical deformations. This theory was subsequently developed by Biezeno and Hencky, Biot, Neiber, Trefftz, Novozhilov. In the year 1952, Green, Rivlin and Shield obtained the basic relations of linearized theory in the most general form for elastic isotropic body with arbitrary form of elastic potential.

In present research three groups of the most widespread residual stress models are considered; the models differ from each other by a form of the constitutive relation which binds together the Piola stress tensor with residual stress tensor and displacement gradient: 1) Truesdell’s model [1], 2) Hogers model [2], and 3) the model proposed by Novozhilov, Vasidzu, Robertson, and Guz [3]. The comparison of formulations and solutions of problems on steady-state longitudinal and flexural vibration of beams is made for each of the residual stress models considered. By means of finite element method the numerical comparison of models for plates in presence of residual stress is made. The effect of residual stress components on dynamical characteristics (frequency response functions and natural frequency spectrum) is investigated. It is revealed that the numerical results in frames of each model are close to each other and do not contradict the data of real experiments on a definition of resonant frequencies of axially compressed metal beams.

The problems on steady-state vibration of thin plates and cylindrical bodies are studied using finite element method; the influence of different types of residual stress states on dynamical characteristics is explored. The inverse problems on the identification of residual stress components in plates and cylinders are viewed on the basis of the acoustical probing and recordation of frequency responses in some frequency range. The iterative process of solving the inverse problem is built; at every step of the process the integral Fredholm equation of the first kind with continuous kernel is solved, or an ill-conditioned system of linear algebraic equations is solved. The way of solving the inverse problem is proposed on the basis of projection method and approximation of biharmonic Airy function using polynomials of the 4th order. The computational experiments on residual stress reconstruction are conducted showing enough sufficiency of the method proposed and permitting to reveal the most auspicious ranges of frequency probing.

Acknowledgements The present research is conducted with the support of Russian Foundation of Basic Research (the project code: 13-01-00196).

REFERENCES


Rostislav Nedin, 8a, Milchakova Street, Rostov-on-Don, 344090, Russia

MOLECULAR-DYNAMICS STUDY OF BEHAVIOR OF GRAIN BOUNDARY IN POLYCRYSTALL UNDER SHEAR LOADING

A. Yu. Nikonov A. I. Dmitriev
nikonov@usgroups.com dmitr@ispms.tsc.ru

The behavior of polycrystalline copper fragment, containing various types of grain boundaries under the shear loading was studied in the framework of classical molecular dynamics. Grain size, their number and relative orientation were varied. It was shown that the parameters such as grain orientation, proximity of triple junctions, the orientation of the boundary relative to the direction of loading influence on behavior of boundary. It was found that for certain orientations of grains sliding of grain boundary can be accompanied by displacement of the boundaries in the direction perpendicular to the applied loading. In the scale of the polycrystal, this can lead to the growth of some grains at the expense of neighboring grains, reducing the total number of grains. Studies have shown that in case there is no movement of the border, numerous of structural defects may occur as a result of loading in grains. That can leads to nanofragmentation of grains.

Anton Y. Nikonov, 2/4, pr. Akademicheskii, Tomsk, 634055, Russia

FEATURES OF THE BEHAVIOR OF THE GRAIN BOUNDARIES IN THE THERMO-MECHANICAL IMPACT. MOLECULAR DYNAMICS STUDY

A. Yu. Nikonov A. I. Dmitriev
nikonov@usgroups.com dmitr@ispms.tsc.ru

Molecular dynamics simulation of behavior of grain boundaries in bicrystal of copper under shear loading were carried out. The influence of temperature of the sample on the behavior the grain boundaries was studied. The stability of discovered earlier effect of moving boundaries in a direction perpendicular to the applied loading was analysed. It was found that with increasing of temperature, the rate of such movement of the boundary decreases. As it was shown by studies of the structure, it is accompanied by a violation of order of the atomic structure near the boundary. The violation is caused by inconsistency of position of

84
the grain boundaries in the various atomic layers. A similar effect was also found for other pure FCC metals (Ni, Al, Ag). These results can help to understand the features of development of plastic deformation in polycrystals under shear loading.

Anton Y. Nikonov, 2/4, pr. Akademicheskii, Tomsk, 634055, Russia

MATHEMATICAL MODELING OF POWDERS SINTERING TAKING INTO ACCOUNT CONVERSION STAGING AND VOLUME CHANGE

O. O. Onoprienko  S. N. Sorokova  A. G. Knyazeva

s_sorokova@tpu.ru

The mathematical model of powders sintering at the condition of uniform controlled heating had been proposed and investigated. It had been assumed that the chemical conversions are accompanied by the volume change and the appearance of chemical and concentration stresses and strains additionally to temperature ones. It had been taken into account that volume change effect on heat and chemical processes. The time evolution of the temperature, elements and compounds concentrations, the relative change of the sample volume and the volume strains had been investigated.

Svetlana N. Sorokova, Lenina 30, Tomsk, 634063, Russia

STOCHASTIC FINITE ELEMENTS, KRIGING AND ITO INTEGRAL ON PROPERTIES DISTRIBUTION ESTIMATION

S. Osmani

s_osmani@yahoo.com

In this paper the following problems are treated:
- Estimation of the mean value of a random function Z(x), defined in a stochastic finite element (SFE) v,

\[ z_v = \frac{1}{v} \int Z(x)dx, \]

where the distributions of Z(x) at each node are known;
- Kriging solution with SFE under the non-stationary hypothesis:

\[ E(Z(x)) = m(x), \]

\[ C(x, h) = E(Z(x + h)Z(x) - m(x + h)m(x)). \]

-A view on applications of Riemann - Sietles integral, Ito integral, stochastic finite element, and Kriging in reservoir engineering and materials on parameter estimation, fluid reserves, stochastic oil-water, contact displacement, fractures etc.

Finally are given the conclusions underlying the importance of above stochastic instruments not only in mention “stochastic” disciplines but also in other ones as in energy, geology, hydrogeology, geophysics, mechanics, dynamics, elastostatics, finance, engineering, environment, climate etc. in which the distributions are used.

Key words: stochastic, distribution, Ito’s integral, finite element, kriging, differential equation, proprieties, process, fluid reserve, estimation.

Skender O. Skender Osmani, Faculty of Geology and Mines, Tirana, Rr. Elbasanit, Fakulteti Gjeologjise, Tirana, No, Albania

SIMULATION OF THE LINEAR OSCILLATIONS IN THE MONATOMIC AND DIATOMIC CRYSTAL LATTICES.

A. Osokina

aeosokina@gmail.com

The motion of particles in different crystal lattices is investigated. The one-dimensional and two-dimensional cases are considered. Some lattices consist of the identical types of particles and the other lattices have two different particles in the elementary cell. Atoms in a lattice are considered as masses connected with linear springs. The equations for the oscillation frequencies in one-dimensional chain were derived. The equations of motion of the particles in a square lattice were obtained. The program simulating the motion of a particle in a one-dimensional chain is being written. The results obtained will be used in further investigation dedicated to simulation of interatomic interaction in graphene.

Alena E. Osokina, Polytechnicheskaya, 29, Saint Petersburg, 195251, Russia

BIFURCATION ANALYSIS OF VIBRATIONS MECHANICAL SYSTEM WITH AN ELECTRIC DRIVE WITH LIMITED CAPACITY

G. Y. Panovko  A. M. Gouskov

gpanovko@yandex.ru

The report examines the effect of Sommerfeld in mechanical oscillating system with an electric drive with limited capacity. Periodic oscillation regimes considered. Bifurcation diagrams of successive extrema on the parameter field (voltage in armature winding) are built. The influence of damping on the existence of unstable modes found.

Grigory Panovko, Maliy Khariton’evskiy per., 4, Moscow, 101990, Russia

THE POINT ELASTOHYDRODYNAMIC CONTACT UNDER NON-STEADE STATE LOADING

M. Ya. Panovko

mpanovko@yandex.ru

A non-steady state elastohydrodynamic problem for heavily loaded deformable ball rolling over rigid half-space with a Newtonian lubricant is formulated and studied numerically. The problem is reduced to a system of nonlinear integrodifferential equations and inequalities with an initial and boundary conditions.
The dimensionless system of equations and inequalities is solved using Newton method. The numerical results show that dynamic loading of the rolling ball with a given mass may causes significant qualitative and quantitative changes of the pressure and film thickness distributions in the elastohydrodynamic contact.

Mikhail Y. Panovko, Maliy Kharitonievsky, 4, Moscow, 101990, Russia

STUDY THE SYNTHESIS OF COLLOIDAL GOLD AND ACCOMPANYING COLOR TRANSFORMATIONS
A. V. Pan'teleev A. V. Alfimov E. M. Aryslanova D. N. Vavulin S. A. Chivilikhin pantandrej@yandex.ru

In this paper, for the synthesis of gold nanoparticles using citrate method. A distinctive feature of this method is that the citrate anion simultaneously acts as a stabilizer and a reducing agent, therefore the concentration of this ion plays a crucial role: its change affects both the rate of recovery and the processes of particle growth. During synthesis, the reaction mixture changes color. Initially slightly yellow color of AuCl4-ion disappears, the solution turned dark blue, then purple and finally ruby (nanoparticles Au). Change the color of the solution indicates the structural changes occurring in the system. A transmission electron microscopy method revealed that a colorless solution, which is formed immediately after the addition of citrate, contains gold nanoclusters diameter of 3-5 nm. Dark blue solution formed a complex structure that can be described as an extensive network of nanowires with a diameter of 5 nm. Under dark purple as small segments, which are formed as a result of breaking the main extensive network of nanowires. Spherical nanoparticles with a diameter of 10-13 nm nanowires begin to break away from when the solution becomes purple. Finally gold nanospheres are formed when a solution is ruby red. To solve the problems in the work was carried out the chemical synthesis of colloidal gold by Francie. The used components - distilled water tetrahloraurouvyu acid and sodium citrate. First poured into the flask 48 ml of H2O and brought to boiling on a hot plate. Then added a glass pipette, 0.5 ml of 1% HAuCl4 and boiled for 2 min (Fig. 7). After adding glass pipette 1.5 ml of 1% Na3Cit and boiled for 20 minutes. (Color conversion solution, occurring at the same time, are shown in Figure 8 and Figure 9). Then turn off the stove, and after the termination of the boiling solution poured into a sterile vial, heated in an oven. In the synthesis, we received 50 ml of colloidal gold. The solution we exposed a number of experimental studies on a spectrophotometer nanosayzer and scanning electron microscope. A spectrophotometer to measure the stability of the solution was to look and check the changes of the transmission spectra and absorption in two weeks. According to the results of scanning electron microscopy, it can be concluded that the size of the particles seen in the photos are similar to the size of the particles measured nanosayzerom. Exactly compare them does not make sense, because the time between the experiments was relatively large.

Andrey Panteelev, Kronverkskiy, Saint-Petersburg, 171071, Russia

FATIGUE DESIGN OF EXPANSION JOINT IN SHIP SUPERSTRUCTURE
S. V. Petinov R. V. Guchinsky sergei.petinov@gmail.com

Despite the long history of application of subdivided structures and deckhouses, and efforts of ship designers and researchers a sensible solution in design of reliable details at the cut endings was not found yet. It may be explained as consequence of controversial requirements in design of the cut endings.

Fatigue design of the superstructure details is addressed to solution of the problem. Presented is an example of fatigue design of the cut ending in a fast ship superstructure based on application of modified “Strain-Life” criterion for fatigue and subsequent approach which utilizes Neuber’s formula and material cyclic properties. To realize the approach a procedure of the long-term stress distribution transformation to the block-type format is developed.

Efficiency of the developed technique is illustrated by comparing the results with those of application standard S-N criteria based techniques. The results of analysis allowed selection of the expansion joint detail of the superstructure geometry and construction procedure providing necessary reliability.

Sergei V. Petinov, 29 Polytechnicheskaya Str., St.Petersburg, 195251, Russia

MODELS AND SOLUTIONS OF FORCED QUASI 2D TURBULENCE WITH CHEMICAL REACTIONS
V. E. Petrov ALLUSR@itp.nsc.ru

The paper presents the results of mathematical modeling of forced quasi 2D turbulence with chemical reactions. This model leads to a new phenomenons in comparison without the chemical reactions. The KLB (Kraichnan-Leith-Batchelor) theory 2D forced quasi 2D turbulence with chemical reactions. This model predicts the existence of two inertial ranges. The influence of chemical reactions 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.

Vladimir E. Petrov, Ac. Lavrentiev str.,1 , Novosibirsk, 630090, Russia

FATIGUE FRACTURE OF THIN RECTANGULAR PLATES WITH CENTRAL CRACK UNDER UNIAXIAL HIGH-CYCLIC SYMMETRICAL LOADING
A. V. Plashchynska P. N. Baranova plashchynska.alla@gmail.com polina.baranova@yahoo.com

There are various criteria for determining crack extension conditions which play an important role in the study of fatigue fracture. Authors present an approach based on the phenomenological viewpoint which uses continuum mechanics concepts. The
criterion of fatigue crack growth as due to the microdamage accumulation in the vicinity of a crack tip is considered. The approach has been proposed in [1] to the construction of fatigue fracture models for infinite plates with cracks. A special emphasis has been made on high-cycle loading which do not produce any significant macroplastic strains, while the stage of the stable growth of a crack may occupy a dominant proportion of the fatigue lifetime.

In this work the approach is used to construct the generalized two-stage fatigue crack growth model for thin finite plates under high-cyclic uniaxial symmetrical loading. The model makes it possible to take into account the incubation stage as well as propagation stage of cracks growth and includes the function that estimates the effect of finiteness of the plate dimensions and cracks length. One of advantages of the model is the fact that the coefficients of the model are material constants to be determined from two base experiments of plain cylindrical specimens.

Within the framework of the developed models some problems of fatigue cracks growth in thin isotropic finite plates for two different materials have been solved. The results calculated on the basis of developed two-stage model agree well with those obtained by experiment.

Keywords: finite plate, fatigue crack, damage, cyclic plastic zone.

REFERENCES


Polina N. Baranova, 3, Nesterov str., Kyiv, 03057, Ukraine

FIELD DESCRIPTION OF ROTATIONAL MOTION

M. Podolsky
ttt88@mail.ru

Two ways of description of stable rotational motion and the examples of their simple applications are considered. The first way is based on investigation of nonstationary case. According to the second one Euler’s field approach is used. In the last case the procedure of differentiation with respect to vector elaborated by author was used.

Marlen E. Podolsky, 3, Lotsmanskaya Str., Saint Petersburg, 190008, Russia

CORIOLIS INERTIA FORCES IN THE PROBLEM OF EULER’S TURBINE EQUATION

M. Podolsky
ttt88@mail.ru

Motion of the fluid pumped through the canal, which rotates around fixed point, is considered. Formula for the moment of forces about this point is received. It is shown that the well-known Euler’s turbine equation is a special case of general formula, obtained in this work. The role of Coriolis inertia forces is discovered and it is shown that in general case these forces influence the moment of forces, acting on the fluid, by two ways, but in the plane problem one of these ways is absent. Physical sense of Euler’s turbine equation is clarified.

Marlen E. Podolsky, 3, Lotsmanskaya Str., Saint Petersburg, 190008, Russia

REFERENCES


Tamara Pogosian, Kronverkskiy pr., 49, Saint Petersburg, 197101, Russia

RESEARCH OF INSTABILITY DEVELOPMENT OF NANOPARTICLE SURFACE SHAPE

T. N. Pogosian S. A. Chivilikhin I. Yu. Popov V. V. Gusarov edo-chan@mail.ru

The aim of this work is the theoretical investigation of instability development of the nanoparticle surface shape during diffuse growth. The unperturbed surface is considered as an ideal sphere. The mass diffusive stream promotes increase of the sphere volume and development of free surface perturbations.

The relaxation of these perturbations due to action of capillary forces is also considered along with development of small perturbations of a free surface at the expense of perturbation of a mass diffusive stream. We use the effective coefficient of viscosity and surface tension coefficient of nanoparticle to describe a surface shape relaxation.

For the description of a mass stream to a free surface we solved the quasi steady-state diffusion equation where concentration is a solution of the Laplace’s equation in spherical coordinates. We take into consideration only axisymmetric perturbations.

Action of capillary forces is taken from [1]. Perturbation of surface is expanded in series of Legendre polynomials. The coefficients of expansion change over time and have dependence on indexes n, which is polynomial degree.

There is an area of indexes n at certain ratios between parameters of system where the loss of stability of a nanoparticle surface happens. For large values of indexes n, if the unperturbed velocity of sphere radius increasing is bigger than surface tension coefficient divided into the doubled effective coefficient of viscosity, coefficients of expansion correspond to unstable harmonics and speed of instability development increases with index growth. That corresponds to formation of fractal structure of a surface. We revealed various modes at which the surface of nanoparticle loses the stability and investigated dynamics of instability development of surface.

REFERENCES

ABOUT THE PROBLEM OF REMOVAL OF RESIDUAL STRESS IN SOLID AT HEATING

M. V. POLONIK  E. E. ROGACHEV

In the manufacture of metal products and hardening materials there takes place accumulation of residual stresses. The cause of the residual stresses in materials under intensive thermomechanical treatment is the presence in them of all kinds of heterogeneity. In [1] the level of such residual stress is calculated, and their distribution in the vicinity of single defect continuity is given. A necessary condition for this process is statically determine plastic flow [2-3]. On the example of a hollow sphere with accumulated irreversible deformations let’s indicate another concrete possibility of determining the parameters of elastic-plastic process on the ending of the process of unloading and consider the level of relief of residual stresses in the tempering. Tempering is modeled by quasi-static process of additional deformation process under slow heating, holding at a given temperature and cooling.

REFERENCES


Egor E. Rogachev, Suhanova 8, Vladivostok, 690950, Russia

NONLINEAR DYNAMICS OF DIATOMIC LATTICES

A. PORUBOV

A possible improvement of continuum model for diatomic crystals is examined using continuum limit of the discrete diatomic model. For this purpose, various discrete models of a diatomic lattice are compared at the linearized and weakly nonlinear levels. The suitable numbering of the atoms in the lattice is found which is better adopted for continualization than the familiar pair numbering with introducing two sub-lattices. The coupled governing partial nonlinear differential equations for a longitudinal strain and relative distance between the atoms are obtained in the continuum limit that allows us to describe localization of the strains due to the presence of the atoms of two kinds. It is found, that the equations obtained possess two kinds of localized wave solutions, one related to the acoustical branch and the other related to the optical branch. The work has been supported by the Russian Foundation for Basic Researches, grant No 12-01-00521-a.

Alexey V. Porubov, Bolshoy av., 61, V.O., Saint-Petersburg, 199178, Russia

SELF-SIMILAR SOLUTION OF THE PROBLEM OF A LONGITUDINAL SHOCK WAVE REFLECTION FROM THE ELASTIC SOLID FREE BOUNDARY

D. A. POTYANIKHIN

potyanikhin@iacp.dvo.ru

It is known that in solids the velocity of heat propagation is appreciably less than the velocity of strain waves propagation. Therefore the heat conduction may be neglected in dynamical problems of elasticity theory. To this effect coefficients of thermal conductivity are assumed equal to zero. However, this assumption results in non-uniqueness of the solutions of boundary problems for the equations of elasto-dynamics, including even the elementary self-similar problems. It means that different wave patterns (combinations of elastic waves propagating as a result of boundary shock action) may satisfy the same boundary and initial conditions. In terms of mathematics all these solutions are available and equally possible within the scope of adiabatic elasto-dynamics.

Dynamical deformation of non-linear elastic media in Eulerian coordinates is defined by system of equations

\[ v_i = \dot{u}_i + v_j u_{ij}, \quad \dot{v}_i = \dot{u}_i, \quad \dot{w}_i = v_j u_{ij}, \]

\[ \alpha_{ij} = \frac{1}{2}(u_{ij} + u_{ji} - u_{ki}u_{kj}), \quad \rho \dot{w}_i = \sigma_{ij,}, \]

\[ \sigma_{ij} = \frac{\rho}{\rho_0} \frac{\partial W}{\partial \alpha_{ij}} (\delta_{kj} - 2\alpha_{kj}), \]

\[ \frac{\rho}{\rho_0} = \left(1 - 2I_1 + 2I_2^2 - 2I_2 - \frac{4}{3} I_1^3 + 4I_1I_2 - \frac{8}{3} I_3 \right)^{1/2}, \]

\[ W = \frac{\lambda}{2} I_1^2 + \mu I_2 + \kappa I_1 I_2 + \chi I_1^3 + \eta I_3, \]

\[ I_1 = \alpha_{ii}, \quad I_2 = \alpha_{ij} \alpha_{ji}, \quad I_3 = \alpha_{ij} \alpha_{ji} \alpha_{ki}, \]

where \( u_i, v_i \) and \( w_i \) are components of the displacement vector, the velocity vector and the acceleration vector respectively; \( \alpha_{ij} \) and \( \sigma_{ij} \) are components of the strain tensor and the stress tensor; \( \rho_0 \) and \( \rho \) are the initial and current density respectively; \( \delta_{ij} \) is the Kronecker delta. Strain-energy function \( W \) depends on deformation tensor invariants \( I_1, I_2, I_3 \) and elastic constants \( \lambda, \mu, \kappa, \chi \) and \( \eta \) provided that deformation is adiabatic and elastic media is isotropic.

Parameters of stress-strain state on wave surfaces are related by dynamical and kinematical compatibility conditions. The law of degradation of energy on shock wave results in thermodynamical compatibility condition

\[ \sigma_{ij} [v_i] n_j - \rho (v_j n_j - G) \frac{[w_i][v_i]}{2} + \frac{[W]}{\rho_0} \geq 0, \]

which is Zemplen's theorem analog for elastic solids.

Let plane longitudinal shock wave propagates in elastic half-space. The angle between the wave and the half-space boundary

\[ \phi = 0. \]

\[ \psi = 0. \]

\[ \theta = 0. \]

\[ \phi = 0. \]

\[ \psi = 0. \]

\[ \theta = 0. \]
is referred to as the incidence angle. Provided that the wave intensity and incidence angle are constant the self-similar solution of the boundary problem is existed.

Feasible reflected wave patterns may consist of shock waves and Riemann waves. Proposed finite-difference method makes possible to solve formulated problem, that is to calculate stress-strain state in deforming body as a function of wave intensity and incidence angle as well as to choose unique wave pattern from the set of feasible wave patterns. The existence condition of evolutionary shock waves and thermodynamical compatibility condition serve as a criteria for reflected wave pattern choice.

Dmitrii A. Potianikhin, Radio 5 St., Vladivostok, 690041, Russia

A MODEL OF THE ANATOMY AND ELECTROPHYSIOLOGICAL AND MECHANICAL ACTIVITY OF THE LEFT VENTRICLE OF THE HEART

S. F. PRAVDIN A. V. PANFILOV V. I. BERDYCHEV L. B. KATSNELSON O. E. SOLOVYVA V. S. MARKHASIN

sfpravdin@imm.uran.ru
Alexander.Panfilov@UGent.be bvi@imm.uran.ru
l.katsnelson@iip.uran.ru
o.solovyova@iip.uran.ru
V.Markhasin@iip.uran.ru

The ventricular myocardium is a twisted thick muscular band. When modelling the electrophysiological and mechanical activity of the myocardium, it is necessary to have data not only about the properties of cardiomyocytes and the shape of the heart, but also concerning the direction of muscle fibres in the heart wall. Streeter (1979) and Torrent-Guasp (1973) proposed the idea of constructing a mathematical model of the geometry of the left ventricle with the help of a family of surfaces uniformly filled with curves. We propose the first analytical realization of this idea. Using some geometrical transformations, we map a flat semicircle with the given chords on it which are parallel to the diameter of the twisted surface, simulating one muscular layer. At the same time, images of the chords come into the model muscle fibres on one layer. By rotating one surface with the curves on it around the axis of symmetry of the ventricle, we obtain all other layers and curves filling the ventricle. This body of revolution is filled with curves that simulate muscle fibres. We compared the angles of inclination of fibres in our model with measurements in vitro from (Streeter, 1979) and (Nielsen et al., 1991). The results of verification showed that our model and experiments in vitro from (Streeter, 1979) and (Nielsen et al., 1991) agree well both qualitatively and quantitatively. Based on this model of the LV structure and models of cardiac cells (Aliev, Panfilov, 1996; Ten Tusscher et al., 2003) with the addition of the diffusion term, we modelled the propagation and attenuation of the waves of electrical excitation in the anisotropic myocardium. We also calculated one LV cycle using the method of virtual hexagon (Jarrousse, 2011) and the model of the passive stiffness (Hunter et al., 1997). Blood pressure was modelled by application of pressure, dependent in some way on the time, to the endocardium. In addition, we took into account the gravity and the force of viscous friction. One of the important results of the calculations is that, as in the real heart, ejection fraction 60%

The work is supported by grant 12-M-14-2009 of the Presidium of UrB RAS and grant 01SF1511 of the Ghent University (Belgium).

Sergei F. Pravdin, S. Kovalevskoj 16, Ekaterinburg, 620990, Russia

INFLUENCE DISPERSION IN SOLID AND GAS-SOLID FOR MOVING BODY

E. V. PROZOROVA A. V. SHADRIN

prozorova@niimm.spbu.ru shmbox@gmail.com

The purpose of this work is development of more full mathematical model for continuous mechanics and rarefied gas for great gradients. It is devoted to the influence of consideration an angular momentum variation in an elementary volume. Conjugated conditions at surface without the Knudsen layer are written to count friction and heat flow to the surface by solution the Boltzmann equation without collision integral in thin layer and by solution the Navie-Stokes equations with addition new terms. The main attention gave to concrete examples. The beams under the different conditions are investigated. We considered different aspect of interaction gas O2 with solid structure (aluminium-oxide film on aluminium substrate) with different potential.

Evelina V. Prozorova, University av. 28 , St. Peterburg (Peterhof), 198504, Russia

NUCLEATION OF PLASTICITY IN BCC METAL UNDER NANOINDENTATION

S. G. PSAKHIE K. P. ZOLNIKOV D. S. KRYZHEVICH A. V. KORCHUGANOV

kryzhev@ispms.tsc.ru

Molecular dynamics simulation of nucleation and development of structural defects in BCC metal under nanoindentation was carried out. Interatomic interaction was described by using many body potentials. Nanoindenter had cylindrical shape and loading was realized by lateral face of that cylinder. This shape of nanoindenter was chosen in order to make the analysis of structural phase transformation in loaded crystallite easier and more obvious. Absolutely hard nanoindenter was consisted of the same atoms as loaded metal. The discreteness of nanoindenter resulted in sufficient oscillations of load curve. For decreasing influence of nanoindenter discreteness on simulations results the indentation was realized by external field of cylindrical shape as well. The peculiarities of interactions of generated structural defects with interfaces, in particular, with free surface and grain boundary were investigated.

This work was supported by grant RFBR No 11-08-00680-a.

Dmitrij S. Kryzhevich, pr. Akademicheskij 2/4, Tomsk, 634021, Russia
COMPUTER INVESTIGATION OF PECULIARITIES OF ENERGY TRANSFORMATION BY THIN-FILM METALLIC NANOSTRUCTURES

S. G. Psakhie  K. P. Zolnikov
I. G. Konovalenko  I. V. Konovalenko
sp@ms.tsc.ru  kost@ispms.tsc.ru
igkon@ispms.tsc.ru  ivkon@ispms.tsc.ru

The object of the study are nanostructures formed by self-rolling of nano-thickness two-layer crystal films, each layer of which is composed of one sort of atom: Al and (Cu or Ni). Investigations are carried out on the base of molecular dynamics method using potentials of interatomic interactions obtained by the embedded atom method. It is shown that simulated nanostructures can transform the supplied thermal energy into the mechanical oscillations of their free edges. This is due to a significant difference in the coefficients of thermal expansion of the film layers and their temperature dependences. For simulated nanostructures oscillation frequency is in the range from 0.2 to 45 GHz. The behavior of simulated nanostructures under impulse heating with different rate and duration is studied. The investigated temperature range is from 50 to 450 K. It is revealed that the frequency of simulated nanostructures weakly depends on the heating rate and the oscillation amplitude increases with growth of thermal action intensity. The investigation of the transformation of thermal energy supplied to the nanostructures into its mechanical oscillations with account for the environment viscosity properties is carried out. The structural changes at the micro-level in nanostructures responsible for the transformation of thermal energy, supplied to them, into mechanical one are studied. It is shown that these structural changes due to the occurrence of the collective atomic motions with a vortex character. These atomic motions are generated near the free edges of the film. The vortex generation is associated with the free surfaces and the interface between the layers of the film. Duration of the vortex motion of atoms in the investigated films is less than the order of tens of picoseconds, and the displacement of the vortex is at a distance of up to 5 lattice parameters. The efficiency estimation of thermal energy transformation, supplied to nanostructures, into mechanical oscillations of their free edges versus rate of impulse heating, nanostructure configuration, and film chemical composition is carried out.

Ivan S. Konovalenko, pr. Akademicheskii, Tomsk, 634021, Russia

THE INFLUENCE OF CHARACTERISTICS OF MESOSCOPIC INTERNAL STRUCTURE ON THE MECHANICAL PROPERTIES AND FRACTURE PATTERN IN METAL-CERAMIC COMPOSITES

S. G. Psakhie  E. V. Shilko  V. E. Ovcharenko  S. V. Astafurov
sp@ispms.tsc.ru  shilko@ispms.tsc.ru
ove45@mail.ru  astaf@ispms.tsc.ru

Metal-ceramic (MC) composites (MC) are advanced representatives of the class of dispersion-reinforced materials, which have enhanced values of mechanical and service characteristics, such as strength, stiffness-to-weight ratio, crack growth resistance, wear resistance, fracture energy, ratio of thermal conductivity to thermal expansion coefficient, thermal stability and so on. One of the most important structural factors that determine the range of service characteristics of particle-reinforced MC composites, are the interfaces between high-strength particles and plastic binder. During the process of loading the interphase boundaries are regions of local stress concentration and potential sites of incipient failure of composite. Presented paper demonstrates the importance of taking into account the physical and mechanical properties of interfaces between particles and binder under construction of theoretical models and the design of real composite materials.

A theoretical study on the influence of the mechanical properties of interphase boundaries on the integral (“macroscopic”) mechanical properties of TiC particle-reinforced (Ni-Cr) matrix composite was conducted. A given research was carried out by means of computer-aided simulation by movable cellular automaton method. To provide the research, a structural model of metal-ceramic composites was developed. The model takes into account main features of mesoscale structure of metal-ceramic composites including presence of extended (“wide”) transition zones at the interphase boundaries characterized by a certain gradient of the physical and mechanical properties. With the use of developed formalism the influence of interface strength on the mechanical properties of the metal-ceramic composite TiC-(Ni-Cr) under dynamic loading was studied. The simulation results show that even the “narrow” interphase boundaries have an essential influence on integral (“macroscopic”) mechanical properties of composites despite the the fact that the volume fraction of such boundaries is insignificant. In particular, fracture character of composites with interphase boundaries changes from a traditional “interfacial” type (debonding of particles from the binder) to the initiation and development of cracks in the binder. As a result, the “macroscopical” strength of the composite can grow in several times, and the fracture energy can increase by order of magnitude.

A promising way to achieve a high strength of interphase boundaries is the formation of wide transition zones (areas of variable chemical composition). As shown by simulation results, extended (wide) transition zones at the interphase boundaries produce a considerable increase in the strength and deformation capacity of the composite and make the fracture energy higher by order of magnitude. This effect is concerned with a significant reduction in stress gradient on wide interphase boundaries characterized by gradual changes in the mechanical properties of the material in the transition zones.

It is shown both experimentally and theoretically that an additional increase in mechanical characteristics of composite can be achieved by means of high-energy surface treatment leading to formation of multiscale internal structure including submicron- and nano-scale secondary ceramic particles in plastic binder.

The investigation has been carried out within the SB RAS Program III.23.2 for Basic Research and at partial financial support of the Project No.5 of the Belarus NAS and SB RAS Program for Joint Basic Research.

Evgeny V. Shilko, pr. Akademicheskii 2/4, Tomsk, 634021, Russia
Nonstationary processes of solids intensive deformation, which are accompanied by the formation and propagation of shock waves, can be described only on the basis of nonlinear mathematical models. The simplest of them is a model of a nonlinear elastic isotropic medium. For this model, we know that the wave processes cannot be divided into purely longitudinal or transverse and become mixed character in the general case. The preliminary deformation of the medium, the wave intensity, after the shock effect on loaded surfaces and geometric characteristics of the wave surface influence to movement of the shock waves. The listed properties of boundary value problems with the surfaces of strong discontinuities, with the exception of automodel productions, not provide to obtain the exact analytical solutions. The presence of several deformation processes does not allow to build numerical solutions based only on the calculation methods used in gas dynamics. Therefore there is a need to combine approximate analytical methods (perturbation methods, the method of ray series) as a tool to obtain estimates of the solutions behavior for the areas in the vicinity of the wave fronts and the finite-difference calculation methods in the rest of the deformation areas. One of the most effective methods for the construction of approximate analytical solutions is the method of matched asymptotic expansions. On its base it is shown that the basic information about the solution is determined by the so-called evolution equations in the frontal area of the shock wave. For example, the Cole-Hopf equation will be such equation for the plane longitudinal shock waves in inhomogeneous medium. In practice, often is necessary to know the character and laws of shock waves motion in the great length arrays, for which should be considered the possible inhomogeneity of the medium. Various versions of inhomogeneity of the elastic medium, combined with the nonlinearity of intensive deformation leads to a variety of evolution equations. In this paper we consider the problem of a plane longitudinal shock wave with the inhomogeneity of the nonlinear elastic medium in the direction of wave motion. Financial support of the Russian Foundation for Basic Research (Grant N 11-01-00360-a) is gratefully acknowledged.

Yulia E. Ivanova, 5 Radio St., Vladivostok, 690041, Russia

GASDYNAMIC SYNTHESIS OF DIAMOND-LIKE FILMS

A. K. REBROV
rebrov@itp.nsc.ru

The results of study of the diamond-like film deposition from a high velocity flow of the hydrogen-methane mixture, activated in the high temperature channel are presented. Besides diamond phase, the film contents crystals in the form of hexagonal cross section prisms, which can be related to lonsdaleite.

The synthesis of different allotrope carbon structures has great fundamental value as well as base for wide practical applications. Amid different methods of CVD the method of HW CVD was intensively developed last decades. Being attracted by technical simplicity, it has constrictions on the range of mass flux, density of gas mixtures and transportation velocity of active fragments. From these points the gas jet method [1] is considered as alternative one.

In this work the reactor was elaborated with heating (activating) element in the form of tungsten spiral surrounded by the ceramic or metal screen. The mixture of H2+CH4 is heated to the temperature 2100-2500K, and activated.

The Raman spectrum with excitation in UV range (325nm) is obtained for the film on the Mo substrate with temperature 1100K from the flow of mixture 99%H2+1%CH4, having volume flux of H2 about 1500 sccm. The pick at 1336.8cm⁻¹ is shifted diamond pick. The film is an electric isolator. The film morphology from SEM shows the isles of hexagonal cross section prisms with the length about 1μm and characteristic cross section size 50-100nm.

The question arose on nature of these crystals. The X-ray phase analysis has shown definitely the presence of lonsdaleite. The lonsdaleite synthesis in a pure crystalline form is an unexpected hardly probable event, though it is possible, if take into account the deposition peculiarities from intensive directed high velocity flow [2].

This work was supported by the Grant of Presidium RAS No. 25.9 and Federal Grant-in-Aid Program “Human Capital for Science and Education in Innovative Russia” (Contract No. 8583).

REFERENCES


Alexey K. Rebrov, Kutateladze Institute of Thermophysics of the Siberian Branch of Russian Academy of Sciences, Novosibirsk.

VECTOR-MATRIX BOUNDARY VALUE PROBLEMS IN THE THEORY OF 2D COMPOSITE MATERIALS

S. ROGOSIN M. DUBATOVSKAYA
rogosinsv@gmail.com

It is presented a survey of models of 2D composite materials for which the considered problem can be reduced to a vector-matrix boundary value problem for an analytic vector. As an illustrative example, heat conduction in 2D bounded composite material with symmetric inclusions and symmetric conducting properties of its components is studied.

Sergei V. Rogosin, Zolotaya Gorka 10-2, Minsk, BY-220005, Belarus
NUMERICAL SIMULATION OF A TIBIA WITH IMPLANT USING THE FINITE–ELEMENT METHOD

M. Roland T. Tjardes R. Otchwemah S. Diebels
m.roland@mx.uni-saarland.de
Tjardes7@kliniken-koeln.de otchey@gmail.com
s.diebels@mx.uni-saarland.de

The use of numerical simulations on the basis of imaging techniques in medicine has high potential benefits. Due to the possibility of considerations of patient-specific characteristics and features, our goal is to realize patient-based simulations directly from computed tomography data.

Fractures of the tibia can be treated in some cases by means of implants. In this cases the question of the stresses and strains of the implant arises. Based on CT data we have generated several finite element meshes of such a tibia with implant. Through the application of modern visual computing algorithms we were able to generate these meshes direct from the CT images without the use of additional software.

The results of the simulations allow an assessment of the impact of the state of healing due to the stress and strain distribution in the complex structure consisting of the tibia, the implant and its anchorage. In particular, the influence of changes with respect to the healing process inside the fracture area can be computed and visualized.

REFERENCES


Michael Roland, Campus A4.2, Saarbrcken, 66123, Germany

ABOUT THE NATURE OF THE THRESHOLD TENSION

Ya. I. Rudaev D. A. Kitaeva T. A. Miasnikova
dkitaeva@mail.ru tatiana.miasnikova@mail.ru

The problem is to determine the threshold tension of the high-temperature deformation of aluminium alloys in a wide speed range, including intervals of superplasticity. The problem is solved in the framework of a dynamic model, formulated from the perspective of synergy; the catastrophe theory have been used for a mathematical description. Analyzed the discussion over the existence of the threshold tension and its dependence on temperature and the size of feed grain. In this case, the threshold tension is the value considered as a limit of tension when strain rate tends to zero. In a sense, the presence of the threshold tension is linked with the ability to implement the effect of superplasticity.

Yakov I. Rudaev, Kievskaya str., 44, Bishkek, 720000, Kyrgyzstan

ON THE DYNAMICS OF A HOMOGENEOUS PUCK ON AN INCLINED PLANE WITH FRICTION

A. Rusinova
annarusinova@mail.ru

The problem of motion of a homogeneous circular cylinder on an inclined plane with friction is discussed. Dynamically consistent model of friction suggested by A. P. Ivanov is used. Pressure distribution in this model is uneven. It is proved that, if the ratio of the coefficient of sliding friction to the slope of the plane is greater than unity, thecylinder comes to rest after a finite time. Moreover sliding and rotation of the cylinder cease at one and the same time, when the angular velocity isn’t 0 at the initial time. The nature of the limit motion of the cylinder is investigated in this case.

Anna M. Rusinova, Leninskie Gory, 1, Moscow, 119991, Russia

CYCLIC LOADING OF ELASTIC–PLASTIC GRANULES AT UNIAXIAL COMPRESSION

A. Russell P. Müller J. Tomas
alexander.russell@ovgu.de
peter.mueller@ovgu.de juergen.tomas@ovgu.de

At cyclic loading, granules deform by abrasion, dislocation and eventually undergo fracture at stresses which are substantially lower than the failure stress at static loading. The knowledge about the mechanical properties of individual granules and their macroscopic behavior at cyclic loading paves the basis for physical modeling of particle dynamics and understanding the development of fatigue processes. The material behavior of granules at cyclic loading still proves to be an area of investigation due to the complexity observed in the influence of parameters like particle size and moisture content.

The material behavior of dry, moist and wet spherical elastic-plastic granules during multiple stressing conditions at unique and random contacts was experimentally studied using uniaxial compression tests. The force-displacement curves were approximated, the energy characteristics were worked out and the coefficient of restitution was determined using appropriate mechanical models from literature. The phenomenon of cyclic hardening was studied and the critical number of cycles to reach fracture was determined. Furthermore, the influence of particle size and moisture content on the material behavior at cyclic loading, coefficient of restitution and the critical number of cycles to reach fracture was investigated.

Keywords: Coefficient of restitution, Compression, Cyclic loading, Force-displacement curve, Fracture, Granules.

Alexander Russell, Gebaeude-18, Raum-502, Universitaetsplatz-2, Magdeburg, 39106, Germany
Temperature factors are modeled with the help of associated heat generential stresses, and the kinematic equations for vector-director equations, written for pressure and antisymmetric tensor of translation and rotational motion, the governing equations of translational and rotational motion, the governing equations of the Cosserat continuum were written, has served the methodological basis of this approach. The model of a liquid crystal was firstly proposed by Cosserat brothers, where the equations of moment elastic constitutive theory in the form of thermodynamically consistent system of elasticity theory in the form of thermodynamically consistent system of thermodynamics of the particles is analyzed. In the adiabatic approximation the equations of both models are written in the form of symmetric equations of the Cosserat elastic-viscoelastic resistance to rotation. The fundamental work by the Cosserat brothers, where the equations of moment elastic continuum were written, has served the methodological basis of this approach. The model of a liquid crystal was firstly proposed by Eriksen and developed by Aero, Leslie, as well as in more recent works by Bulygin, Kalugin, Kuvshinsky, Kondaurov and many others. However this model is so complicated that for a detailed study of the processes occurring in liquid crystals it is appropriate to obtain more simple variants of the model, describing the particular cases of motion.

This paper is devoted to the construction of simplified models of a nematic liquid crystal as an acoustic microinhomogeneous medium with rotating particles under the action of weak mechanical and thermal disturbances. Two mathematical models are obtained on the basis of nonlinear equations of the Cosserat elasticity theory in the form of thermodynamically consistent system of the conservation laws. In first of them the strains are assumed to be small, and the potential energy of elastic deformation nonlinearly depends on the specific volume, the angle of relative rotation and the entropy. In the spatial case the model consists of the equations of translational and rotational motion, the governing equations, written for pressure and antisymmetric tensor of tangential stresses, and the kinematic equations for vector-director. Temperature factors are modeled with the help of associated heat equation, in which the thermal conductivity tensor is determined by orientation of the particles.

In the case of plane strain the tangential stress in a medium and the angle of relative rotation satisfy the Klein-Gordon equation. By means of numerical methods for solving this equation it is shown that the liquid-crystal medium possesses a resonant frequency of rotational motion, which is independent of the sample size and of the boundary conditions on its surface.

The second (dual) approximate model is based on the hypothesis about the antisymmetry of deviator of the stress tensor. Qualitative difference between the models taking into account finite rotations of the particles is analyzed. In the adiabatic approximation the equations of both models are written in the form of symmetric systems, hyperbolic by Friedrichs, that guarantees the mathematical correctness of the Cauchy problem and the boundary-value problems with dissipative boundary conditions in the framework of these models.

The technique of research of air flow in a human nasal cavity is developed on the basis of mathematical modeling by means of package ANSYS. The three-dimensional geometry of a nasal cavity is constructing on the basis of the series tomography pictures received from clinic. Programs GRAPHER and GAMBIT are used for the construction. The flow in the constructed mathematical model of a nasal cavity is calculated in fluid-dynamics section FLUENT of package ANSYS on the basis of incompressible Navier-Stokes equations system. By means of a time-dependent method a stationary solution is founded for designated pressure difference between an exit and input of a nasal cavity.

There are constructed about 30 models of nasal cavities of real people. For them fields of velocity, temperature, pressure are calculated and visualized. Integral characteristics are obtained, such as dependence of the volume flow rate on pressure difference, distribution of the minimum and average values of temperature on length of a nasal cavity depending on temperature of inhaled air, distribution of size of hydraulic diameter along a nasal cavity, dependence of resistance factor of nasal cavity on Reynolds number. The analysis of results is carried out for establishing of regularities and specific features in an effort to reveal the signs of physiological norm and a pathology.

Aleksey V. Chichvarin, Makarenko, 42, Staryy Oskol, 309516, Russia

ON THE ACOUSTIC APPROXIMATION OF THERMOMECHANICAL MODEL OF A LIQUID CRYSTAL

V. M. Sadovskii
sadov@icm.krasn.ru

Vladimir M. Sadovskii, Akademgorodok 50/44, Krasnoyarsk, 660036, Russia

THE COMPARATIVE ANALYSIS OF THE RESULTS OF AIRFLOW NUMERICAL MODELING IN A HUMAN NASAL CAVITY

A. S. Sadovskii  V. L. Ganimedov  M. I. Muchnaya
as_s6@mail.ru ganim@itam.nsc.ru mim@itam.nsc.ru

The technique of research of air flow in a human nasal cavity is developed on the basis of mathematical modeling by means of package ANSYS. The three-dimensional geometry of a nasal cavity is constructing on the basis of the series tomography pictures received from clinic. Programs GRAPHER and GAMBIT are used for the construction. The flow in the constructed mathematical model of a nasal cavity is calculated in fluid-dynamics section FLUENT of package ANSYS on the basis of incompressible Navier-Stokes equations system. By means of a time-dependent method a stationary solution is founded for designated pressure difference between an exit and input of a nasal cavity.

There are constructed about 30 models of nasal cavities of real people. For them fields of velocity, temperature, pressure are calculated and visualized. Integral characteristics are obtained, such as dependence of the volume flow rate on pressure difference, distribution of the minimum and average values of temperature on length of a nasal cavity depending on temperature of inhaled air, distribution of size of hydraulic diameter along a nasal cavity, dependence of resistance factor of nasal cavity on Reynolds number. The analysis of results is carried out for establishing of regularities and specific features in an effort to reveal the signs of physiological norm and a pathology.

Aleksey S. Sadovskii, Institutskaya str., 4/1, Novosibirsk, 630090, Russia
DISTINCTIVE FEATURES OF THE AIR FLOW IN VARIOUS PARTS OF A HUMAN RESPIRATORY TRACT OBTAINED BY NUMERICAL SIMULATION

A. S. Sadorvskii  V. L. Ganimedov  M. I. Muchinaya

as_s6@mail.ru

Mathematical modeling is a perspective direction in research of air flow in human respiratory ways. It allows to investigate in detail flow structure that is inaccessible to modern tool methods. It enables one to perform virtual operations and to predict results of real surgical intervention. It can help with definition of a way of address delivery of medicines at inhalation.

In the present work the geometry of respiratory ways of the person was modeled on a series of the tomograms executed in parallel coronary sections (for a nasal cavity) and parallel axial sections (for other part of respiratory tract). Tomography pictures were received with step 1÷5 mm. Construction of model geometry and calculations in the context of the of Navier - Stokes equations were spent by means of the package of applied programs FLUENT and its geometrical preprocessor GAMBIT.

On the base of calculations results flow visualization was made for respiratory ways from a nose vestibule to trachea bifurcation. Calculations were carried out for inspiration and expiration regimes at various values of pressure difference. Fields of velocity and temperature in coronary and sagittal sections are presented. Presence of zones of a counterflow and stagnant areas in a nasal cavity is established. Assumptions of their role in breathing are made. It was made the analysis of the forces operating on a nasal septum from the right and left nasal parts during breathing. Possibly these results can predict a future direction of a nasal septum curvature. By calculations results the conclusions are drawn on influence of specific features on flow structure. It is established that air flow in an average part of a respiratory path (nasopharynx, pharynx, throat and trachea) represents a flow with system of vortices for all breath regimes. The vortices form and intensity depend on anatomical features of a respiratory tract.

Aleksey S. Sadovskii, Institutskaya str., 4/1, Novosibirsk, 630090, Russia

NUMERICAL SIMULATION OF DEFORMATION OF A METAL FOAM

O. V. Sadovskaya

o_sadov@icm.krasn.ru

Porous metals are new artificial materials, which can be widely used in engineering because of their low density and good damping properties. The main difficulties in mathematical modeling of porous metals are related to the fact that their deformation properties are significantly different in tension and in compression. In tension there are the stage of elastic deformation of porous skeleton and the stage of plastic flow up to the fracture. In compression there are the stages of elastic and plastic deformation of a skeleton until the collapse of pores, and the subsequent stage of elastic or elastic-plastic deformation of a solid material without pores. At small sizes of pores the collapse can occur on the elastic stage with the appearance of plasticity only under a sufficiently high level of load.

The mathematical model for the description of small deformation of a porous metal with a random distribution of pores as an inhomogeneous medium is constructed on the basis of generalized rheological method. In this method a new rheological element, so-called rigid contact, is used to describe the uniaxial deformation of materials with different resistance to tension and compression. Change in the resistance of a porous metal to external loads, when the collapse of pores occurs, is taken into account by means of the von Mises-Schleicher strength condition. Irreversible deformation is described with the help of yield condition, modeling the plastic loss of stability of porous skeleton. The random nature of distribution of the pores size is described on the basis of the empirical histogram, which depends on technological process of metal foaming. Phenomenological parameters of the model are determined based on the approximate computations for the problem of static loading of cubic periodicity cell with spherical voids.

For a homogeneous porous medium the fields of displacements and stresses in the problem of radial expansion of spherical and cylindrical cavities under the action of internal pressure considering the effect of collapse of pores are constructed in closed form. Transition to the plastic state is described by means of the Tresca-Saint-Venant yield condition. Dilatancy is not considered. It is shown that the porosity does not change at the stage of elastic deformation. When the pressure increases, the stage of plastic compaction is formed in the vicinity of a cavity, in a part of which the collapse of pores takes place.

The algorithm of numerical realization of the model of dynamic deformation of metal foams on multiprocessor computer systems of the cluster type is worked out. Parallel version of programs, implementing this algorithm, is included in the previously developed and registered by Rospatent parallel program systems 2Dyn_Granular and 3Dyn_Granular, intended for numerical analysis of dynamic processes in elastic-plastic and granular media. Testing and verification of programs were carried out on some model problems. A series of methodical computations was performed, the ultimate goal of which is to simulate and optimize the damping properties of spatial elements of constructions from porous metals.

Oxana V. Sadovskaya, Akademgorodok 50/44, Krasnoyarsk, 660036, Russia

SOME ASPECTS OF THE THERMODYNAMICS OF THE DISSIPATIVE SYSTEMS

T. Salmikova  A. Alekseevskova

tatiana.salmikova@gmail.com  Aanna_A@inbox.ru

Let’s consider the dynamical system under the forces of isotropic viscous friction. Hamiltonian of our problem depends on some constant parameters. Following the ideas of Gibbs, we can lead our finite-dimensional dissipative system to a thermodynamic system with variable temperature. We study the main thermodynamic characteristics and the asymptotics behavior of the models with viscous friction of the pendulum in the gravity force and of a mass point moving on the vertical curve with two local minima in the gravity force.
The performance of multistage fracturing operations on horizontal wells is currently one of the most perspective trends in the development of hydraulic fracturing technologies. Multistage fracturing concepts realization ensures accumulation of practical experience. However, there is still a lack of processed statistic data results for making strategic decisions in order to enhance technologies’ efficiency. Rational effectiveness evaluation can only be carried out by means of processing field development modeling results. A practical solution to the problem of integrated multistage fracturing processes modeling includes a number of sub goals which should be approached in an integrated way:

1. The objective of geomechanical fractures modeling;
2. The objective of making a sector model of a field (geological and hydrodynamic models);
3. The objective of transferring fractures parameters into the sector hydrodynamic models;
4. The objective of history matching to actual oil and/or gas production data;
5. Change of the number and parameters of fractures in the history matched model (in technically attainable boundaries);
6. Cost and technical efficiency evaluation of options under consideration. The article is devoted to the analysis of applied modeling methods and approaches and is related to one of the horizontal wells at Samotlor field. Modeling results serve as the way to define economic efficiency and technologically effective number of fractures on the defined area of the reviewed field.

Mikhail I. Samoilov, Pervomaiskaya, Build 6, Tyumen, 625000, Russia

A FINITE ELEMENT APPROACH TO A MECHANICALLY STIMULATED BIOCHEMICAL FRACTURE HEALING MODEL

A. Sapotnick U. Nackenhorst
alexander.sapotnick@ibnm.uni-hannover.de
nackenhorst@ibnm.uni-hannover.de

Following the fracture of a bone, a well orchestrated cascade of cellular events usually leads to the reunion of the fractured bone ends and to the recovery of its original functionality. Suitable biochemical and mechanical conditions within the fracture region are required for a successful regeneration. Recent computational approaches attempt to combine biochemical and biomechanical stimuli. The simulation of the chemical events involve the concurrent solution of several non-linear hyperbolic differential equations. The arising stability issues within the finite element framework will be discussed and a stabilization scheme, utilizing the time-discontinuous Galerkin (TDG) and the Finite Calculus (FIC) methods, will be presented.

The coupled partial differential model applied in this context was developed by Geris et al. (2008). It consists of twelve equations, which represent the evolution and activities of five cell types (mesenchymal stem cells, fibroblasts, chondrocytes, osteoblasts and endothelial cells), four tissues (fibrous tissue, cartilage, woven bone and vasculature), as well as three types of growth factors (chondrogenic, osteogenic and angiogenic growth factors). In general these equations contain advection, diffusive and reactive terms, where the coefficients depend in part on the concentrations of the unknowns.

Therefore, the underlying mathematical problem for the biochemical part of the simulation can be stated as, solve

$$\frac{\partial \phi}{\partial t} = - \frac{\partial}{\partial x} (a(x,t) \phi) + \frac{\partial}{\partial x} (d(x,t) \frac{\partial \phi}{\partial x}) + \gamma(x,t) \phi, \quad \text{in} \quad \Omega,$$

for \( \phi(x,t) \) in a domain \( \Omega \) fulfilling the initial condition \( \phi(x,0) = \phi_0 \) in \( \Omega \) and suitable boundary conditions on \( \partial \Omega \). With \( a, d \), and \( \gamma \) being the time dependent advection, diffusion, and reaction coefficients, respectively.

It is well known, that spurious oscillations are likely to pollute the numerical solution of this problem, while further stability issues arise from the time integration. In this work, the necessary stabilization was achieved by combining the Finite Calculus, by Oñate et al. (1998,2007) and the time-discontinuous Galerkin method.

The biochemical fracture healing model is furthermore linked to a biomechanical simulation. Here, the healing callus is exposed to basic loading conditions, while taking into account the properties of the current tissue configuration. In this work, the local strain or stretch is then used to define a biomechanical stimulus acting on the different cell types. The local level of the deviatoric strain is assessed by computing the second invariant of the Green-Lagrange strain tensor, given by the principal stretch ratios \( \lambda_i \)

$$\varepsilon_V = \frac{\sqrt{2}}{6} \sqrt{(\lambda_1 - \lambda_2)^2 + (\lambda_2 - \lambda_3)^2 + (\lambda_3 - \lambda_1)^2}. \quad \text{(2)}$$

In relation to the different strain levels biomechanical stimuli are defined for three major tissue formation pathways, i.e. a fibrous stimulus \( \psi_{fibro} \), a chondrogenic stimulus \( \psi_{chondro} \) and an osteogenic stimulus \( \psi_{oste} \). These are simply factors, varying in value between 0 and 1, for the differentiation of stem cells to the corresponding cell types, determining the pathways appropriate for the prevalent mechanical milieu.

Results obtained by this model for a two dimensional, axisymmetric callus domain will be presented and discussed.

Alexander Sapotnick, Appelstr. 9a, Hannover, 30167, Germany

“UNCONVENTIONAL” CHALLENGES OF HYDRAULIC FRACTURING MODELING

A. A. Savitski
alexei.a.savitski@shell.com

Recently a combined application of two technologies, horizontal drilling and multi-stage massive hydraulic fracturing, has made vast resources of shale gas commercially viable. The hydraulic fracturing is a well-established reservoir stimulation technique, which has been developed over the last half a century.
There are reliable numerical tools for designing hydraulic fracturing in conventional reservoirs, in which a planar hydraulic fracture is assumed.

The results of field monitoring and gas production strongly indicate that the hydraulic fracturing process in shale formations maybe rather different from that in conventional reservoirs. Natural fractures, cluster, stage and well interference add significant and challenging requirements for the hydraulic fracturing modeling and design tools. We review the field observations and discuss various numerical requirements for a new tool that would be able to address the complexity of the fracturing process in ultra-tight shale formations.

Alexei A. Savitski, 3333 Highway 6 S, Houston, 77082, USA

SIMILARITY SOLUTIONS TO ONE MODEL OF A ROUND TURBULENT JET

A. V. SCHMIDT

schmidt@icm.krasn.ru

Semi-empirical model of a round turbulent jet including transport differential equations of the normal Reynolds stresses is considered. Similarity reduction of the model to a system of ordinary differential equations (ODEs) is obtained. System of ODEs satisfying natural boundary conditions is solved numerically. We use modified shooting method and asymptotic expansion of the solution in the vicinity of the singular point to solve the problem. The obtained solutions are in close agreement with experimental data and computational results of the full model.

Alexey Schmidt, Akademgorodok, Krasnoyarsk, 660036, Russia

A NEW APPROACH FOR THE INCORPORATION OF EIGENSTRESSES IN ARTERIAL WALL SIMULATIONS

J. SCHRÖDER  S. BRINKHUES

j.schroeder@uni-due.de
sarah.brinkhues@uni-due.de

As experimentally shown eigenstresses are present in arterial walls: when an axial section is cutted in longitudinal direction, the artery springs open, see e.g. [3]. The inherent stresses have a significant influence on the overall tissue behavior since they reduce high stress gradients through the thickness of the wall. The “opened” configuration is often assumed to be stress-free. However, this is only an approximation. In various works dealing with the numerical simulation of arterial walls, as for example [1], it is accounted for residual stresses by closing an opened, unstressed artery by an initial bending to form a load-free, but internally stressed configuration. In this contribution we propose a novel approach for the incorporation of residual stresses in patient-specific human arteries, see [2]. In contrast to the approach described above, we focus directly on the gradients of the fiber stresses in radial direction. As an underlying optimization criterion we assume that these gradients have to be smoothed between the inner and outer margins of the individual layers. In order to do so we define sufficiently small radial sections of the media and adventitia, in which this condition has to be enforced independently. The functionality of the proposed model will be demonstrated by means of several numerical examples.

REFERENCES


J Schröder, Universit?tstra?e 15, Essen, 45141, Germany

NUMERICAL SIMULATION OF DEFORMATION AND FRACTURE IN A MATERIAL WITH COMPOSITE COATING

E. SCHWAB  R. BALOYKONOV  V. ROMANOVA  V. KOVALEV

schwab@mail.ru rusy@ispms.tsc.ru varvara@ispms.tsc.ru polosatic@sibmail.com

Presented is the numerical analysis of deformation and fracture in materials with a composite coating providing oxidation protection. A dynamic boundary-value problem in a plane strain formulation is solved numerically by the finite-difference method. The coating-substrate interface geometry corresponds to the configuration found experimentally and is accounted for explicitly in the calculations. To simulate the mechanical response of a substrate and a coating use was made of the relaxation constitutive equation based on microscopic dislocation mechanisms and a fracture model taking into account crack initiation and growth in the regions of bulk tension. Macroscopic behavior of the Al-TiC composite is shown to be controlled by interrelated processes of localized plastic flow and cracking occurring near the interfaces of two types: “composite coating-aluminum substrate” and “aluminum-TiC”.

Acknowledgements. The work is supported by Russian foundation for basic research (grant No 12-01-00436-a).

Eugen Schwab, pr. Akademicheskii 2/4, Tomsk, 634021, Russia
INFLUENCE OF NANOSCALE MORPHOLOGICAL CHARACTERISTICS ON THE MECHANICAL PROPERTIES OF BONE TISSUE

A. S. SEMENOV  A. S. AVRUNIX
A. I. GRISHCHENKO  B. E. MELNIKOV
A. A. DOKTOROV

semenov.artem@yandex.ru gai.gr@yandex.ru

Bone is a hierarchically structured material with mechanical properties depending on its morphological parameters at all levels of hierarchy. At a nanolevel, bone can be considered as a composite with a quasiperiodic structure, consisting of hydroxyapatite crystals, which are embedded into the collagen fibrils. The purpose of the paper is to analyze the influence of the nanostucture of bone on its elastic and strength properties. Such studies are important for the creating artificial bone-substitute materials.

The new morphological nanoscale model of bone is proposed with taking into account the mineral bridges between the associations of the hydroxyapatite crystals. By means of the direct finite element simulation and homogenization the analysis of variation influence in the morphological characteristics (hydroxyapatite crystals disorientation, sizes and orientation of mineral bridges, mineralization) on the local stress-strain state and mechanical properties of the representative volume element of bone. The comparison of obtained results with experimental data is performed and discussed.

Alexey I. Grishchenko, Polytechnicheskaya, 29., Saint-Petersburg, 195251, Russia

APPLICATION OF LINEAR AND NONLINEAR FRACTURE MECHANICS CRITERIA FOR CRACK PROPAGATION ANALYSIS IN SINGLE CRYSTAL BODIES

S. G. SEMENOV  A. S. SEMENOV  L. B. GETSOV
B. E. MELNIKOV

semenov.serg@ksm.spbstu.ru
semenov.artem@yandex.ru
quetsov@yahoo.com kafedra@ksm.spbstu.ru

The actual problem of the crack growth prediction in anisotropic elastic and inelastic materials has not been fully investigated neither theoretically nor experimentally. In particular the analysis of crack growth in single-crystal gas turbine blades is of great interest to assess their strength and durability. The present research is devoted to the comparison of various linear and nonlinear fracture mechanics criteria of the crack propagation in anisotropic materials under different loading conditions (fatigue, thermal fatigue and creep) with published experimental data.

The computational features of the stress intensity factors (SIF) \( K_I, K_{II}, K_{III} \), resolved shear SIF \( K_{RSS} \), J-integral and \( C^* \)-integral for anisotropic materials in the framework of the finite-element analysis is considered. Verification of implemented procedures for fracture mechanics parameters is carried out on compact tension specimens (CT) of different crystallographic orientations. The results of the crack growth simulation in the single crystal blade of gas-turbine engine using finite element program PANTOCRATOR are presented and discussed.

Sergei G. Semenov, Polytechnicheskaya, 29, St.Petersburg, 195251, Russia

TORSIONAL OSCILLATIONS OF A CURVED DRILLSTRING AT SLOPING DIRECTIONAL DRILLING

A. D. SERGEYEV
dievich@rambler.ru

Torsional oscillations of a curved drill string are studied. A new chain-like system of \( N \) rigid rods is presented to simulate dynamical phenomena in a \( S \)-curved as well as in a \( C \)-curved drill string. To simulate the local drill sting dynamics by using of the new model there is no necessity to integrate partial equations on the stage of the approximate analysis of the drill string dynamics. It is obtained a one degree of freedom approximation of a hammer rotating. The hammer is placed at the end of a drill string and it is under an arbitrary load.

Alexander D. Sergeyev, Bolshoy pr. 61, Vasil’evsky ostrov, St-Petersburg, 199178, Russia

SINGULAR SOLUTIONS AT SINGULAR POINTS OF COMPOSITE WEDGES FOR DIFFERENT TYPES OF BOUNDARY AND CONTACT CONDITIONS

N. V. SEVODINA  A. Yu. FEDOROV

natsev@icmm.ru fedorov@icmm.ru

In the problems of the linear theory of elasticity the existence of singular solutions is associated with the occurrence of infinite stresses at points or lines, which are called singular. Singular points are the points on a surface, at which a disturbance of surface smoothness, a change in the type of boundary conditions or a contact of dissimilar materials take place, or the points inside the body, at which, for instance, the non-smoothness of the contact surface of dissimilar materials can be observed. The presence or absence of singular solutions in the vicinity of singular points and, consequently, the character of stress singularities are defined by the geometry, boundary and contact conditions near a singular point and the mechanical characteristics of the material. Hence, the problem of finding appropriate engineering (optimal, if possible) solutions for reducing stresses in the examined zone or in the whole structure has arisen.

In the vicinity of a singular point, the geometries optimal for reducing stresses are said to have one common property [1, 2]. Based on the results obtained during investigation of eigenvalues for a wedge, this property can be formulated as follows. The mechanical characteristics of the material and the parameters of the optimal geometry in the vicinity of a singular point are those determined on the boundary between the solutions with singularity and free of singularity. The wedge was formed by two tangent lines toward the body surface at a singular point. On the plane of two parameters (opening angles of the parts of the wedge), the desired boundary is a curve separating the domains of solutions with singularity and free of singularity. This curve can be plotted.
based on the analysis of eigenvalues obtained for plane composite wedges.

In the present work, the character of behavior of stresses in the vicinity of singular points of plane composite wedges in the plane strain state are analyzed for different conditions of the contact surface of the wedge parts (perfect contact, perfect slip) and various combinations of boundary conditions on the lateral sides (fixed wedge, edge free of stresses, perfect slip, dry friction). Eigensolutions are found by the characteristic equation and depend on the geometry and physical-mechanical characteristics of composite wedge materials. For each variant, a set of curves separating the domains of solutions with singularity and free of singularity are presented. The points corresponding to the optimal geometry lie on these curves. Geometries that are sufficiently close to optimal are those in which no singular solutions exist. The work was supported by the grants of the Russian Foundation for Basic Research (projects 11-01-96017-a, 12-01-33042, 12-01-31007).

REFERENCES


Natalja V. Sevodina, Akademiya Koroleva, 1, Perm, 614013, Russia

ELASTIC PROPERTIES OF OOLITIC LIMESTONE: MICROMECHANICAL MODELING AND EXPERIMENTAL VERIFICATION

I. SEVOSTIANOV  A. GIRAUD

igor@nmsu.edu
albert.giraud@univ-lorraine.fr

A new micromechanical approach to analytical modeling of oolitic limestone is proposed. Limestone is modeled as a multiphase composite consisting of sparry calcite matrix, spherical oolitic inhomogeneities, oblate spheroidal pores of aspect ratio 0.2, and concave pores in the shape of superspheres. The pores concavity factor is the key parameter affecting overall properties. Maxwell’s homogenization scheme is used to calculate effective bulk and shear moduli of this multiphase composite as functions of total porosities. The results are in good agreement with experimental data available in literature.

Igor Sevostianov, MSC 4350, Las Cruces, NM, 88011, USA

REVIEWS OF INTEGRABLE CASES IN DYNAMICS OF SMALL- AND MULTIDIMENSIONAL RIGID BODY IN A NONCONSERVATIVE FIELD

M. V. SHAMOLIN
shamolin@imec.msu.ru

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 four-dimensional (4D-) rigid body which residing in a certain nonconservative field of the forces. Its type is unoriginal from dynamics of the real smaller-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 plane-parallel 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.

Maxim V. Shamolin, Michurinskii Ave., 1, Moscow, 119192, Russia

TRANSITION FROM MD TO CONTINUUM BASED ON STATISTICAL MECHANICS

W. SHAN  U. ACKENHORST
shan@ibnm.uni-hannover.de

Many macroscopic physical properties, such as energy, entropy, temperature, stress, etc., can be derived from atomistic models by statistical mechanics, which essentially establishes the theoretical connection between the measurable macroscopic quantities and quantities at atomic scale. In this work we use the connections between the motion of atoms and temperature as a natural constraint for constructing thermal-mechanical coupling between the molecular dynamics model and continuum mechanics model. The kinetic energy of the atoms is decomposed into a ‘coherent’ part and a ‘random’ part. The coherent part represents
averaged motion of the group of atoms which also appears as kinetic energy at larger scales, while the random part reveals itself as thermal energy at macroscopic level. Therefore, the coherent part from the MD model is coupled with the mechanical motion of the continuum model while the random part and the temperature field from the continuum model act as boundary conditions for each other.

Wenzhe Shan, Appelstraße 9A, Hannover, 30165, Germany

MODELING OF ROCKS HARDENING AND SOFTENING
A. A. Shapovalova  R. M. Sultanalieva
alinash90@gmail.com raia-ktu@mail.ru

As deeper precious metals mining operations are developed, new ways of thinking about rocks deformation behavior near open pits and drill holes are required. In particular the much higher loads encountered at depth necessitate consideration of inelastic strain and straining conditions.

The proposed correlations model rock behavior during axial compression as a functional connection between maximum shear stress and shear strain taking into account initial imperfections. Relationships are established between imperfection and damage-ability parameters in a kinetic equation form that follows the deformation process up until the stage of rock crushing.

A state equation has been developed using catastrophe theory methods where transition processes are presented as dissipative structures of increasing denseness. Comparison of theoretical and experiment data was performed for a number of rocks to demonstrate applicability of the methodology.

Alina A. Shapovalova, Kievskaya str., 44, Bishkek, 720000, Kyrgyzstan

THE EVOLUTION OF A SATELLITE MOTION IN THE GRAVITATIONAL FIELD OF A VISCOELASTIC PLANET WITH A CORE
A. V. Shatina  E. V. Sherstnev
shatina_av@mail.ru sherevv@gmail.com

We investigate the motion of a satellite in the gravitational field of a massive deformable planet. Planet is modeled as body, that consists of a solid core and a viscoelastic shell of a Kelvin-Voigt material. The satellite is modeled as a point mass. The system of integro-differential equations for a motion of a mechanical system is got out from the variational principle of the d’Alembert-Lagrange according to the linear theory of elasticity. Approximate equations of motion in vector are constructed with asymptotic method of motions separation. This system of equations describes the dynamics of the “planet-satellite” with regard to the perturbations caused by elasticity and dissipation. The solution of the quasi-static problem of the elasticity for a deformable shell of the planet obtained explicitly. To describe the evolution of the orbital parameters of a satellite, averaged differential equations was derived. Phase trajectories were constructed for particular cases, their stationary solutions were found and investigated on stability. In the case of the existence of two stationary orbits stationary solution that corresponding to the motion along the orbit of larger radius is asymptotically stable, and the orbit of smaller radius is unstable. Some of the planets in the solar system and their satellites are considered as examples. This problem is a model for the study of the tidal theory of planetary motion. In the research we used the methods of analytical mechanics for systems with an infinite number of degrees of freedom.

Evgeny V. Sherstnev, Vernadskogo prospect, 78, Moscow, 119454, Russia

OPTIMAL RIGIDITY OF THIN INCLUSIONS IN ELASTIC BODIES
V. Shcherbakov
sherbakov87@gmail.com

The paper concerns an optimal control problem for a 2D elastic body with a thin rigid inclusion and a crack. Inequality type boundary conditions are imposed at the crack faces to provide a mutual nonpenetration between the crack faces. The cost functional characterizes a derivative of the energy functional with respect to the crack length. Rigidity of the inclusion is considered as a control function. The main result consists in a proof of the solution existence to the optimal control problem.

Victor V. Shcherbakov, pr. Lavrentyeva, 15, Novosibirsk, 630090, Russia

MODELING OF CELLULAR ARTICULAR CARTILAGE REPLACEMENT TISSUES IN MODERN BIOMECHANICS
M. Shehadeh  B. Zhou  M. Stoffel  D. Weichert
shehadeh@iam.rwth-aachen.de

Predicting the mechanical properties of soft replacement tissues seeded with human chondrocytes is a main requirement in modern medical applications. The implants that are designed to fill in articular cartilage defects should exhibit the same strength and damping properties as the native material itself. For this reason, the acellular basis material of an implant, as well as cellular tissues, are investigated theoretically, numerically, and experimentally in this study. Knowing all of that, the main aim of this work is to reach a common methodology of theory and experiments that determines the mechanical properties of the native material and hence choose a suitable replacement one. This work is financed by the Federal Ministry of Education and Research in Germany (BMBF).

Experimental validations are performed by material tests with acellular material as well as with cellular tissues in bioreactors. The experimental validations include compression and tension tests performed with different displacement velocities and strain rates. The test results define the material parameters that need to be satisfied. In order to achieve that, two mechanical models are proposed; one accounts for viscoelasticity and deformation dependent diffusion of acellular collagen material, and the other for
the permeability and elasticity. Both models are implemented using the finite element program ABAQUS, the first model using a user-subroutine, and the second one using the default poro-elastic material properties in the software. In theory and numerical analysis, both models have predefined parameters and identified parameters. For the elastic-diffusion model only Poisson’s ratio is predefined, while Young’s Modulus and two diffusion parameters are identified. Meanwhile, the poroelastic model has Poisson’s ratio and the initial void ratio as predefined parameters, and Young’s modulus, initial permeability, and the material constant M as identified parameters.

Via ABAQUS, these parameters of each model are calculated in order to obtain numerical results which are as close as possible to the resulting experimental results.

As a result, the values of the different identified parameters are calculated and improved by optimization until the difference between the experimental and numerical results (cost function) approach zero.

In summary, the parameter studies verified that both models have really good results when observing their relative cost functions. Further research is still on going; for the sake of comparison, a sensibility study is performed on the parameters of the elastic-diffusion model and the poro-elastic model, to see which are more sensitive to slight or extreme variations; and with this we are able to compare the sensibility analysis of both models. This opens a new horizon where we will be able to interpret these comparisons and deduce the physical meanings behind the parameters and acquire methods to improve them more.

Mohammad Shehadeh, Templergraben 64, Aachen, 52062, Germany

ENERGY EXCHANGE AND LOCALIZATION IN CARBON NANOTUBES

D. Shepelev  V. V. Smirnov  L. I. Manevitch
deshepelev@ya.ru smirnovvv@gmail.com manevitchleonid3@gmail.com

Energy exchange and localization in carbon nanotubes (CNT) are among of the most perspective filler particles for polymer nanocomposites. The CNT possess the high specific surface and electric conductivity as well as the unique stiffness and strength characteristics. Therefore, a comprehensive research of their mechanical and physical properties is a problem of a primary importance. The CNTs’ behavior is strongly dependent on its dynamical properties, first of all on spectral characteristics. Nevertheless, the nonstationary processes, such as the energy exchange and localization in the CNT are not studied yet.

We present a new nonlinear dynamical model for analytical study of the low-energy processes in CNT under different boundary conditions. Both the analytical and numerical descriptions of energy exchange in the CNT have been performed. We formulate also the condition of transition from intensive energy exchange to spatial energy localization.

Leonid I. Manevitch, Kosygina str., 4, Moscow, 119991, Russia

BUCKLING OF NONLINEARLY ELASTIC RODS OF INHOMOGENEOUS MICROPOLAR MATERIALS

D. N. Sheydakov  A. G. Fedorenko
sheidakov@mail.ru afedorenko@mail.ru

The problem of equilibrium stability for deformable bodies is of major importance both from theoretical and practical point of view, because the exhaustion of load-carrying capability and collapse of buildings and engineering structures quite often occurs due to buckling under external loads. In the case of elastic medium, the stability theory is extensively developed for classic non-polar materials. However, due to the increasing number of new structural materials, the problem of stability analysis for bodies with a microstructure becomes relevant. One example of such materials is a porous material. Engineering structures made of porous materials, especially metal and polymer foams, have different applications in the last decades. The foams are cellular structures consisting of a solid metal (for example aluminium, steel, copper, etc.), or polymer (polyurethane, polisocyanurate, polystyrene, etc.) and containing a large volume fraction of gas-filled pores. There are two types of foams. One is the closed-cell foam, while the second one is the open-cell foam. The defining characteristic of metal and polymer foams are the very high porosity: typically, well over 80 %, 90 % and even 98 % of the volume consists of void spaces.

Constructions made of porous materials are widely used in modern industries with airspace or automotive applications among others. The reason for this is the advantages of such materials: better density-stiffness ratios in comparison with classical structural materials, the possibility to absorb energy, etc. As a rule, these constructions have a functionally graded structure. For example, the porous core is quite often covered by hard and stiff shell, which can be necessary for corrosion or thermal protection, and optimization of mechanical properties in the process of loading.

The present research is dedicated to the buckling analysis of nonlinearly elastic highly porous rods. In the framework of a general stability theory for three-dimensional bodies, we have studied the stability of a circular micropolar rod subject to axial compression and external pressure. It is assumed that the elastic properties of the rod vary along the radius. Using the linearization method in a vicinity of a basic state, the neutral equilibrium equations are derived, which describe the perturbed state of a rod. For a few commonly used porous materials these linearized equations have been solved numerically. The critical curves and corresponding buckling modes have been found, and the stability regions have been constructed in the plane of loading parameters, namely relative axial compression and external pressure. Using these results, we have studied the influence of elastic properties as well as the rod geometry on the loss of stability. Special attention has been given to the analysis of how the pattern of variation for elastic properties affects the stability of a circular rod made of micropolar material.

This work was supported by the Russian Foundation for Basic Research (grant 11-08-01152-a) and by the President of Russian Federation (grant MK-2652.2013.1).

Denis N. Sheydakov, Chekhov Ave. 41, Rostov-on-Don, 344006, Russia
A MULTISCALE STRUCTURAL MODEL FOR INVESTIGATION PECULIARITIES OF MECHANICAL RESPONSE OF NI3AL INTERMETALLIC ALLOYS ON THE BASIS OF DISCRETE ELEMENTS METHOD

E. V. Shilko S. G. Psakhie V. E. Ovcharenko S. V. Astafurov A. V. Dimaki
shilko@ispms.tsc.ru sp@ms.tsc.ru
ove45@mail.ru svastafurov@gmail.com
dav@ispms.tsc.ru

On the basis of movable cellular automaton method [1] was developed a two-dimensional structural model of hard-strength intermetallic alloy Ni3Al. In this model, the intermetallic alloy is regarded as multiscale composite system. Developed approach take into account the properties of grain boundaries, the characteristics of the geometry and internal structure of the grains and their size distribution. Internal grain structure of hard-strength alloy is constructed in the framework of MCA method using the algorithm of Voronoi diagram [2]. To simulate the processes of deformation and fracture of such complex systems by MCA method the two-dimensional model of elastic-plastic interaction of cellular automata is used. This model is based on the use of many-particle potentials/forces of interaction of cellular automata. An incremental theory of plasticity of isotropic medium with von Mises plasticity criterion was used to model deformation of intermetallic alloy. Radial return algorithm of Wilkins was adopted for this purpose. Two-parameter criterion of Drucker-Prager was used as fracture criterion in proposed model. When modeling the mechanical response of hard-strength alloy peculiarities of its multiscale internal structure (the presence of subgrains in grains) at lower scales with respect to the considered one was taken into account implicitly using a specially developed multiscale approach. The approach consists in carrying out of special series of calculations on modeling of the response of individual structural elements of the material (grains with a complex internal structure) to determine the basic mechanical parameters. The resulting data are then used to simulate the deformation and fracture of materials at the next (higher) scale level. Note that the amount of such series is determined by the required level of detail of the research and the number of scale levels to be considered in solving a particular problem. Verification of the developed model is performed by simulation of tests on uniaxial compression of Ni3Al samples and comparing the simulation results with the experimental data. Comparison of the obtained “theoretical” loading diagrams with experimental data showed good qualitative and quantitative similarity. This indicates the adequacy of the developed model and the possibility of its use to describe the deformation and fracture of such complex heterogeneous systems.

The investigation has been carried out within the Project No. 2.12.2 of the Program No.12 of the Department of Energy, Mechanical engineering, Mechanics and Processes Control of RAS.

REFERENCES


Sergey V. Astafurov, Akademicheskii ave., 2/4, Tomsk, 634021, Russia

NEW BIFURCATION GROUPS IN THE FORCED DAMPED DUFFING EQUATION WITH RARE ATTRAJECTORS AND WEAK UNKNOWN CHAOS

E. Shilvan M. Zakrzhevsky
ed_shilvan@inbox.lv mzakr@latnet.lv

Keywords: complete bifurcation group, periodic skeleton, bifurcation diagram, asymmetry, rare attractors, chaos.

It is known that the method of complete bifurcation groups helps to find new previously unknown bifurcation groups with complex protuberances, rare and chaotic attractors in all archetypal nonlinear dynamical systems [1]. This paper considers classical forced damped Duffing equation [2-3] with changing parameters of its driving forces, linear damping, and also symmetry. Results of our investigation show that in this system there are many unknown bifurcation groups with important attractors.

Our new results are presented in one-parameter and two-parameter bifurcation diagrams for different bifurcation groups. The use of periodic skeleton allowed us to find a full zoo (more than fifty) of unknown subharmonic bifurcation groups with simple and complex topology, rare and chaotic attractors. The main results obtained for parameter space with amplitude of excitation (in the range from 0 to 35) - damping coefficient (in the range from 0 to 0.7). Also in article it is shown the coexistence of several bifurcation groups with UPI in the same range of parameters.

Some rare attractors appear only on the branches of a sufficiently high order of subharmonic regimes, for example, on the unstable branch with period-8. Many bifurcation groups have a narrow stripe with rare chaotic attractors in two parameters space. The high sensitivity to the appearance of asymmetry in the system also is under consideration.

REFERENCES


Eduard P. Shilvan, 1 Klaku Street, Riga, LV 1658, Latvia 101
SELF-SYNCHRONIZATION OF PAIR VIBRATION EXCITERS IN THE CONE CRUSHER

E. Shishkin
wiwiki@rambler.ru

The cone crusher includes a softly amortized crusher’s body with unbalance vibration exciters and internal mobile crushing cone, which is elastic related to the body. The axes of vibration exciters being installed on the crushing head symmetrically by angle $\beta$ to horizontal plane in opposite directions, that provides oncoming linear-screw oscillations of working members with a frequency, equal to vibroexciters rotational frequency.

The crusher’s symmetrical three-dimensional dynamic design is considered. The energy losses, caused by impact of a crusher’s body with the crushing cone through the layer of crushed material, are taken into account approximately by means of introduction of a special viscous damper. The differential equations of the considered system with ten degrees of freedom are set up and analyzed within the framework of the general theory of self-synchronization.

The equations of oscillations of crushing cone and crusher’s body are derived, as well as the equation of power balance for synchronously co-phasal operational regime. It is established that antiphase synchronous movements of the crushing cone and the crusher’s body exist, only if synchronous frequency exceeds partial frequency of crusher’s body. Stability of synchronously co-phasal regime is analyzed, showing that stability may be achieved in the above-resonance frequency range.

This work was supported by Russian Foundation for Basic Research (grant No 12-08-01009a).

Evgeniy V. Shishkin, 21 line, 2, Saint-Petersburg, 199106, Russia

APPLICATION OF HYBRID ALGORITHMS TO COMPUTATIONAL MODEL UPDATING FOR HYDROMECHANICAL SYSTEMS

P. M. Shkapov V. D. Sulimov
spm@bmstu.ru

Intensive practical studies related to the safety and early diagnostics of signif-icant objects in the nuclear power industry are based on reliable mathematical modeling in hydromechanical system dynamics. Consideration is being given to problems of building accurate mathematical models for identification anomalies in the phase consti-tution of the coolant flowing throw the reactor primary circuit. Main dynamical charac-teristics 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 detected owing to changes in dynamical characteristics of the two-phase flow. Computational model updating techniques are used for adjusting selected parameters of hydromechanical system models in order to make the models com-patible with measured experimental data. This is done by minimizing the differences of analytical and measured data with the use of numerical optimization methods. Incom-pleteness of measured spectral data and presence of multiple frequencies result in the error function of the extremal problem being non-convex and nondifferentiable, Two novel hybrid algorithms for solving the correspond-ing global minimization problem are proposed. The first algorithm PCAMNM combines the stochastic Particle Collision Algorithm (scanning of the search space) and deterministic Modi-fied Nelder-Mead simplex algorithm (local minimization). The second algorithm M-PCAMNM implements the global search procedure using the Multi-Particle Collision Algorithm. Results of suc-cessful computational experiments are presented to show the efficiency of the approach.

Valeriy D. Sulimov, 5, Baumanskaya 2nd street, Moscow, 105005, Russia

VALIDITY OF THE CLASSICAL LINEAR ELASTICITY THEORY IN THE CRACK-TIP REGION

G. Singh R. W. Zimmerman

g.singh10@imperial.ac.uk r.w.zimmerman@imperial.ac.uk

It is known that classical linear elasticity theory predicts that the stresses in the region near a crack tip are very high, and be-come infinite at the tip. The credibility of the use of small-strain elasticity theory in this high-stress crack tip region has been ques-tioned for many years. We have used molecular dynamics to compute the initial and deformed (“relaxed” after loading) atomic positions of a fractured silica with a semi-infinite crack along a fixed (111) plane, using the Stillinger-Webber interatomic potential. Using these displacements, we calculate both the finite strain and the infinitesimal strain tensors, and use Hookes law to compute the stress components. We then compare these to the stresses given by Knauss analytical solution. We find, surprisingly, that the stresses given by the classical elasticity solution agree very well with the stresses inferred from the molecular dynamics sim-ulations, up to as close as two atoms from the crack tip.

Keywords: Infinitesimal Strain, Finite Strain, Molecular Dy-namics, Crack tip

Gaurav Singh, 2.45K, Royal School of Mines, Imperial College London, London, SW7 2AZ, United Kingdom

DYNAMICS OF CONDUCTIVE SOLID BODIES IN HIGH-FREQUENCY ALTERNATING MAGNETIC FIELD

D. Skubov D. Vavilov

skubov.dsk@yandex.ru londr@yandex.ru

It’s well known that alternating magnetic forces can destabilize early stable equilibrium position and backward. In other words, under the action of alternative magnetic field, it’s possible to change stability of equilibrium position or (and) there may occur new equilibrium position. Besides equilibrium positions in this systems any others mechanical motions can arize, in partic-u-lar self-oscillations. Some physical experiments, which demon-strated this effects, had been done by Beteno-Duboshinsky.

In our study for mathematical description of these effects we used mathematical models. In these models of electromechani-
FUNDAMENTALS FOR A LASER BIOMECHANICS OF LIVE SYSTEMS

A. K. SKVORCHEVSKIY

Skvorch.imash@yandex.ru

The present explain in the paper that informational character and special features of their biomechanical research of live systems is due to the fact that live organisms (including human beings) thanks to their anatomic and physiological structure, polymorphism, the compositions of their hard, elastic and flexible structures, liquid and vapor phases, - live structures present a very complex heterogeneous oscillating system with distributed parameters. The present in the paper developed scientific fundamentals, methods, techniques and technical means on the basis of fiber-optic measurement systems (FOMS) for research into problems of live systems biomechanics, namely-biological fundamentals for tactile information and for an artificial muscle, biological electrodynamics, a physical model of light sensitivity of live Systems.

Anatoliy K. Skvorchevskiy, Kharitonjevskiy Lane, Building 4, Moscow, 101990, Russia

HYDROGEN ENGINES NUMERICAL MODELING

N. N. SMIRNOV V. F. NIKITIN YU. G. PHYLIPPOV

ebifsun1@mech.math.msu.su

Hydrogen being an ecological fuel is very attractive now for engines designers. It is already actively used in rocket engines. There exist plans to use hydrogen in pulse detonation engines. However, peculiarities of hydrogen combustion kinetics, the presence of zones of inverse dependence of reaction rate on pressure, etc. prevent from wide use of hydrogen engines. Computer aided design of new effective and clean hydrogen engines needs mathematical tools for supercomputer modeling of hydrogen oxygen components mixing and combustion gas dynamics.

The paper presents the results of developing verification and validation of mathematical model and numerical tool making it possible to simulate unsteady processes of ignition and combustion in engines of different types.

Rocket engines using hydrogen-oxygen mixture have the following peculiarity. On injecting liquid components fuel (hydrogen) having much lower critical temperature comes pre-evaporated and pre-heated in combustion chamber, while oxygen could be liquid then evaporating inside the chamber. Thus contrary to most types of engines hydrogen engine has an inverse mixture entering combustion chamber, in which fuel is gaseous and oxidant is liquid. Onset of detonation being very dangerous for classical RAM engines could, however, serve the basis for creating new generation of engines - pulse detonating engines (PDE). For this issue the problems of detonation onset, decay and deflagration to detonation transition should be simulated quite accurately, because these processes strongly depend on inlet conditions, mixture composition and geometrical characteristics of combustion chamber.

The authors gratefully acknowledge financial support from the Russian Foundation for Basic Research (RFBR Grant 13-03-00003)

Nickolay N. Smirnov, Leninskie Gory 1, Moscow, 119991, Russia

HIGH VELOCITY GLIDING OF A PLATE WITH FINAL LENGTH CA VITY FORMATION

M. N. SMIRNOVA A. V. ZVYAGUIN

wonrims@inbox.ru

The two-dimensional problem of thin body motion in fluid parallel to the boundary at a distance comparable with the length of the body was regarded. The fluid was assumed occupying infinite semi-space, gravity was neglected as compared with fluid inertia. The solution was obtained for a problem of plate motion in compressible fluid at a definite depth under free surface, constant velocity and inclination angle. The formation of final length cavity behind the body was taken into account. Vapor pressure in the cavity is assumed to be less than the pressure on free surface. The solution allows determining drag and lift forces. The relation between the body length and the cavity length in the case of small depth or high compressibility was obtained. It was determined that the forces increase when the pressure in the cavity decreases. When the pressure in the cavity tends to the pressure on the free surface the length of the cavity infinitely increases and forces tend to the values obtained in independent solutions with infinite cavities. The increase of depth under free surface and decrease of compressibility brings to decrease of cavity length.

Maria Smirnova, Leninskie Gory 1, Moscow, 119992, Russia

MODELLING OF BOND SATURATION IN HYDROCARBONS

A. A. SOKOLOV A. M. KRIVTSOV

sokolovalexey1@gmail.com

A model based on classical mechanics and physics for the simulation of saturation in bonds in hydrocarbons using discrete element method [1] is proposed. It is proposed to consider each atom as a set of material points, one of which represents the center of mass of the nucleus, and the others centers of the mass of the electron clouds. Number of material points, representing electronic clouds is equal to maximum oxidation number of the element.
A modification of the model proposed by R.V. Vlasov, E.A. Ivanova, A.M. Krivtsov [2] is used. The interaction forces and their parameters are chosen in the following way. Every cloud interacts with the nucleus of the atom to which it belongs. The force meet the following requirements. For atoms with the maximum degree of oxidation greater than 1, the material point representing electron cloud of the atom is in the center. For atoms with a maximum degree of oxidation greater than 1, it is necessary that the material points representing electronic clouds to be at the same distance from the center of the nucleus of the atom, and to be located evenly in the space around the center of the atom, repelling each other. The interaction between clouds that belongs to different atoms meets following rules. Clouds attract each other. When the distance between two clouds is small, interaction between them and other clouds becomes negligible i.e. bond between these two clouds is saturated.

The expressions for energy and stiffness of the bond are derived. It is shown that the model makes it possible to describe formation of simple hydrocarbons from atomic hydrogen and carbon. Two simple computer simulations of molecules of hydrocarbons are given. The structure of the obtained compounds corresponds to concepts of classical theoretical chemistry [3]. References:

REFERENCES


Aleksei A. Sokolov, Polytechnicheskaya, 29, St. Petersburg, 195251, Russia

MODELING OF HUMAN BEHAVIOR IN THE NATURAL AND MAN-MADE ENVIRONMENT

A. A. Sokolov V. V. Vanushkina A. L. Khaytin A. M. Krivtsov
sokolovalexey@gmail.com vasiokne@list.ru

Modern methods of finding people have a number of drawbacks. Finding a person runs a tight group of people who are combing the forest, feeding sounds. Such events have short range and require a large number of participants, and the probability of detecting a person falls if he is unconscious. Realm of the possible detection is based on the topographic and geodetic data. This process is not automated, done by hand and little accurate. Consequently, the modelling of human behaviour can be used for improving search technology.

The created algorithm includes:
1) A method to convert the map data into the map probability of finding person at a given point in view of the topographic features, cross-country, etc.
2) A model of human behavior, taking into account factors that could influence the decision go to this or that point (the availability of open spaces, roads, landmarks)
3) The calculation of the route on which a man could walk from the starting point to the end point possible detection.

Model of human behavior is based on the following factors:
- The attractiveness of the countryside
- Open spaces such as swamps, lakes and rivers are the most attractive, despite their obstruction
- Roads, towers, fields can strongly influence the choice of direction
- Patency
- Rivers, swamps, lakes are impassable obstacles
- Difficult terrain, impenetrable forest complicate movement
- Time spent in unfamiliar territory
- Endurance
- Age

Map is converted to a bitmap. And the person being in one of the points, browse nearby points and chooses the next step on the basis it’s parameters.

Valentina V. Vanushkina, Polytechnicheskaya, 29, St. Petersburg, 195251, Russia

INVESTIGATION OF THE AGGREGATE STATE CHANGES OF CLAY SOILS

V. V. Sokurov I. K. Sokolovskiy
sokurovvv@vniig.ru sokol.ik.091057@yandex.ru

For the variety of clay soils there exists a linear functional relation between the moisture, at which the soil state converts from liquid to plastic, and the moisture, at which it converts from plastic to solid (pseudo elastic). In this work the origin of this functional relation is investigated.

It is hypothesized, that the aggregate state of soil changes, if the thickness of water film of soil particles reaches the limit value. Thus, the linear relation between two limit moistures is caused by the fact, that each of them is a linear function of the soil particles surface area per unit volume.

At the result of experiments the information on granulometric composition and physical and mechanical properties of 180 clay soil specimens originating from St. Petersburg is obtained. The calculation method to estimate the soil particles surface area per unit volume is proposed. This method considers irregular forms of soil particles and limited capacities of experimental research. For each clay soil specimen the area of soil particles surface per unit volume is calculated with the accuracy up to a constant multiplier.

By means of averaging the tolerable precision of experimental data is achieved. Using these data, the relationship between the moisture, at which the soil state converts from liquid to plastic, and the area of soil particles surface per unit volume is obtained. The form of obtained dependence is close to linear. The results of this research confirm the validity of the hypothesis.

Igor Sokolovskiy, 21, Gzhatskaya str, St. Petersburg, 195220, Russia
THE EFFECT OF VISCOSITY ON WAVES AND STABILITY OF THE RANKINE VORTEX WITH AXIAL FLOW

I. N. Soldatov  N. V. Klyueva  M. E. Tkach
erfv@newmail.ru

The model of the Rankine vortex is simple: undisturbed column consist of a core of uniform vorticity (solid-body rotation), surrounded by irrotationally revolving liquid, but nonetheless in many cases this is a good approximation for real columnar vortices and vortex filaments.

Kelvin showed in his pioneering paper (1880) that the Rankine vortex is neutrally stable for small disturbances (both for axisymmetrical and spiral modes). The disturbances that do not depend on the axial coordinate have been reviewed by H. Lamb (1932). The instability develops if the axial flow in the core is imposed upon the Rankine vortex. Some aspects of the problem of temporal and spatial instability have been studied by Moore, Saffman, Uberoi et al., Lessen et al., Drazin and Reid, Loiseleux et al.

The effect of fluid viscosity on the stability of hydrodynamic flows is not trivial. On the one hand, at low undisturbed flow velocities the viscosity has often a stabilizing effect but, on the other hand, it can also be destabilizing (i.e. a cause of instability). In this report we shall restrict consideration to the effect of the viscosity of only inner fluid on the stability. Inviscid liquid occupy the external region. The surface of separation between these two liquids would be a surface of tangential discontinuity. Eigenvalues are calculated numerically for different values of the Kibel number and the Ekman number. It is shown that instability may arise in larger region.

Igor N. Soldatov, 85, Belinskogo Str., Nizhny Novgorod, 603024, Russia

WHY IT IS NECESSARY TO CONSTRUCT THE MECHANICS OF STRUCTURED PARTICLES AND HOW TO DO IT

V. Somsikov
vmsoms@rambler.ru

The questions why necessary to build the mechanics of the structured particles which are the systems of potentially interacting of the material points, basing on the laws of Newtonian mechanics, are discussed. We will show how to do it without the restrictive hypotheses and assumptions used in the classical mechanics for construction of the Hamiltonian formalism of the systems. We will show also how concept of entropy appears in the mechanics. Some of important problems in physics, the solution of which can help the mechanics of structured particles will be listed.

Vyacheslav Somsikov, Institute of Ionosphere Kamenskoe Plato, Almaty-20, 050020, Kazakhstan

REFERENCES

Vladislav S. Sorokin, V.O., Bolshoj pr., St. Petersburg, 199178, Russia

MOTION OF A PENDULUM WITH VIBRATING SUSPENSION AXIS AT UNCONVENTIONAL VALUES OF PARAMETERS

V. S. Sorokin
slavos87@mail.ru

In the classical papers [1,2] motion of a pendulum with vibrating suspension axis was considered in the case, when frequency of external loading is much higher than the natural frequency of the pendulum in the absence of this loading. The present paper is concerned with the analysis of pendulum’s motion at unconventional values of parameters. Case, when frequency of external loading and the natural frequency of the pendulum in the absence of this loading are of the same order, is studied. Vibration intensity is assumed to be relatively low. A new modification of the method of direct separation of motions (MDSM) [3,4] is proposed to study corresponding equations, which in the considered case don’t contain a small parameter explicitly. A condition of pendulums upper position stabilization is determined for this case by its means. It is noted that in the considered range of parameters not only the effective “stiffness” of the system changes due to the external loading, but also its effective “mass”. It is shown that application of the classical asymptotic methods in this case leads to erroneous results. So, the applicability range of the MDSM turns out to be broader than the one of these methods.

EVALUATION OF FATIGUE STRENGTH OF NOTCHED SPECIMENS BY THE POINT METHOD WITH HIGH STRESS RATIOS IN THE LOW CYCLE REGIME

M. Srinivasan  G. Chiandussi  M. Rossetto
srimukund23@gmail.com

The Low cycle fatigue behavior of the notched specimens are evaluated through the point method with high stress ratios. Notch root and tip strain analysis were investigated using the flat dogbone and cylindrical fatigue specimens with different stress ratios R using literature experimental data. This work would concern with the elasto-plastic reformulation to evaluate the fatigue life of notched specimens failing through low cycle medium using
MULTIBEAM IGNITION TRANSDUCER-DISTRIBUTOR FOR INTERNAL COMBUSTION ENGINE

E. SVIJAZHENINOV
sviage@gmail.com

The invention can be used in the internal combustion engine ignition system as well as in commutation, telemetry or armament systems, for example, for control of military payload activation. The proposed internal combustion engine ignition transducer-distributor contains a stationary stator equipped with a lid having an inner round surface, supplied with \( n \) contacts with spark igniter terminals circumferentially and uniformly arranged thereon, and a rotary rotor positioned inside the stator along its symmetry axis; attached to the rotor, coaxial and in parallel, are a current-dispensing plate and a shielding cylindrical shell with slots uniformly distributed in the circumferential direction separating the pair of sensors radially mounted on the stator at a small clearance; the transducer-distributor specificity is as follows: the rotor current-dispensing plate is designed in the form of a regular \( \alpha + 1 \) or \( \alpha - 1 \)- armed star while the cylinder shield has, accordingly, \((\alpha + 1)n\) or \((\alpha - 1)n\) slots for direct or reverse sparking where \( n \) is the number of the internal combustion engine cylinders. The effect consists in ensuring multiply longer action of the spark igniter discharge, multiply slower rotational speed of the rotor and, therefore, sufficient reduction of vibration and wear of the transducer-distributor elements, heat generation and instability of operational properties. As a result functionality and reliability of such a demanding device as a transducer-distributor of ignition increases significantly.
behavior. For FEM analysis, a constitutive model to describe the nonlinear viscoelastic behavior is necessary. The separability of time and strain effects on stress should be verified to establish the constitutive model. The separability has been studied on rubber vulcanizates by many researchers. However, the conclusion is still unsettled. In the present study, the separability for carbon black filled and unfilled styrene butadiene rubber (SBR) is examined on the basis of the nonlinear stress relaxation under uniaxial stretching, pure shear, and equibiaxial stretching. We demonstrated that the separability is valid on the relaxation component, \( \Delta \sigma(t) = \Delta \sigma(x, y, t_{\text{int}}) - \Delta \sigma_{\infty}(x, y) \), both of filled and unfilled SBR \( \Delta \sigma(t) = \Delta \sigma_{\text{total}}(x, y) \); \( \Delta \sigma_{\text{total}}(x, y) = \sigma(x, y, t_{\text{int}}) - \sigma_{\infty}(x, y) \), \( t_{\text{int}} \) represents shortest time scale for analysis. Here \( \psi(t) \) is defined as \( \Delta \sigma(t)/\Delta \sigma_{\text{total}}(x, y) \) and time dependent term. We revealed that \( \psi(t) \) can be approximated by sum of exponential function with 5 terms and \( \psi(t) \) for carbon black filled SBR is common to that for unfilled SBR. We also found that \( \Delta \sigma_{\text{total}}(x, y) \) can be described by \( c \sigma_{\infty}(x, y) \) regardless of type and degree of deformation [1]. Here \( c \) is a constant intrinsic for filled and unfilled SBR, and \( c \) for filled SBR is larger than that for unfilled SBR, reflecting the higher degree of relaxation strength on filled SBR.

On the basis of these results, we propose a constitutive model \( W(x, y) = (c \psi(t) + 1) W_{\infty}(x, y) \), where \( W_{\infty}(x, y) \) represents equilibrium state. \( W_{\infty}(x, y) \) can be obtained by fitting a experimental stress-strain curve at a loading speed sufficiently longer than that corresponding to relaxation time. We will exhibit the comparison between stress-strain relation calculated by the constitutive model and that obtained experimentally at different loading speed.

Toshio Tada, 2-1-1, Tsutsui-cho, Chuo-ku, Kobe, 6510071, Japan

ELECTROSTATIC INTERACTION OF CHARGED CONDUCTING BODIES ON SMALL DISTANCES

E. L. TARUNIN
tarunin@psu.ru

A force of interaction of two charged conducting bodies was calculated by means of finite-difference method. It was used postulates of electrostatic: electric charges are placing only on surface, and a density of charges depends on normal component of tenseness of electric field. The bodies had a form of shot cylinders (pucks). The problem has axis symmetry and potential of the electric field was found from solving of the corresponded Dirichlet problem. The problem was solved by means of the iteration method method SO - successive over relaxation. Approximation of the Laplace equation for potential was fulfilled as usual with 5-points pattern. For having of a good accuracy calculations number of grid we had to use number of space grid several millions.

The main value of solution was relation of forces

\[ k_1 = \frac{F_0}{F} \]  

(1)

Here \( F \) is the calculated force and \( F_0 \) is the force, calculated with using of Coulomb’s formulae and with assumption that charges concentrated in the center of the pucks. So the coefficient \( k_1 \) shows relative deviation of the force from the Coulomb’s law.

The coefficient \( k_1 \) depends on many parameters. It was investigated mainly the case of interaction of bodies with charges of the same sign. The thickness of bodies was additional parameter of the problem. It was shown (like in [1-2] for balls and in [3] for pucks) that the force of interaction for the case of small distances strongly differs from the corresponded Coulomb force. It was found the formula that describes the coefficient \( k_1 \) as function on distance between bodies and thickness of pucks.

REFERENCES


Evgeniy L. Tarunin, Perm state national investigation university, Bukireva, Perm, 614090, Russia

ON THE SATELLITE’S ELECTRODYNAMIC ATTITUDE STABILIZATION

A. A. TIKHONOV A. Yu. ALEKSANDROV
aatikhonov@rambler.ru
alex43102006@yandex.ru

The paper deals with a satellite in a circular near-Earth orbit. The problem under consideration is the satellites attitude stabilization. As the satellite interacts with geophysical fields by the moments of gravitational, magnetic and Lorentz forces it is appropriate to use parametric attitude control systems for the satellites attitude stabilization. So the satellites electromagnetic parameters, namely the intrinsic magnetic moment and electrostatic charge moment of the first order are considered as the controlled quasiperiodic functions. The control algorithms for the spacecraft electromagnetic parameters, which allow to stabilize the spacecraft attitude position in the orbital frame are obtained [1]. With the use of numerical analysis of characteristic numbers it was proved that there exists a domain of parameters of the satellite and its orbit which ensures the total stability of the direct equilibrium position. The direct Lyapunov method and the developed approach for the Lyapunov functions construction are used, the sufficient conditions of the asymptotic stability of the satellite direct equilibrium position in the orbital coordinate system are obtained [2]. The disturbing effect of the gravitational moment is taken into account.

At the same time the accurate preliminary analysis of the forces acting upon a satellite and the construction of thoroughly analyzed mathematical model of the problem is the urgent task for achievement the required stabilization accuracy. Therefore the software complex was designed for comprehensive analysis of problems concerning the satellite attitude dynamics in geophysical fields. Through the use of computer algebra methods the
problem of constructing the simplest possible, but correct mathematical model that ensures the prescribed accuracy is solved. As a result the octupole approximation of the Earth's magnetic field was accepted and the stability of the satellites stabilized orientation was proved analytically and confirmed by computer modeling. The report describes the complex as a complete software product, designed primarily to assess the effectiveness of the method of electrodynamic stabilization of satellites, combined with the possibility of using some of its modules to address a wide variety of local problems. The asymptotic stability of the satellite's direct equilibrium position in the orbital coordinate system is proved analytically on the basis of analysis of nonlinear differential equations of the satellite's attitude motion.

REFERENCES


Alexey A. Tikhonov, Stary Peterhof, Universitetsky pr., 28., St. Petersburg, 198504, Russia

POSTCRITICAL DEFORMATION STAGE OF MATERIALS IN PLANE STRESS STATE

M. P. TRETIAKOV V. E. VILDEMAN
cem.tretyakov@mail.ru wildemann@pstu.ru

Dissipative processes of inelastic deformation, including the processes of structural failure and fracturing, reflected on the deformation curve as nonlinearity. At the final stage this leads to softening materials and appearance loss of strength section on deformation curve. Issues of experimental and theoretical study of the postcritical strain laws are attract the attention of researchers in connection with the possibility of materials deformation reserves, increasing the carrying capacity and survivability of constructions [1-3]. In emergency situations, the most important property of materials is survivability. Accounting for the postcritical deformation stage in the more exact calculations is reveals reserve load-carrying capacity of structures. Completeness of the load-carrying capacity implementation of critical constructions and buildings is determined by the degree of postcritical deformation. On the postcritical stage of deformation is the formation of macro-destruction conditions. They, unlike the traditional view that defines the use of force or deformation criteria are not definitely related to the stress-strain state at the point of a deformed body. During the transition from the stage of equilibrium damage accumulation to non-equilibrium stage of destruction the key role plays the interaction between a deformed body and the loading system. The rigid loading system may contribute to the “adaptation” of the object in the process of destruction due to local dissipation of elastic energy [1, 3].

The work is devoted to study of behaviour of materials at a postcritical deformation stage. Problems of implementation of the strain softening stage of materials during testing where considered. Issues of limit states depending on the stiffness of loading systems under uniaxial tension experimentally were studied. In uniaxial and biaxial (tension and torsion) tests shown the possibility of obtaining diagrams with advanced stage of strain softening and complete strain curves of materials with sufficient high stiffness of loading system. Tests carried out on biaxial servohydraulic test system Instron 8850. Strain were registered by dynamic extensometer Instron 2620-601 and biaxial extensometer Epsilon 3550-010M. Uniaxial tension tests carried out on solid cylindrical specimens with diameter of test part is 5 mm, length of test part is 8 mm. Torsion and proportional tension with torsion tests carried out on thin-walled tube specimens with length of test part is 14 mm, outside diameter is 10 mm, wall thickness is 1 mm.

REFERENCES


Mikhail P. Tretyakov, 29, Komsomolskiy Pr., Perm, 614990, Russia

EXPERIMENTAL RESEARCH OF SPACE-TIME INHOMOGENEITY IN INELASTIC DEFORMATION PROCESSES IN SOLIDS BY USING THE DIGITAL IMAGE CORRELATION METHOD

T. V. TRETIAKOVA V. E. VILDEMAN
cem.tretyakova@gmail.com

A great number of scientific literature deals with experimental study issues of plastic strain in solid bodies, specifically, authors repeatedly point out that plastic strain develops nonuniformly both in space (strain localization) and in time (time evolution of localization). There are several macroscopic effects of inelastic strain localization, such as the effects of Savart-Masson and Portvin-Le Chatelier (the intermittent yielding of plastic materials), Chernov-Lüders Lines, initiation and evolution of necking effect on postcritical deformation stage, and also waves of localized plastic strain.

The aim of this research was experimental investigation of the space-time inhomogeneity in inelastic deformation processes in solids by complex use of contemporary testing equipment and non-contact strain measuring facilities. The aluminum-magnesium alloy AMg2 was chosen as the research subject. Mechanical tests on uniaxial tension of flat dog-bone samples (thickness of 1.9 mm, test portion length of 50 mm, width of 12 and
I consider the two-dimensional crowd dynamics model. People in the crowd represented as particles. A force field to simulate the motion of a particle to the intended target and the interaction of the particles with each other was developed. The positive part of the Lennard-Jones potential was used to describe the mechanical interactions - the particles repel each other, but do not attract. To assess the situation two values are measured: time of the particles movement depending on their initial position was investigated. Also was determined the dependence of passage time of different fencing geometries. Optimal geometry was revealed, allowing to minimize the passage time and the pressure level occurred in the crowd.

Denis V. Tsvetkov, Polytechnicheskaya, 29., St.Petersburg, 195251, Russia

ON THE INVERSE COEFFICIENT PROBLEM FOR THE TRANSVERSALLY INHOMOGENEOUS ELASTIC LAYER

P. Uglisch
puglich@inbox.ru

A problem of forced antiplane vibrations of the transversally inhomogeneous elastic layer is considered. The numerical method for problem solving is presented. This method may be used to calculate the wave field in an elastic layer with any mechanical parameters distribution law.

The inverse coefficient problem of the mechanical parameters definition using surface field data is also considered. The inverse problem is reduced to iterative sequence of integral equations, the program for its numerical solution is developed.

Pavel S. Uglich, Markus str., 22, Vladikavkaz, 362027, Russia

ON PROBLEM OF INTERFACE CRACK PARALLEL TO FREE BOUNDARY; EQUIVALENT ELASTIC CLAMPING CONDITIONS

K. B. Ustinov
ustinoff127@mail.ru

A semi-infinite crack separating a layer from a half-plane is considered. The layer and the half-plane are supposed to have different elastic properties remaining linear and isotropic. The problem is restricted to 2-D. The general formulation of the homogeneous problem for which two components of the total force and one component of the total (bending) moment are applied at infinity is written down. Following [1, 2] by using Laplace transform the problem, generalized for the case of different elastic moduli of the layer and half-plane, has been reduced to matrix Riemann problem. The matrix factorization procedure was found to be possible to a particular, but not too narrow, class of combination of elastic constants (not only for the same materials). As the result asymptotic behavior of stresses and displacement fields both near the crack tip (SIFs) and far apart from the crack tip was found for this case. It is shown that the leading terms of the displacements far apart from the crack tip correspond to displacement of a beam (plate) loaded by the total force and moment far from the point of its conjugation with the elastic half-plane and subjected to the boundary conditions of the elastic clamping type, which means that the displacements in both directions and the angle of rotation at the clamping point are related to the acting bending moment and the total force acting at point of clamping.

Simplified variants of the problem are also considered, in the frame of which the normal and shier displacements were considered separately. It has been shown, that this simplification yields
The application of atomic force microscopy (AFM) makes it possible to study a broad range of nanoscale properties of materials, including topology, friction, adhesion, etc. The AFM uses a cantilever to scan a sample surface. Scanning is done by approaching and retracting the probe at different points of the material surface. The curves plotted then are analyzed by appropriate mathematical models. So to make reliable measurements, it is necessary to properly account for all the forces applied to the AFM probe.

It is well known that when the AFM measurements are made in ambient air, the sample and the tip are coated with an adsorbed layer. This results in a more complicated interaction between the probe and the sample, because the surface tension forces play a key role at such a small scale. When the AFM probe comes into contact with the liquid film, a liquid meniscus is formed on the surface of the sample, and capillary forces begin to impact the contact with the liquid film, a liquid meniscus is formed on the surface of the sample, and capillary forces begin to impact the interaction.

So this study is focused on capillary phenomena that arise from the indentation of the AFM cantilever probe into the liquid film on the sample surface and the effect of van der Waals intermolecular force.

This work has been executed according to financial support of the RFBR Grant 11-08-96001_ural_a and the Program RAS 12-T-1-1004.

Nadezhda I. Uzhegova, Academic Korolev Str., Perm, 614013, Russia

PHYSICS AND MECHANICS OF BULK NANOSTRUCTURED METALS

R. Z. Valiev

rzvaliev@mail.rb.ru

In recent years the development of bulk nanostructured metallic materials has become one of the most topical directions in modern materials science. Nanostructuring of metals and alloys paves the way to obtaining unusual properties that are very attractive for innovation applications. In this research topic, the use of severe plastic deformation (SPD) techniques [1] attracts special attention since it offers new opportunities for developing new technologies of fabrication of various large semi-products from nanostructured materials in the form of sheets, rods, thin foils, wire, for various specific applications. Especially significant progress has been made recently, when the achievement of new unusual properties, such as very high strength and ductility, record endurance, superplasticity, have been demonstrated on a number of metals and alloys [2,3]. The important scientific principle underlying the enhancement of properties in nanostructured materials is tailoring of grain boundary structure in such materials, i.e. the so-called grain boundary engineering of nanomaterials. The latter makes it possible to fundamentally change their properties through the formation of various types of grain boundaries (low- and high-angle, special and random, equilibrium and non-equilibrium, as well as with grain boundary segregations and precipitations) by varying the regimes of severe plastic deformation (temperature, strain rate and degree). Large innovation potential of the subject also comes into view, and the present report considers a number of such innovation developments. In particular, special attention is focused on the development of nanostructured metals and alloys for advanced structural and functional applications.

REFERENCES


Ruslan Z. Valiev, Institute of Physics of Advanced Materials and Nanocenter, Ufa State Aviation Technical University, 12 K. Marx, Ufa, 450000 Russia

HIGH-PERFORMANCE COMPUTATIONS IN NUMERICAL MODELING OF WAVE PROPAGATION IN BLOCK MEDIA WITH THIN INTERLAYERS

M. Varygina

vmp@icm.krasn.ru

Several nature materials such as rock have distinct structurally inhomogeneous block-hierarchical structure. Block structure appears on different scale levels from the size of crystal grains to...
the blocks of rock. Blocks are connected to each other with thin interlayers of rock with significantly weaker mechanical properties.

Parallel computational algorithms for the numerical modeling of dynamic interactions of elastic blocks through thin elastic and viscoelastic interlayers in structurally inhomogeneous medium such as rock are developed. Monotonous grid-characteristic ENO-scheme with the balanced number of time steps in blocks and interlayers is used for the numerical solution. The algorithms are implemented in 1d and 2d cases with the CUDA technology (Compute Unified Device Architecture) for supercomputers with graphics processing units.

The computations of planar wave propagation induced by short and long \( \Lambda \)-impulses on a boundary of the domain composed from blocks of rock with microfractured viscoelastic interlayers were performed. These computations of the large number of layers allowed to analyze specific "pendulum" waves related to the structural inhomogeneity. The results of numerical analysis demonstrate peculiar quality of planar wave propagation in materials with layered microstructure.

This work was supported by the Complex Fundamental Research Program of the Presidium of RAS no. 18.2 and the Russian Foundation for Basic Research (grant no. 11-01-00053).

Maria P. Varygina, Akademgorodok 50/44, Krasnoyarsk, 660036, Russia

DESCRIPTION OF LIQUID-GAS PHASE TRANSITION
IN THE FRAME OF CONTINUUM MECHANICS

E. VLICHESVKAYA  E. IVANOVA

vilchevska@gmail.com
elenaivanova239@post.ru

A new method of describing the liquid-gas phase transition is presented. It is assumed that the phase transition is characterized by a significant change of the particle density distribution as a result of energy supply at the boiling point that leads to structural changes but not to heating. Structural changes are described by an additional state characteristics of the system - the distribution density of the particles which is presented by an independent balance equation. The mathematical treatment is based on a special form of the internal energy and a source term in the particle balance equation. The presented method allows to model continua which have different specific heat capacities in liquid and in gas state.

Elena Vilchevskaia, V.O., Bolshoj pr., 61, St. Petersburg, 199178, Russia

STATISTICAL DISTRIBUTIONS IN EMPIRICAL STUDY
OF METEORITE FRAGMENTS

V. VINNIKOV  M. GRITSEVICH

vvinnikov@list.ru gritsevich@list.ru

This work is concerned with the study of optimal statistical description for mass distribution of meteorite samples. Such description can hint on initial projectile properties and physical parameters responsible for underlying fragmentation processes. If recovered meteorite collection pretend to be complete, number of corresponding fragments is statistically sufficient, and they have been weighted with good precision, one can propose a reliable model well applicable to more general cases when the input parameters are incomplete. We have found that the experimental plots have clearly distinguishable shape, which can be fitted by several distributions, including normal, logistical and other continuous sigmoid cumulative functions like Weibull.

In order to confirm or reject goodness of fit for the selected theoretical distributions we use Pearson’s and Fisher’s chi-squared tests as well as G-test. We found that bimodal distributions are often more suitable than their unimodal counterparts. Another approach to statistical investigation deals with the cumulative number of fragments instead of their mass fraction. We assume both approaches useful and consider a number of known statistical functions, including the log-normal distribution [1], the Weibull distribution, the linear exponential statistics, known as Graddy distribution [2,3], and the Gilvarry distribution [4,5]. As stated in [6] Gilvarry theory overestimates the number of small lightweight fragments. Both Grady and Gilvarry distributions are correct under assumption of nearly-instant singular breakup [6,7]. If material is exposed to multiple successive fragmentation events, then the above-mentioned distribution laws are no longer applicable. However there is a recent development of the fragmentation theory [8], which can be used.

The considered distributions can provide some additional information about the projectile. Thus, in certain cases, assuming bimodal lognormal, bimodal Grady or bimodal sequential fragments distributions we find a number of fragmentational points taken place. Such conclusion hints on a primary singular pre-fragmentation of the body and the consequent atmospheric entry of independent fragments with respective residual masses.

REFERENCES


DRAG, ABLATION AND FRAGMENTATION OF A METEOR BODY IN THE ATMOSPHERE

V. VINNIKOVO M. GRITSEVICH D. KUZNETSOVA V. LUKASHENKO
vvinnikov@list.ru

Meteorite studies represent a low-cost opportunity for probing the cosmic matter that reaches the Earth’s surface and thus for revealing the nature and origin of our Solar system. Therefore correct interpretation of fireball observation is a highly important task, since it could promptly confirm fresh meteorite fall, and furthermore, provide a link to its parent body. Based on the analysis of the fireball aerodynamic equations we describe the possible results that might accompany collisions of cosmic bodies with the Earth’s atmosphere and surface. After integrating, these equations well characterize the body’s trajectory in the atmosphere, while the exact derived dependency of body’s velocity on the height of the fireball can be further compared to the observations. The solution depends on three key dimensionless parameters defining the meteoroid drag, mass loss and rotation rate in the atmosphere. These parameters are evaluated for a number of bright meteors observed by the Canadian, Prairie and European Fireball Networks.

MEASUREMENT OF ELECTRICAL RESISTANCE IN SELECTED POINTS OF THE HUMAN SKIN BY LOW CURRENTS

V. VITKOVO L. ILIEVA-MITUTSOVA A. PLATONOV O. TRIFONOVO V. YAROSHEVSKY
lidia@imbm.bas.bg TOB@keldysh.ru

Presented device “Skinometer” for the measurement of electrical resistance in selected points of the human skin using extremely small currents. A model of the Skinometer measuring circuits was created. A set of precision resistors was used for optimisation model parameters. The results of experiments on human skin was described.

NUMERICAL INVESTIGATION OF PROBLEMS OF HYPERBOLIC THERMOELASTICITY IN THE CASE OF SHOCK ACTION

E. VITOKHIN
EVitokhin@yandex.ru

Fourier’s law is used for large range of thermal conductivity problems. Parabolic thermal conductivity equation is based on this law. Nevertheless the application area of this equation is limited. To solve some problems there is a need to use hyperbolic equation of thermal conductivity. We consider the problem of finding numerical solution of the hyperbolic thermoelasticity. The proposed numerical algorithm is based on finite difference method that implemented in Delphi software and have graphical interface. We solve the test problem of volume harmonic oscillations in infinite strip in the case of hyperbolic and parabolic thermoelasticity. The influence of frequency of harmonic excitation on the character of acoustic wave propagation in the considered media is studied subject to the type of thermal conductivity equation. It is shown that at low frequencies the amplitudes of acoustic waves are similar for both types of thermal conductivity. However the difference becomes significant when frequency tends to infinity. We compare the obtained numerical solution with analytic. Thus the error of numerical algorithm is estimated. We solve a number of problems of propagation of acoustic and thermal waves that are result of a shock load modeling the laser action.

THE METHODS OF SYNTHESIS AND DIFFERENT CRYSTAL FORMS OF NANODIAMOND

S. VOROPAEV
svoropaev@rambler.ru

The major well-known methods for the synthesis of carbon nanoparticles (HPHT, CVD, detonation and cavitation) are considered. Different crystalline structures of arising nanodiamond will be investigated. New approaches to the controlled synthesis by using interaction of the carbon clusters are discussed.

RADIATION CREEP AND CREEP FRACTURE OF AGING METALLIC ALLOYS

K. S. YAKIMOVO R. A. ARUTYUNYAN
Robert.Arutyunyan@paloma.spbu.ru

Under the attack of irradiation on metallic alloys the following effects are observed: low temperature and high temperature creep and fracture, irradiation aging and embrittlement. According to the experiments the time to fracture of metallic alloys decreases many times depending on temperature, irradiation dose and aging. These effects are investigated well in the context of physical material science. At the same time, not enough attention is paid to describe the effects integrally by the mechanic of materials methods in the framework of mechanical parameters. In our presentation these methods are applied to describe the radiation creep, aging and fracture of metallic alloys. To formulate the creep fracture law the energy conservation law is applied. Some preliminary calculations are carried out according to the received relations. The theoretical curves of creep and creep fracture for different values of irradiation dose are constructed and they are compared with the corresponding experimental results. These investigations allow to predict the possible variants of creep strain.


accumulation and fracture of metallic alloys undergoing irradiation.

Financial support of the Russian Foundation for Basic Research (Grant N 11-08-00763) is gratefully acknowledged.

Robert A. Arutyunyan, Universitetskii pr., 28, Faculty of Mathematics and Mechanics Sankt-Petersburg State University, Sankt-Petersburg, Petrodvorets, 198504, Russia.

Kira S. Yakimova, Institute of Problems in Mechanical Engineering Russian Academy of Sciences, V.O., Bolshoy pr., 61, Sankt-Petersburg, 199178, Russia.

NONLINEAR EFFECTS IN THE VIBRATING CAVITY FILLED WITH A PERFECT GAS

A. V. YAKOVENKO

yak-anuta@yandex.ru

As the technological expansion, people are more and more contact with the phenomena of vibration. Almost all machines are sensitive to mechanical vibrations in a varying degree. It is quite common situations where there are cracks, pores or voids filled with air. Therefore, it is important to study the wave processes inside the region. In the investigation we consider a cavity which subjected to the vibrating effect. The cavity is filled with a perfect viscous gas with air thermophysical characteristics. At the initial moment the cavity was staying at rest and the temperature, pressure and density of the gas was constant in all area. The vibrational motion is realized like an expression Acos(Ωt) with constant amplitude A and constant angular velocity Ω. The vertical walls are adiabatic.

The system of governing equations is written relative to non-inertial frame of reference, which associated with the vibrating cavity. The system was solved with numerical method based on the control volume approach and on the second order treatment of the numerical scheme. The numerical method was verified by the Sod problem and other numerical tests. The mass conservation law and the energy conservation law have been verified. Also there was carried out the comparison with the experimental results where was considered a closed tube with a vibrating piston. The computation grid was uniform and the number of sells was taken depending of the vibrating frequency.

Due to the medium compressibility there is a forming of acoustic waves, which reinforce the heat and mass transfer. Two dominant vibration frequencies are observed: the frequency of the external vibration effect and the natural frequency of the system due to the motion of acoustic waves. With time, the process goes to the “repetitive” mode. The frequency range of vibration covers the non intensive processes, which can be described by the linear theory, and the strong frequencies, which lead to the great nonlinear effects. The amplitude of vibration is constant at these cases therefore the vibrating force increases with the frequency. Specifying high-frequency vibration leads to appearance of shock waves. Pressure and temperature strongly increase at the instant when the wave strikes the wall. This can give undesirable results, when the properties of a definite wall material are taken into account. At the repetitive mode the oscillation of temperature, density and pressure are carried out with a double frequency as opposed to the linear case when there was a node at the centre.

Anna V. Yakovenko, 74, Taymirskaya, Tyumen, 625026, Russia

APPROACHES TO PROBE THE FREE-SURFACE-INDUCED SIZE EFFECT OF MATERIAL BY INDENTATION

R. YANG Q. ZHANG F. KE Y. BAI

yangr@lnm.imech.ac.cn
zhangqun@lnm.imech.ac.cn
kefj@lnm.imech.ac.cn baiy1@lnm.imech.ac.cn

The distances between atoms of nanostructure near the surface are influenced by the existence of free surface. Depending on different potentials and crystalline directions, there can be looser or tighter outermost layers, thus even some basic property of material in continuum sense, such as elastic modulus, may result in two opposite tendencies of decreasing and increasing, and it is tricky to determine such free-surface-induced size effect by experiments.

In this work, the free surface effect is investigated by molecular dynamics simulations on copper (FCC) of finite layers in different crystalline directions, the distances between atom layers from the outermost to the center are obtained. Lennard-Jones potential leads to looser surface layers, withal EAM potential leads to tighter ones. Then the apparent elastic modulus of each layer was derived, the size effect and its range owing to the free surface are determined. It was found that free surface only affects a few (3 to 5) layers of atoms which were just a few nanometers. These effects were later matched up by finite element models of continuous gradient in modulus which then used in indentation FEM simulations, so that the size effect of modulus can be separated from other factors. Base on that, approach to probe the free-surface-induced size effect of material by indentation was proposed.

Rong Yang, Yilong Bai, No. 15 Beisihuanxi Road, Beijing, 100190, China
Fujiu Ke, XueYuan Road No.37, HaiDian District, Beijing, 100191, China

THE SCATTERING OF INCLUSIONS BY ELASTIC WAVE IN TWO-PHASE MEDIA

Z. YANG J. ZHANG Z. SUN

yangzailin00@163.com zhangj1.2005@163.com
610018111@qq.com

The SH-waves scattering by two cavities and a crack near bimaterials interface is reported applying the methods of Green’s function and complex variables in this paper. Based on the idea of “conjunction”, the bimaterials is divided along the horizontal interface into an elastic half space possessing a circular cavity and a crack and an elastic half space containing a circular cavity. Firstly, the scattering displacement field of half space containing an elliptical cavity is constructed, and the corresponding Green’s functions of two half spaces are then deduced. Combined with “crack-division”, a crack is created, and thus expressions of displacement and stress are derived while the cavity co-exists with
ABOUT SOME FEATURES OF DYNAMIC ACCELERATION OF VIBRATION MACHINES WITH SELF-SYNCHRONISATION INERTION VIBROEXCITERS

N. P. YAROSHEVICH A. V. SYLYVONYUK
myaroshevich@mail.ru
andriy.sylyvonyuk@gmail.com

It is shown that in the case of two self-synchronized imbalance vibroexciters the running of vibration machines declines (if only their options are not absolutely equal) compared to machines with one exciter. The separate start of electric engine rotor exciters may be effective for improvement of running process. It is shown that In this case, the value of braking vibration moments, influencing on rotor exciters in resonance zone decreases approximately twice compared to simultaneous start of engines.

In analytical form the expressions for vibration moments (average values of extra dynamic load on the electric engine rotor, caused by baring body fluctuations) when passing resonance zone for vibration machines with two self-synchronized imbalance vibration exciters additional to the well-known results for machines with one imbalance exciter.

Nikolay P. Yaroshevich, 75 Lvivka Str., Lutsk, 43018, Ukraine

ABOUT ONE APPROACH TO RECONSTRUCTION OF INHOMOGENEOUS PROPERTIES FOR LAYERED MEDIUM

O. V. YAVRUYAN A. O. VATULYAN I. V. BOGACHEV
yavruyan@mail.ru vatulyan@math.rsu.ru bogachev89@yandex.ru

Problems of mechanical characteristics identification for inhomogeneous layered medium have application in many areas of a science and technics - biomechanics, mining industry, seismic prospecting, mechanics of functional-gradient and new composite materials.

Creation of theoretical and practical bases of inhomogeneous properties reconstruction on the basis of acoustic sounding data, which measured on an accessible part of investigated areas boundary are actual problems of solid mechanics.

By present time schemes of materials inhomogeneous properties reconstruction are in detail enough developed for finite bodies, basically they are reduced to a minimization problem of residual functional, representing the norm of residual between theoretical and experimental data. For inhomogeneous materials, even in a case when properties depend of one coordinate, the reconstruction problem considerably becomes complicated and is connected with research of boundary value problems with variable coefficients and drawing up of the operational parities connecting reconstruction and measured functions.

It is necessary to notice, that the most part of works is devoted to research of properties identification for layered structures within the isotropic model of material, where one or two functions characterizing inhomogeneous properties of investigated areas in classes either smooth positive, or piecewise constant functions are defined.

In this study the effective reconstruction scheme of inhomogeneous properties for layered medium within the orthotropic material model, allowing serially to reconstruct six functions characterizing inhomogeneous elastic, viscoelastic properties is proposed. The basic investigation stages of considered inverse coefficient problem: the reduction of initial two-dimensional problems for layered medium within the considered models (elastic, viscoelastic) to more simple operational equations that leads to division of problems concerning reconstructed functions and corresponding decisions; the consecutive solving of the received one-dimensional problems with iterative regularization algorithms. On each step of the iterative scheme refinement to unknown functions concerning initial approaches are defined from the systems solving of Fredholm’s integral equations of the first and second kind with attraction of a method of collocations, quadrature schemes, regularization algorithms of numerical differentiation, a method regularization of Tikhonov A.N. The initial approaches of restored functions are defined in a class of linear functions from minimum conditions of residual functional.

The offered scheme is approved on model problems for the viscoelastic isotropic multilayered medium and elastic orthotropic layer. Efficiency of the offered technique is confirmed of computing experiments results, according to which reconstruction of properties for various laws of change (monotonous and nonmonotonic) is carried out with error an order of 2-10 %.


Oksana Yavruyan, Milchakova, Rostov-on-Don, 344000, Russia

REMODELING OF CELL-SEEDED SOFT TISSUES

J.-H. YI M. AZARNOOSH M. STOFFEL
D. WEICHERT B. RATH
yi@iam.rwth-aachen.de

The hyperelastic properties of a condensed collagen gel are of interest to medical research as it is a common replacement material for a damaged articular cartilage. To improve the gel’s mechanical and biomedical properties, live cells (of the patient or a donor) are often used. The aim of the present study is to investigate modifications of the hyperelastic properties of cell-seeded tissues in the human body. For an experimental study, cell-seeded gels are mechanically stimulated in an incubating bioreactor for several weeks, which simulate a real knee joint. Every week a specimen is tested in compression to measure its hyperelastic modulus change. It can be explained by histological evaluation that the newly synthesized collagen type II fibers strengthen the...
The phenomenon of blood flow through arteries is often modeled as an elastic tube conveying Newtonian fluid. A variety of spatially one-dimensional models have been proposed to investigate pulse wave propagation [1-2]. The onset of self-excited oscillations was predicted by these models if flow rate is high enough. Such instabilities are associated with Korotkoff sounds and wheezing in lung airways [3].

It is well known that blood exhibits non-Newtonian behavior due to ability of red cells to aggregate. Experiments show that blood has properties of pseudoplastic power-law fluid. Moreover, red cells form structures which resist low stresses thus making blood a viscoplastic fluid [4].

Two one-dimensional models are presented for power-law and Bingham flow (5) of the blood through an elastic tube. Linear stability of each model is examined. The viscoplastic flow through elastic tube is stable. Stability condition of power-law flow differs from those derived from Newtonian fluid flow (6).

REFERENCES


bodies in cross-sections is analyzed in the directions of meridian and dimensionless radial coordinates. The estimation of an initial strength is carried out on the basis of a multicriteria approach taking into account various fracture mechanisms and areas where the fracture may be initiated and defined.

The problem on equilibrium state of heavy reinforced concrete cylinder located on foundation soil is considered. Contact surface area was assumed to be known and unchanged. The reaction of soil is given in the form of a quadratic function which meets the condition that its integral sum equals weight of the constructions. The assumption allows us to write the boundary conditions for the determination of the integration constants of partial solution. On the basis of this the distribution of displacements and stresses in transversal cross-sections of horizontal monolithic reinforced concrete cylinders are shown, the lower half of which are dug into the soil.

The author acknowledge the support of the Russian Foundation for Basic Research (Grant RFBR 110100910).

About Method of Identification of Unmanned Underwater Vehicle for Control Its Movement

B. Zak S. Hojyc

bogdan-zak@wp.pl

Remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) have been applied in many activities such as different types of inspections (underwater cables, dams, ship hulls), habitat exploration, underwater mapping, rescue missions and many others. Accurate dynamic models are crucial to the realization of ROV precision autopilots and for prediction of performance. However, the modeling and control of underwater vehicles are difficult. The governing dynamics of underwater vehicles are fairly well understood, but they are difficult to determine for practical design and control purposes. The problem includes many nonlinearities and modeling uncertainties [3]. It seems convenient way to apply fuzzy logic controller on the control problem of an autonomous underwater vehicle [2]. This attempt demands incorporating the knowledge and experiences of experts into the controller design. In some applications, however, it is difficult to find an experienced expert or it is not so intuitive to incorporate expert’s knowledge into the control system, particularly when many constraints are imposed on the controller design [1]. The purpose of this paper is to develop simplified dynamic model of ROV for parametric synthesis of fuzzy logic controller. The elaborated model would be useable to determine the controller setting and carry out a simulation study for evaluating various strategy of control algorithms.

Experimental Investigation of a High-Speed Jet Velocity Field by Using Optical Methods

V. I. Zapryagaev V. M. Boiko A. A. Pivovarov

zapr@itam.nsc.ru bmv@itam.nsc.ru pivovarov@itam.nsc.ru

The necessity of experimental researches of jet flows is caused by the practical application of the jets in fuel ejector systems, supply systems, oil-and-gas extracting plants and other facilities where mixing process are important. The instantaneous and averaged velocity fields in free axisymmetric high-speed jets are received by using up-to-date contactless laser optical PIV method.

The paper presents the results of experimental investigation of stream structure in the high-speed jet flows obtained by means of laser-knife technique and schlieren-method. The application of stream visualization by the laser knife technique with a short exposure enables to detect the existence of a coherent vortex structure in the compressible mixing layers which associated with hydrodynamic Kelvin-Helmholtz instability in the supersonic underexpanded jet.

Experimental velocity distributions in the shear layer of the subsonic jet are in satisfactory agreement with the other reference results and with the well-known Prandtl-Schlichting theory.

In this work the structure of the jet exhausting from a nozzle with chevrons is also studied. It is known that vortex-generating
devices are used to reduce of an aerodynamic noise. Chevron are one of the type vortex-generating devices to transform the flow and to intensity the mixing. The performed experiments have revealed that in a supersonic underexpanded jet exhausting from a nozzle with six chevrons, the level of pulsations in the Mach disk region decreases comparing to the experiments performed with the nozzle without chevrons. The significant change in the flow structure and increase of the jet transverse size has been registered; it is associated with the intensifying mixing resulting from chevrons on the nozzle exit.

Andrey A. Pivovarov, Institutskaya str., 4/1, Novosibirsk, 630090, Russia

THE THERMAL ANALYSIS STUDY OF TWO SERIES OF PRESSED GRAPHITE
I. ZERROUK T. DORBANI A. ZAHAF S. HAMAMDA A. BOUBERTAKH
zi.74@yahoo.fr

Graphite is a material with properties covering a wide range of values. These properties may differ qualitatively; depending on the material source and also the process of its development. Graphite is characterized by a dense stacked layered structure but weakly linked. Graphite polycrystalline properties are often isotropic, because of the random orientation of grains. Recently, it has been developed processes of production that have resulted in macroscopic samples that exhibit anisotropic properties. Therefore, the scope of use of this material has become very large.

The samples studied are pure graphite whose preparation method includes a step of pressing. A first series of samples was pressed along the weak interactions direction, while the second was pressed along the strong interactions direction. This study was carried out mainly through dilatometric analysis and X-Ray diffraction. Our analysis allowed us to establish a difference in the thermal behavior of the two series of samples compared to an untreated (not pressed) reference sample. Upon heating, both series of samples undergo familiar multi-step oxygen loss, albeit at lower temperatures. The fine-grained microstructure inferred from X-ray diffraction data, which exhibit evidence of nano-scale crystallites, may be responsible for this acceleration of oxygen loss. Both series exhibit anisotropic behavior that is not detectable in the reference sample. The origin of the anisotropy is traced to an intensification of the membrane effect. The analysis of DSC curves of our samples allowed us to highlight an acceleration of the kinetics of the dissolution of oxygenated compounds.

Keywords: pressed graphite, thermal analysis, thermal expansion, anisotropy, dilatometry, DSC, XRD.

Zerrouk Imed eddine, Univeristy Oum el Bouaghi, Oum El Bouaghi, 04000, Algeria

THE PRESENT SITUATION OF THE RESEARCH ON SH-WAVE IN THE PAST 2 DECADES
J. ZHANG Z. YANG
zhang_1.2005@163.com yangzailin008163.com

Scattering of SH-wave by an elastic half space is an active field in earthquake engineering. The conceptual framework and researching program in the past 20 years was introduced briefly in this article. Besides, scattering theory was reviewed. This report related to the study of SH-waves scattering in different landform including hills, cavities, linings, cracks and some kind of compliant topography in the nearest 2 decades as well as a short summarize of the job of predecessors in this field.

Jianwei Zhang, No.145 Nantong Street, Harbin, 150001, China

NUMERICAL SIMULATION OF DEFORMATION OF MATERIALS WITH POROUS CERAMIC COATINGS
A. V. ZINOVIEV R. R. BALOKHONOV S. A. MARTINOV O. S. ZINOVIEVA V. A. ROMANOVA
Kelast90@gmail.com

Characteristic features of deformation of a material with porous ceramic coating under uniaxial tension were investigated. The boundary value problem in a plane strain formulation is solved numerically using the finite difference method. The composite microstructure was taken into consideration explicitly in calculations. A mesh generation method for porous coatings is developed, which allows us to simulate coatings with varied porosity, location and volume fraction. Two-dimensional test calculations were performed for a volume element of coating with single pore.

Alexander V. Zinoviev, 2/4 pr. Akademicheskii, Tomsk, 634021, Russia

EFFECTS OF MODIFIED SURFACE LAYER AND GRAIN SIZE ON SURFACE ROUGHENING IN STEEL SPECIMENS
O. S. ZINOVIEVA V. A. ROMANOVA E. E. BATUHTINA A. V. ZINOVIEV R. R. BALOKHONOV
emelyanova@ispms.tsc.ru

This abstract is concerned with the numerical analysis of modified surface layer and grain size influence on surface roughening in a high-strength steel under uniaxial tension. The formation and evolution of a deformation-induced relief in polycrystalline materials with different grain size with and without modified surface layers was studied in the context of physical mesomechanics. In order to provide realistic material model, the grain shape and size, elastic and plastic properties and strain hardening behavior were defined from experiments for a high-strength steel
EK-181. The structural heterogeneity was taken into account explicitly through the dependence of physical-mechanical properties (density, yield strength, etc.) on the coordinates. A threedimensional model of a polycrystalline structure was generated by a step-by-step packing method on a regular grid. In order to apply periodical boundary conditions we modified the basic algorithm of step-by-step packing method to generate the periodical microstructure. A model of the mechanical behavior of the polycrystalline high-strength steel considered various grain orientations by a scatter of elastic and plastic characteristics within 10%. Function of strain hardening was constructed by approximation of experimental data for steel EK-181 [1]. The material model developed was implemented in a three-dimensional finite-difference code for parallel computations.

It is evident that grain structure plays a primary role in the development of mesoscale surface roughness. The results obtained show that the evolution of surface roughness is caused by internal stresses acting from the material volume across the free surface. It is shown that the mesoscopic relief is formed at the free surface from the very beginning of loading. Influence of the strengthened layer on the evolution of the stress-strain state on the surface and in the volume of polycrystals was analysed. Comparison of the samples with and without modified surface layer has shown that in the former case small-scale folds associated with the displacements of individual grains relative to each other disappear whereas width of large-scale folds remains to be almost unchanged. The thicker the modified layer, the smoother the surface, i.e. we can observe less small-scale folds in the structure of those of large-scale. It was determined that the grain size plays a significant role. It was established that surface roughness grows linearly with increasing degree of plastic deformation. The work is supported by the RFBR (grant No 12-01-00436-).

REFERENCES


Olga S. Zinovieva, 2/4 pr. Akademicheskii, Tomsk, 634021, Russia

DYNAMICAL STRESS DISTRIBUTION IN THE MOTION OF A BALL ON A ROUGH PLANE

A. A. ZOBOVA M. V. ISHHANYAN

azobova@gmail.com margarita-ish@ya.ru

The problem of the motion of homogeneous rigid sphere on a rough plane is considered. We use the viscous-elastic Kelvin-Voigt model, proposed by D.V. Treschev and A.A. Zobova. The plane interacts with the ball by a contact spot. In each infinitesimal area of the contact spot three kinds of forces occur: elastic force is proportional to the normal deformation of the supporting plane, viscous force is proportional to the velocity of normal deformation of the supporting plane, and dry friction force that is described by Amontons-Coulomb law. Due to viscous properties of the plane the distribution of normal stresses and the shape of the contact spot depend on the velocity of the center of the sphere. We investigate the motion of a ball when the initial angular velocity is perpendicular to the initial velocity of sliding. The side-shift effect (a curvature of the mass center’s trajectory) that cannot be obtained in other models of friction is shown.

Alexandra A. Zobova, Leninskie gory, 1, Moscow, 119991, Russia

INTERFACE INFLUENCE ON RADIATION DAMAGE IN IRON

K. P. ZOLNIKOV D. S. KRYZHEVICH

A. V. KORCHUGANOV

kryzhev@ispms.tsc.ru

Molecular dynamics simulation of peculiarities of radiation defect formation in iron crystallite with grain boundary under radiation affect was carried out. It was shown that grain boundary resists to propagation of atomic cascade displacements in crystallites. Intensive energy dissipation takes place in the grain boundary region. It results in a large radiation damage formation in that region. Investigation of an influence of impulse value and remoteness of the primary knocked atom from grain boundary on peculiarities of nucleation, propagation and distribution of radiation defects in simulated crystallite during main studies of atomic cascade evolution was fulfilled.

The work was supported by RFBR #12-03-00488-a.

Dmitrij S. Kryzhevich, pr. Akademicheskii 2/4, Tomsk, 634021, Russia

ENERGY-BASED APPROACH TO COMPUTATION OF THERMO-ELASTIC PROPERTIES FOR CRYSTALS WITH HEXAGONAL SYMMETRY

I. ZUBKO V. KOCHUROV M. SIMONOV R. GORODILOV

zoubko@list.ru

On the base of atomistic statics approach the elastic moduli of finite sized crystals with hexagonal symmetry (hexagonal close packed (HCP) monocrystal and graphene monolayer) are computed. The Mie interatomic potential is chosen for potential energy calculation. The initial configuration of crystal is defined to satisfy the density of potential energy minimization condition. It is shown that using Mie potential with different power exponents allows getting different values of ratio for two HCP-lattice parameters. The implied deformation gradient transforms the initial crystal into the actual configuration. The full potential energy of the deformed specimen divided by its volume (square for graphene monolayer) is calculated. Quadratic items of its Taylor series in terms of deformational parameters are assumed to be equal to elastic potential in the general non-symmetric form. Energy minimization procedure guarantees that linear items of series are equal to zero. This trick allows finding the HCP-monocrystal and graphene monolayer elastic moduli. It is obtained that under independent computation of the C components
they are turned out to be in strict connection, which corresponds to the symmetric form of tensor $C$. It is shown that both HCP-lattice and graphene lattice, which are combined from two simple sub-lattices, could not be homogeneously deformed under the prescribed affine deformation. For supporting minimum of potential energy density for such crystals in deformed configuration it is necessary to impose a vector of relative shift between sub-lattices depending on deformational parameters. The elastic moduli of HCP-lattice are obtained to be symmetric and depending on specimen size as well as lattice parameters. These dependencies have got a horizontal asymptotes letting identification of interatomic potential parameters by known macroscopic properties. The procedure of macroscopic properties computation based on introducing periodic interatomic potential is realized. The elastic moduli of graphene lattice are obtained to be symmetric and not depending on the specimen size. Using Mie interatomic potential allows getting different values of Poisson coefficient (from 0.2 up to 0.5) under varying of Mie power exponents.

For the aim of crystal temperature control the computational-statistical approach to studying thermo-mechanical properties for finite sized crystals is presented. The approach is based on combination of the high-performance computational techniques and statistical analysis of the crystal response on external thermo-mechanical actions for specimens with statistically small amount of atoms (i.e. nanoparticles). The heat motion of atoms is modelled in the statics approach by including independent degrees of freedom for atoms connected with their oscillations. These oscillations are simulated by applying the random displacements with fixed amplitude $A$ under uniform distribution of directions for such perturbations in space. Equilibrium thermo-mechanical parameters have been computing by averaging of huge amount of different realizations of the perturbed crystal configurations. The dependences of HCP and graphene crystal lattices parameters on heat perturbations amplitude are calculated and their thermal expansion coefficients are obtained for wide interval of $A$. The dependencies of HCP and graphene lattices elastic moduli on temperature are also obtained.

The work is supported by Russian Foundation for Basic Research, grant N 12-08-01052-a, N 11-01-96033-r-Ural-a.

Ivan Y. Zubko, Komsomolsky pr., 29, Perm, 614690, Russia
Index

A.A. Sokolov, 104
Abdrashitov, A. V., 26
Abramian, A. K., 26
Aero, E. L., 26, 27
Aizikovich, S. M., 27
Aleksandrov, A. Yu., 107
Aleksandrova, A. A., 27
Aleksandrova, A., 94
Alimov, A. V., 27, 29, 86
Altenbach, H., 45
Amosov, A. S., 77
Andreeva, O. V., 65, 73
Anferov, G. M., 51
Aptukov, V. N., 28
Arsenieff, D. G., 28
Arutyunyan, A. R., 29
Arutyunyan, R. A., 29, 112
Aryslanova, E. M., 27, 29, 86
Aslanyan, N. S., 56
Astafurov, S. V., 30, 43, 44, 90, 101
Atmanskikh, M. B., 30
Azarnoosh, M., 114
Azarov, E., 30

Babenkov, M., 31
Babeshko, O. M., 31
Babeshko, V. A., 31
Bai, Y., 113
Balokhonov, R., 32, 33, 75, 96
Balokhonov, R. R., 117
Balzani, D., 32
Banichuk, N. V., 32
Baranova, P. N., 86
Barkat, B., 71
Batutkhtina, E. E., 117
Batukhtina, E., 33
Bazhin, A. A., 33
Bekker, A. A., 33
Belyaev, A. K., 34
Benhizia, K., 38
Bentebiche, A., 31
Berdyshnev, V. I., 89
Berinskii, I. E., 34
Bezrukov, L. N., 35
Birikh, R. V., 43
Blekhman, I. I., 35
Bobashev, S. V., 35, 79
Bobylev, S. V., 36
Bocharov, O., 36
Bogachev, I. V., 114
Bogdanova, O., 30
Boiko, V. M., 36, 116
Boltachev, G. Sh., 37
Bonifaz, E. A., 37
Borodin, E. N., 76
Bosiakov, S. M., 62
Bouafia, Y., 55

Boubertakh, A., 68, 117
Bouchenna, A., 38
Boudine, A., 38, 44
Bouhenguel, M., 38, 63
Bratov, V., 38
Brinkhues, S., 96
Bulygin, A. N., 26
Burenin, A. A., 38
Bushueva, C. A., 39

Castellanos, A., 39
Chapwanya, M., 40
Chebbah, M. S., 71
Chernyakov, G. A., 66
Chernyshev, A. S., 35
Chiantussi, G., 105
Chichvarin, A. V., 93
Chivilikhin, S. A., 27, 29, 65, 73, 77, 86, 87
Clennell, B., 33
Cox, S., 40

Dashevskyi, I. N., 41, 42
Dats, E. P., 42
Dedkov, D. V., 43
Denisova, M. O., 43
Diebels, S., 92
Dimaki, A. V., 30, 43, 44, 101
Dmitriev, A. L., 44, 67, 84
Doktorov, A. A., 97
Dorabani, T., 117
Dosta, A., 37
Dreiman, V., 95
Dridi, C., 44
Duan, H., 68
Dubatovskaya, M., 91
Dudko, O., 45
Dushin, V., 45

Erimeyev, V. A., 45
Erofeev, V. I., 46
Evdokimova, O. V., 31
Evlampieva, S. E., 46

Farmanyany, A., 46
Fedorenko, A. G., 100
Fedorov, A. Yu., 97
Fedorova, A. N., 47
Fedotov, A. A., 63
Fedotov, I., 47, 72
Ferguson, D., 47
Filimonov, M. Yu., 48
Filippov, R. A., 48
Fracz, W., 48
Freidin, A. B., 48, 49
Fukalov, A. A., 115

Ganghoffer, J. F., 75
Ganimedov, V. I., 93, 94
<table>
<thead>
<tr>
<th>Name</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tretiakov, M. P.,</td>
<td>108</td>
</tr>
<tr>
<td>Tretiakova, T. V.,</td>
<td>108</td>
</tr>
<tr>
<td>Trifonov, O.,</td>
<td>112</td>
</tr>
<tr>
<td>Trzepieciński, T.,</td>
<td>48</td>
</tr>
<tr>
<td>Tsvetkov, D. V.,</td>
<td>109</td>
</tr>
<tr>
<td>Tuchkova, N.,</td>
<td>71</td>
</tr>
<tr>
<td>Uglich, P.</td>
<td>109</td>
</tr>
<tr>
<td>Urayama, K.</td>
<td>106</td>
</tr>
<tr>
<td>Ustinov, K. B.,</td>
<td>63, 109</td>
</tr>
<tr>
<td>Ustinov, S. A.,</td>
<td>80</td>
</tr>
<tr>
<td>Ustinova, A. S.,</td>
<td>38, 72</td>
</tr>
<tr>
<td>Uzhegova, N. I.,</td>
<td>110</td>
</tr>
<tr>
<td>Vaganova, N. A.,</td>
<td>48</td>
</tr>
<tr>
<td>Vaisberg, L. A.,</td>
<td>57</td>
</tr>
<tr>
<td>Vakulenko, S. A.,</td>
<td>26</td>
</tr>
<tr>
<td>Valiev, R. Z.,</td>
<td>110</td>
</tr>
<tr>
<td>Vanushkina, V. V.,</td>
<td>104</td>
</tr>
<tr>
<td>Varygina, M.,</td>
<td>110</td>
</tr>
<tr>
<td>Vasiliev, A. S.,</td>
<td>27</td>
</tr>
<tr>
<td>Vatulyan, A. O.,</td>
<td>84, 114</td>
</tr>
<tr>
<td>Vavilov, D.,</td>
<td>102</td>
</tr>
<tr>
<td>Vavilov, D. S.,</td>
<td>57</td>
</tr>
<tr>
<td>Vavulin, D. N.,</td>
<td>86</td>
</tr>
<tr>
<td>Vilchevskaïa, E.,</td>
<td>111</td>
</tr>
<tr>
<td>Vilchevskaïa, E. N.,</td>
<td>48, 49</td>
</tr>
<tr>
<td>Vildeman, V. E.,</td>
<td>108</td>
</tr>
<tr>
<td>Vinnikov, V.,</td>
<td>111, 112</td>
</tr>
<tr>
<td>Vinokurova, A.,</td>
<td>37</td>
</tr>
<tr>
<td>Vitkov, V.,</td>
<td>112</td>
</tr>
<tr>
<td>Vitokhin, E.,</td>
<td>112</td>
</tr>
<tr>
<td>Volkov, N. B.,</td>
<td>37</td>
</tr>
<tr>
<td>Volkov, S. S.,</td>
<td>27</td>
</tr>
<tr>
<td>Voropaev, S.,</td>
<td>112</td>
</tr>
<tr>
<td>Weichert, D.</td>
<td>99, 114</td>
</tr>
<tr>
<td>Wrobel, M.</td>
<td>78</td>
</tr>
<tr>
<td>Yakimova, K. S.,</td>
<td>112</td>
</tr>
<tr>
<td>Yakirevich, A.</td>
<td>63</td>
</tr>
<tr>
<td>Yakovenko, A. V.,</td>
<td>113</td>
</tr>
<tr>
<td>Yakovlev, Yu. A.,</td>
<td>34, 81</td>
</tr>
<tr>
<td>Yang, R.,</td>
<td>113</td>
</tr>
<tr>
<td>Yang, Z.,</td>
<td>113, 117</td>
</tr>
<tr>
<td>Yaroshhevich, N. P.,</td>
<td>114</td>
</tr>
<tr>
<td>Yaroshevsky, V.,</td>
<td>112</td>
</tr>
<tr>
<td>Yavruyen, O. V.,</td>
<td>114</td>
</tr>
<tr>
<td>Yi, J.-H.,</td>
<td>114</td>
</tr>
<tr>
<td>Yushutin, V.</td>
<td>115</td>
</tr>
<tr>
<td>Zaabat, M.</td>
<td>38, 44</td>
</tr>
<tr>
<td>Zagordan, N. L.,</td>
<td>115</td>
</tr>
<tr>
<td>Zahaf, A.</td>
<td>68, 117</td>
</tr>
<tr>
<td>Zaitsev, A. V.,</td>
<td>43, 115, 116</td>
</tr>
<tr>
<td>Zak, B.,</td>
<td>116</td>
</tr>
<tr>
<td>Zakrzhevsky, M.,</td>
<td>101</td>
</tr>
<tr>
<td>Zapryagaev, V. I.,</td>
<td>116</td>
</tr>
<tr>
<td>Zdanchuk, E.</td>
<td>68</td>
</tr>
<tr>
<td>Zeitlin, M. G.,</td>
<td>47</td>
</tr>
<tr>
<td>Zerrouk, I.,</td>
<td>68, 117</td>
</tr>
<tr>
<td>Zhang, J.,</td>
<td>113, 117</td>
</tr>
<tr>
<td>Zhang, Q.,</td>
<td>113</td>
</tr>
<tr>
<td>Zhou, B.,</td>
<td>99</td>
</tr>
<tr>
<td>Zhuchkova, M. G.,</td>
<td>56</td>
</tr>
<tr>
<td>Zimin, B. A.,</td>
<td>29</td>
</tr>
<tr>
<td>Zimmerman, R. W.,</td>
<td>102</td>
</tr>
<tr>
<td>Zinoviev, A. V.,</td>
<td>117</td>
</tr>
<tr>
<td>Zinoviev, A. V.,</td>
<td>117</td>
</tr>
<tr>
<td>Zinovieva, O. S.,</td>
<td>117</td>
</tr>
<tr>
<td>Zobova, A. A.,</td>
<td>118</td>
</tr>
<tr>
<td>Zolnikov, K. P.,</td>
<td>26, 65, 89, 90, 118</td>
</tr>
<tr>
<td>Zubko, L.</td>
<td>118</td>
</tr>
<tr>
<td>Zubkov, P. T.,</td>
<td>30</td>
</tr>
<tr>
<td>Zvyagin, A. V.,</td>
<td>103</td>
</tr>
</tbody>
</table>