SIBERIAN BRANCH OF
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IV ALL-RUSSIAN CONFERENCE
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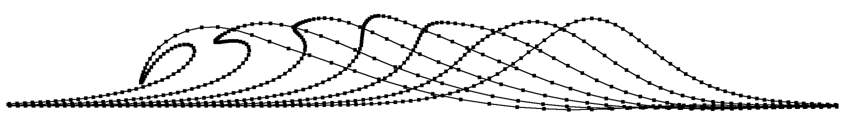
FREE BOUNDARY PROBLEMS: THEORY, EXPERIMENT AND APPLICATIONS

July 5 – 10, 2011
Biisk, RUSSIA



NOVOSIBIRSK
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LAVRENTYEV INSTITUTE OF HYDRODYNAMICS OF SB RAS
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Book of Abstracts

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FREE BOUNDARY PROBLEMS: THEORY, EXPERIMENT AND APPLICATIONS

Book of Abstracts for IV All-Russian Conference with Foreign Participants. July 5 – 10, 2011, Biisk, Russia.

Free boundary problems are characterized by their rich content and a variety of applications: from technological processes to the environmental problems and problems of efficient nature management. In 2002, 2005 and 2008 in Biisk there were held three conferences devoted to free boundary problems. There participated scientists from over 20 organizations from 12 Russian cities as well as scientists from foreign countries. Informal cooperation of mathematicians and physicists, theorists and experimentalists contributed to enrichment of conference subjects and establishment of professional contacts.

The book of abstracts contains abstracts on the following subjects:

- Surface and internal waves. Stratified flows.
- Interaction between waves and deformable constructions.
- Wave motion of thin films. Thermocapillary convection.
- Phase transitions in moving media.
- Processes of interphase interaction in heterogeneous systems.
- Magnetohydrodynamics and electrohydrodynamics flows with a free surface.
- Technological applications.

ORGANIZING COMMITTEE

The Conference is supported by Russian Foundation for Basic Research (Grant No. 11-01-06058), Lavrentyev Institute of Hydrodynamics of SB RAS, Biisk Technological Institute of Altai State Technological University, Kutateladze Institute of Thermophysics of SB RAS, Institute of Computational Modeling of SB RAS, Altai State University.

NUMERICAL MODELIING OF INTERACTION SOLITARY WAVES IN A VISCOUS FLOWS WITH VARIOUS OBSTACLE

K.E. Afanasiev, T.S. Rein

Recently intensive development of the breaking waves theory is observed. However, despite of numerous works till now all strict researches are made within the framework of approach of an ideal liquid [1,2]. The most correct attempts of the account of influence of viscosity on nonlinear evolution of the form of a free surface of a viscous liquid are executed within the framework of the theory of a boundary layer. The problem of research of wave movement in a viscous flows is actual in connection with numerous academic, technical and technological appendices. However, breaking wave process especially plunging breaking waves, is investigated superficially enough. In details mechanisms of formation and overturning of a crest of a wave, capture of a air, resulting to occurrence nonstability and turbulence in flows, and also to formation of whirlwinds are not known.

In the given work results of numerical modelling of movement and breaking solitary and shock waves in a viscous incompressible flow (2D statement) are submitted. As a numerical method it is used meshfree a method of finite elements. It is resulted comparisons of forms of a free surface with the results received at use of model non-viscous liquid.

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EVAPORATION AND GRAVITY-DRIVEN FLOW OF LIQUID FILM ON HEATED SURFACE

V.S. Ajaev, D. Brutin, L. Tadrist

We consider evaporation and viscous flow in a liquid film flowing down an inclined heated surface under the action of gravity. The gas phase above the film is assumed to be moist air with fixed vapor concentration far away from the interface. The leading edge of the macroscopic part of the film flows over the region covered with an ultra-thin film. The thickness of the latter is expressed in terms of the surface temperature and the air humidity for two commonly used disjoining pressure models. The same models are then incorporated into the description of the transition region between the macroscopic film and the ultra-thin one. Our modeling approach is similar to the one introduced by Poulard et al. [1] for the case of evaporating droplets except that the flux of vapor away from the interface is found based on the numerical solution of the unsteady diffusion equation. The rates of evaporation and contact line speed are found as functions of the inclination angle and the solid surface temperature. Results are compared to the case when the liquid film is in contact with pure saturated vapor [2].

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LOCAL SOLVABILITY INITIAL-BOUNDARY VALUE PROBLEM FOR EQUATIONS ONE-DIMENSIONAL MOTION OF THE TWO-PHASE MIXTURE

I.G. Akhmerova

One-dimensional nonstationary motion of the heat-conducting two-phase mixture (gas-particulate pollutant) is considered. The equations of mass and momentum conservation and energy balance are the following [1]:

$$(\rho_1^0 s)_t + (\rho_1^0 s v_1)_x = 0, \quad (\rho_2^0(1-s))_t + (\rho_2^0(1-s)v_2)_x = 0,$$

$$\rho_1^0 s(v_{1t} + v_1 v_{1x}) = -(sp_1)_x + (\mu_1(s)v_{1x})_x + F + \rho_1^0 sg,$$

$$\rho_2^0(1-s)(v_{2t} + v_2 v_{2x}) = -((1-s)p_2)_x + (\mu_2(s)v_{2x})_x + F + \rho_2^0 sg,$$

$$F = B(s)(v_2 - v_1) + p_2\frac{\partial s}{\partial x}, \quad p_1 - p_2 = p_c(s,\theta), \quad p_2 = R\rho_2^0\theta,$$

$$c_1\rho_1^0 s(\theta_t + v_1\theta_x) + c_2\rho_2^0(1-s)(\theta_t + v_2\theta_x) = (\chi(s)\theta_x)_x.$$

Here ρ_i^0, v_i – real density and velocity of the i-th constituent ($i = 1$ – solid particles, $i = 2$ – gas) respectively, s – bulk concentration of solid particles, θ – absolute temperature of mixture, p_1 – effective solid pressure, p_2 – internal gas pressure, g – density of mass forces, $c_i = const > 0$ – heat capacity at constant volume, $R = const > 0$ – absolute gas constant; besides, $\mu_i(s)$ – dynamic viscosity of phases, $B(s)$ – coefficient of phases interaction, $\chi(s)$ – coefficient of mixture heat conductivity, $p_c(s,\theta)$ – pressure difference (intended functionality). Real density of solid particles ρ_1^0 is supposed to be a constant. The quantities s, θ, ρ_2^0, v_i, p_i, $i = 1, 2$ are to be found.

This work is carried out in the framework of the programs "The development of scientific potential of the Higher School (2009–2010)" (Project No.2.2.2.4/4278) and "Scientific and academic and teaching staff of innovative Russia" for 2009-2013 years.

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THERMOCAPILLARY WAVES IN LIQUID FILM

S.P. Aktershev

Wave formation conditions in a heated liquid film with thermocapillary effect is explored. In the first part the stability of a film is viewed for cases of the fixed substrate temperature and the fixed heat flux. The equation for perturbation of a temperature profile is output and its solution for any values of Peclet number is gained. It is revealed, that for a vertical film the thermocapillary effect leads to expansion of area of instability only at small values of Peclet number, and at great values there is a waist of area of instability. Influence of slope angle on the thermocapillary waves is studied (fig. 1). In the second part the numerical modelling of stationary travelling waves is presented. Numerical calculations agree well with the linear stability theory.

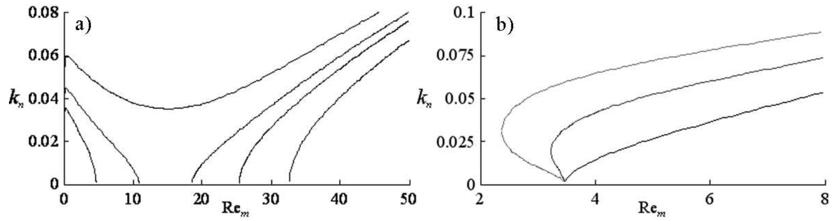

Fig. 1 Neutral curves at various Marangony number. (a) fixed substrate temperature, (b) fixed heat flux

HEAT TRANSFER IN FALLING LAMINAR-WAVY LIQUID FILMS

S.P. Aktershev

Intensive investigation of free falling thin liquid films is caused by their wide application in engineering. It is known that the waves on the film surface intensify heat and mass transfer significantly even in the laminar flow. Heat transfer in the laminar-wavy liquid film of on the heated plate is studied numerically. Calculation results [1] demonstrate the effect of physical properties of liquid (Biot and Prandtl numbers) and wavy flow parameters on heat transfer intensification by stationary traveling waves

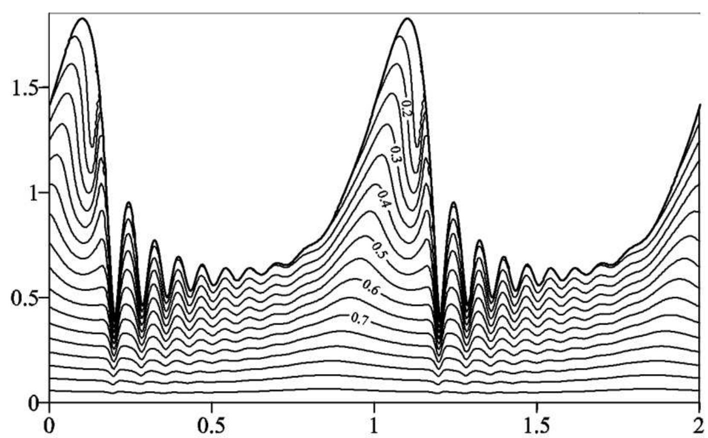

Fig. 1. Isotherms in liquid film (plate temperature is fixed)

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MODEL OF DYNAMIC OF THE VAPOR CAVITY AT THE EXPLOSION BOILING-UP

S.P. Aktershev, V.V. Ovchinnikov

The dynamics of boiling up of a liquid on a surface of a heater is investigated. For great values of an overheat the evaporation front spreads in a metastable liquid along a heater with constant velocity [1]. Calculations of critical overheat ΔT*=$(T_w - T_s)$ (fig. 1) and velocity of evaporation front V (fig. 2, 3) are carried out for the liquid sodium used as the heat transfer medium in nuclear reactor. Numerical simulation of growth of vapor cavity agrees well with available experimental data for water, nitrogen and various organic liquids [2].

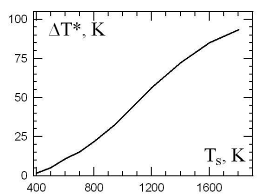

Fig. 1

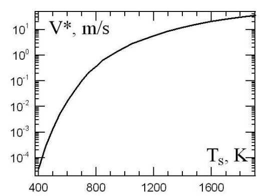

Fig. 2

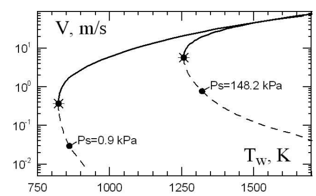

Fig. 3

The work was supported by the President of Russian Federation (NSh 8888.2010.8).

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EFFECT OF CONTACT ANGLE HYSTERESIS ON THE DYNAMICS OF A CYLINDRICAL DROP

A.A. Alabuzhev

The forced oscillations of a cylindrical drop are considered in the present work. The drop is suspended in the different fluid and confined by two parallel rigid plates, subjected to vibrations. The vibration axis is perpendicular to the symmetry axis. The amplitude of vibrations is small in comparison with the drop radius. The equilibrium contact angle is right. The specific boundary conditions, assumed by Hocking [1], is applied to take into account: the contact line starts to slide only when the deviation of the contact angle exceeds a certain critical value. As a result, the stick-slip dynamics can be observed.

The diagram of contact line motion on the plane (frequency, critical contact angle) is drew. We calculate the maximum amplitude of the surface deviation depending on the external frequency. Demonstrated the existence of antiresonance frequency, similar to the work [2], when the contact line is fixed at a nonzero frequency.

The work was supported by the President grant MK-22368.2011.1.

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PARAMETRIC INFLUENCE ON MARANGONY CONVECTION IN A THIN FILM

A.A. Alabuzhev, M.V. Khenner

We consider impact of vertical vibration on longwave Marangoni convection in a thin layer heated from below. The thermal conductivity of the lower sold boundary is assumed high. Vibration period is comparable with the characteristic time of the film evolution, vibration amplitude is of the order of the layer thickness. We have demonstrated that under above conditions the vibration results only in the gravity modulation in the conventional amplitude equation derived in [1].

Linear stability analysis shows that in a noise-free system the stability threshold is independent of the vibration intensity; in presence of noise the layer destabilization occurs. Nonlinear calculations confirm the latter conclusion, subcritical excitation of the convection is found.

We also carried out an asymptotical analysis of large vibration frequency, matching both the above parametric effects and averaged description similar to that applied in [2].

The work was supported by RFBR (grant No. 11-01-96001-r_ ural_ a) and the President grant MK-22368.2011.1.

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WAVY STRUCTURE OF ANNULAR GAS-LIQUID FLOW

S.V. Alekseenko, D.M. Markovich, A.V. Cherdantsev

When liquid film is sheared by high velocity gas stream, longitudinal size and amplitude of waves, appearing on film surface, reduce. In the same time, frequency and passing velocity of waves increase [1]. Investigation of wavy hydrodynamics of gas-sheared liquid films requires field measurements of local film thickness with high spatial and temporal resolution. Such a system was created on basis of high-speed modification of laser-induced fluorescence technique [2]. Experiments showed that two types of waves coexist on liquid film surface under action of strong gas shear. The main volume of liquid is carried by long-living primary waves, which are characterized by high velocity and amplitude. On the back slopes of primary waves short-living secondary waves appear, which can move either faster or slower than parent primary wave. Scattering of fast secondary waves leads to entrainment of liquid into the core of gas stream.

The work was supported by RFBR grant 10-08-01145 and RF President grant MK-115.2011.8

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ANALYSIS OF CONTROL PROBLEMS FOR THE HEAT CONVECTION MODELS

G.V. Alekseev, D.A. Tereshko

This work is concerned with a numerical solution of optimal control problems for stationary and nonstationary models of heat transfer in viscous fluids. The model consists of the Navier-Stokes equations and the convection-diffusion equations for temperature that are nonlinearly related via buoyancy in the Boussinesq approximation and via convective heat transfer (see [1,2]). The velocity of fluid and the heat flux on some parts of the boundary are used as controls when minimizing a quadratic functional depending on the velocity or temperature. Boundary control problems for the Boussinesq equations are formulated. Optimality systems describing first-order necessary conditions for the minimizer are deduced.

Numerical algorithm based on Newton's method for the optimality system solution is proposed. Some computational results connected with the vortex reduction in the flow around a cylinder in plane channels are given and analyzed. The influence of the initial guess and some parameters on the speed of convergence and the accuracy of the obtained numerical solution is investigated.

The work was supported by RFBR (grant No. 10-01-00219-a) and Far Eastern Branch of RAS (projects 09-I-P29-01, 09-I-OMN-03 and 09-II-SU03-003).

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UNIDIRECTIONAL TWO-LAYER FLOWS OF FLUIDS IN CYLINDRICAL DOMAINS

V.K. Andreev

The invariant solution of the type

$$u_j = v_j = 0, \quad w_j = W_j(r,t), \quad p_j = -\rho_j f_j(t) z + P_j(t),$$

$$\theta_j = Az + T_j(r,t), \quad j = 1, 2,$$

a viscous heat conducting liquid equations is investigated. This solution can be interpreted as follows. Suppose that in cylindrical tube $0 \leqslant r < b$, $|z| < \infty$ on the interface $r = a < b$ the surface tension linearly depends on the temperature. Then the thermocapillary effect and pressure gradients $f_j(t)$ induce the unsteady motions. Substituting invariant solution in the governing equations and taking into account the conditions on the interface we obtain two conjugate initial boundary value problem for unknowns W_j, T_j.

The following results were obtained:

1) the stationary solutions under different boundary conditions are found;

2) it was proved that the functions W_j, T_j tend to stationary state as $t \to \infty$ when the pressure gradient of one liquid tends to constant;

3) the volume flow rates through the domains are found and inverse problem with respect to pressure gradients are solved.

The work was supported by grant of RFFI N 11-01-00283.

A STUDY OF NONLINEAR EVOLUTION EQUATION FOR LIQUID FILM FLOWING DOWN A VERTICAL PLANE

D.G. Arkhipov, D.I. Kachulin , O.Yu. Tsvelodub

In [1] a new divergent system of equations for modeling of the nonlinear waves on a free surface of liquid film flowing down a vertical plane was derived. It was shown [2] that the system can be reduced to one equation for special function similar to the hydrodynamic stream function. In the case of small Reynolds numbers Nepomnyashiy's equation follows from the equation mentioned, and the Shkadov's model follows from it in assumption of self-similar profile of longitudinal velocity. In this paper a comparison of the new equation with a number of traditional models was performed on the base of linear analysis.

The neutral stability curves, dispersion characteristics of linear waves and profiles of the perturbation of longitudinal and transverse velocities were calculated. By comparative analysis of the solutions with the corresponding solutions of Orr-Sommerfeld equation, Shkadov's and Nepomnyashiy's models the domains of applicability of the investigated mathematical models were established in a linear approach. It was shown that the new equation describes the dynamics of linear perturbations and the picture of disturbed flow well.

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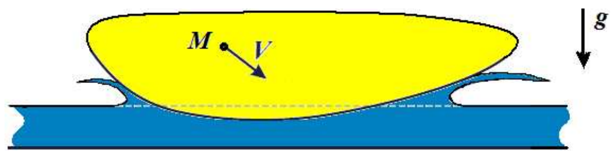
INCLINED ENTRY OF BODY ONTO THIN LAYER OF LIQUID

E.A. Batyaev, T.I. Khabakhpasheva

Two-dimensional problem of inclined entry of a free rigid body with flat bottom onto the thin layer of an ideal incompressible liquid is considered. Initial velocity of the body is so large that water jets arise at the boundary of the contact region during the entry process. The knowledge of the hydrodynamic loads and the body motions during impact is of importance in many engineering applications such as aeronautic and ship hydrodynamics.



The problem is solved as a coupled problem - liquid flow, body motion modified by the hydrodynamic loads distributed along contact region and the position of this contact region are determinated simultaneously. The liquid flow is analyzed using Korobkin's approach based on the method of matched asymptotic expansions [1]. The flow region is subdivided into several complementary regions that exhibit different properties: the region beneath the entering body surface, the jet root, the spray jet, and the outer region. A complete solution is obtained by matching the solutions within these subdomains.

Body motions under the hydrodynamics forces which themselves depend on the body motion are investigated. The coupled problem is reduced to a system of integro-differential equations. The system is solved numerically. The body motion and effects of rotation under hydrodynamic loads are investigated.

The work was supported by the grant of RFBR 10-08-00076.

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INSTABILITY OF TWO-LAYER THERMOCAPILLARY FLOW IN ZERO GRAVITY CONDITIONS

V.B. Bekezhanova

The problem on stationary flow of two viscous heat-conducting liquids, whose densities are constant, in plane layer with temperature longitudinal gradient and in absence gravity is studied. Outer boundaries are solid walls, one of them is motionless and second one can move with constant velocity w_{10}. Tangential forces act along the interface $x = 0$ and surface tension depends on temperature linearly at that.

Flows in the layers are generated by pressure gradients, thermocapillary forces and wall motion in this system. There is situation, when choosing the velocity w_{10}, we can assure zero volume flow rate in second layer. The arising unidirectional flow is described by Ostroumov-Birikh solution [1, 2]

$$\mathbf{v}_j = (0, 0, w_j(x)), \quad \theta_j(x, z) = F_j^1(x)z + F_j^2(x), \quad p_j(x, z).$$

In linear theory framework the stability of this flow regime is investigated. Crisis induced by hydrodynamic mode relates to formation of immovable vortices on boundary of opposite streams. Wall motion deceleration results in stabilization of the regime. In the case of thermal mode the instability is generated by development of monotonic (stagnant) thermal waves or oscillatory (running) hydrothermal. The monotonic mode is the most dangerous.

The work was supported by Integration grant of SD RAS No. 116.

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SIMULATION OF CONCENTRATION CONVECTION IN REGIONS WITH THE INTERFACE: THE FEATURES OF THE BOUNDARY CONDITIONS

R.V. Birikh

Solutal convection due to the large diffusion time has a number of important differences from the thermal convection. Experiments [1-3] show the simultaneous existence of the solutal buoyancy convection and capillary convection usually leads to an oscillating mode. The appearance of it is attributed to the destruction of the Marangoni convection concentration field of surfactant, created by gravitational convection. In the experiments, the oscillation period depends strongly on Grashof number and comprises a few units of viscous time. Another feature of the solital convection in the presence of phase boundaries is that the exit of surfactant molecules on the boundary has a mechanism that is different from the formation of the temperature perturbation on the surface. On the fluid free boundary the surface phase is formed in which the concentration of surfactant is determined by the competition of the adsorption and desorption processes. Experiments show that the solutal Marangoni convection starts when a gradient of surfactant concentration is achieved a finite value in the interface. Upon simulation of the surface phase, this requires to ascribe "Bingham" properties to it – the elements of the surface phase are set in motion when shear stresses excess certain limit.

This work was supported by RFBR N 08-01-00503 and RFBR N 09-01-00484, Integration Project of Siberian, Ural and Far East Academy of Sciences N 116 and Ministry of Education Grant (number of state contract – 14.740.11.0355).

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SOLUTION OF THE SINGULARLY PERTURBED FREE BOUNDARY PROBLEM FOR THE SYSTEM OF PARABOLIC EQUATIONS IN THE HÖLDER SPACES

G.I. Bizhanova

There is considered multidimensional two phase free boundary problem for the system of the parabolic equations with two small parameters $\kappa > 0$ and æ > 0 at the principal terms in the conditions on the free boundary. The unique solvability of this problem is proved in the weighted and classical Hölder spaces and coercive estimate of the solution is obtained for small T_0. The constant in the estimate of a solution and T_0 do not depend on these small parameters. From the solution of this problem letting κ to zero and then æ to zero we obtain the existence, uniqueness and estimates of the solutions in the classical Hölder spaces without loss of smoothness of the solutions to the second problem (with $\kappa = 0$) and then to the third one (with κ=0 and æ $= 0$).

This problem was studied jointly with J.F.Rodrigues.

NUMERICAL DEFINITION OF 3-DIMENSIONAL STATIONARY RUNNING PERTURBATIONS ON THE LIQUID LAYER FREE BOUNDARY

A.A. Bocharov, G.A. Khabakhpashev, O.Yu. Tsvelodub

In the present paper it is considered that the stationary components of the incompressible liquid flow equal zero; the typical horizontal dimension of a perturbation is noticeably larger and the disturbance amplitude is considerably smaller than the equilibrium layer depth h; the capillary effects are not large (the Bond number Bo $= \rho g h^2/\sigma > 1$, where ρ is the fluid density, g is the free fall acceleration, and σ is the surface tension); the fixed rigid bottom is horizontal; and finally, a dissipation may be neglected. The last two suppositions needed in order to exist steady solutions.

Under these assumptions, in the article [1] the following spatial modified Boussinesq equation for the perturbation of the liquid layer free surface η has been received:

$$\frac{\partial^2 \eta}{\partial t^2} - gh\nabla^2\eta - \frac{3}{2}g\nabla^2(\eta^2) - h^2\left(\frac{1}{3} - \frac{1}{\mathrm{Bo}}\right)\nabla^2\frac{\partial^2\eta}{\partial t^2} = 0. \qquad (1)$$

Here t is the time, and $\nabla = (\partial/\partial x, \partial/\partial y)$ is the 2D gradient operator.

Periodic solutions of Eq. (1) were found numerically, just as it was done in the article [2] for the "differential" model of surface waves in water of arbitrary depth. Some of the most distinctive and interesting spatial stationary running solutions of Eq. (1) was constructed, as well as the influence of basic parameters of the problem (an amount and a direction of the wave vector, a surface tension) in the form of perturbations was demonstrated.

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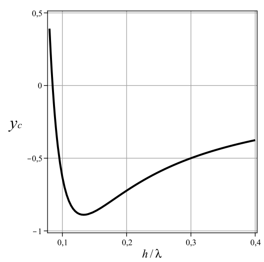
CONSERVATION LAW OF THE FULL MECHANICAL ENERGY AND STABILITY OF THE STEADY-STATE WAVES ON THE SURFACE OF A FLUID OF FINITE DEPTH

T.A. Bodnar

The conservation law of the full mechanical energy of one wave on the surface of a fluid with depth h is expressed as $c^2(\lambda)f_1(\lambda) + y_c(\lambda)f_2(\lambda) = const$, where $\lambda, c(\lambda)$–length and velocity of the wave, $f_1(\lambda), f_2(\lambda)$–known from [1] functions,$y_c(\lambda)$–co-ordinate of wave's masses centre. Dependence $y_c(h/\lambda)$ at $h = 10$м is given on the drawing.

From the law of the change of wave's kinetic energy, presented in [2] as a mathematical theorem,follows that the kinetic energy is equal to zero on the interval boundaries $(0, \lambda_{max})$ and has the maximum at point $\lambda_0 \in (0, \lambda_{max})$. At the points $\lambda = 0, \lambda = \lambda_{max}$ the full mechanical energy is equal to potential energy.If $\lambda = \infty$, then $y_c(\infty) = \infty$ and the conservation law of full mechanic energy of the wave is broken. Let's view a wave as a compound pendulum with a suspension center in the origin of co-ordinates arranged on unperturbed surface of the fluid. The wave is stable if $y_c(\lambda) < 0$ and unstable when $y_c(\lambda) > 0$. Unstable waves overturn or in other way change the profile and cease to be periodic. Any gravitational wave with $\lambda = \infty$ breaks laws of conservation of mass and (or) of full mechanical energy.



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STABILITY OF ROLL WAVES OF THIN FILMS ON INCLINES

A. Boudlal, V.Yu. Liapidevskii

This communication deals with stability of periodic travelling waves of finite amplitude for the thin film flow on an incline. The film flow rate corresponding to moderate Reynolds numbers is considered. In the frame of long wave approximation, the flow is described by the nonhomogeneous hyperbolic equations. The stability criterion is formulated in terms of the hyperbolicity of modulation equations for the periodic wave trains (roll waves). It is shown for the particular case of vertical wall that the roll waves of infinitesimal amplitude are unstable, but the periodic packets (roll waves) become stable after reaching the critical amplitude.

The first order approximation in the shallow water theory for thin film flows on an incline is represented by the nonlinear hyperbolic model, in which the viscous effects are taken into account by considering a self-similar velocity profile in a liquid layer. Capillarity effects in the model are ignored to reveal the interplay between nonlinear and viscous terms in the governing equations. It is shown that like the open channel flow with high Reynolds numbers the instability of steady-state flow of liquid films results in the quasi- periodic long wave generation. The question on nonlinear stability of the periodic wave trains (RW) is solved for film flows by the analysis of the modulation equations in the similar way as for open channel flows [1]. Moreover, the explicit asymptotic formulae for the boundaries of the stability domain derived for the model under consideration show their efficiency in the stability analysis of nonlinear wave packets.

The work was supported by Russian Foundation for Basic Research (grant 10-01-00338) and by RAS (project 4.7).

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DYNAMICS FORMATION OF THE SURFACE PHASE OF THE SURFACTANT

D.A. Bratsun, L.I. Lutsik, L.I. Mizev

We study the surface properties and dynamics of the surface phase formation in single-component and binary aqueous solutions of surface-active substances using the Wilhelmy plate method and the Langmuir-Blodgett barrier system. This method allows us to study the surface properties of the solutions in a wide range of lifetimes of the boundary and is more sensitive at low concentrations. As a surfactant we used the salts of fatty organic acids - potassium laurate and potassium caprylate. They are the members of the same homologous series, differing in properties. The barriers located at the surface of the tray filled with the investigated solution, first came close to each other and then moved in the opposite direction with a fixed velocity. The Wilhelmy balance immersed in a solution registered the surface pressure. In this paper, we investigate the properties of ingle-component and binary solutions, and their dependence on both the total concentration of the surfactants and relative contribution of each surfactant to the solution. The curves of maximum surface pressure versus surfactant concentration were constructed for different barrier velocities. It has been found that for single-component and binary solutions this dependence is of non-monotonic character. At a certain value of the surfactant concentration (different for the examined surfactants) the dependence is maximal. It has been shown that at relatively small (less than CMC for each component) concentrations the surface phase is formed more quickly in a mixture of surfactants than in a solution of each of the surfactants taken alone.

The obtained results are interpreted in the framework of the proposed model, in which the diffusion equation for a two-dimensional case is applied to describe the dynamic processes occurring during the formation of the surface phase of surfactant solutions.

This work was supported by RFBR (project N 10-01-96009), the Federal Program (HA N 14.740.11.0352) and the program of the Department of Power Engineering, Mechanical Engineering, Mechanics and Control Processes of RAS N 09-T-1-1005.

MODELING CHALLENGES IN COASTAL RESEARCH OF THE ALFRED WEGENER INSTITUTE FOR POLAR AND MARINE RESEARCH

Thomas P. Brey, Karen H. Wiltshire

The Alfred Wegener Institute for Polar and Marine Research (AWI) is a leader in German and European physical and biological marine oceanography with strong emphasis on cold water systems, i.e. Arctic, Antarctic and northern boreal environments. Coastal environments and their ecosystems which are under particular pressure by climate change and direct human impact are a major focus of our work. In these dynamic systems, we investigate physical, biogeochemical and ecological key-processes at high temporal and spatial resolution. In order to gain a mechanistic understanding of such processes we have to develop appropriate models. This is particularly challenging regarding biological and ecological functions. Here we present a selection of actual research projects that exemplify our approach and indicate the challenges we encounter.

EVOLUTION OF A LAYER OF FERROFLUID, LYING ON A LIQUID SUBSTRATE, SUBJECTED TO THE ACTION OF THE MAGNETIC FIELD

C.A. Bushueva, K.G. Kostarev

The report provides the result of experimental research of the influence of magnetic field on a horizontal layer of ferrofluid, lying on a liquid substrate. It is found that turning on the magnetic field normal to the surface of ferrofluid leads to the instability of the layer. Thus, in case of the uniform magnetic field ferrofluid layer splits into separate drops forming an ordered structure. The shape of drops and characteristic spatial period of structures depend on the initial thickness of ferrofluid layer and the value of the field intensity.

Vertical non-uniform axisymmetric magnetic field deforms the layer surface till the rupture in the form of a regular circle. Herewith the appeared rupture could remain after turning the magnetic field off if the thickness of the initial layer of ferrofluid does not exceed the critical value. In turn, already existing stable rupture could be deformed till it's closer by the uniform magnetic field applied parallel to the layer surface[1].

The work was supported by the grants of the research program of the RAS N 09-T-1-1005, in part by Award No. RUX0-009-PE-06 of the U.S. Civilian Research and Development Foundation for the Independent States of the Former Soviet Union (CRDF), the RFBR projects N 10-02-96022.

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FREE FLUCTUATIONS OF THE STRATIFIED LIQUID IN A ROTATING BASIN

A.A. Chesnokov

The nonlinear system of equations of the theory of long waves, which describes spatial fluctuations of the multilayered stratified liquid in a rotating circular parabolic basin, is transformed to the usual equations of model of multilayered shallow water on an equal motionless bottom. This transformation is discovered as a result of the analysis of symmetry properties of the equations of motion of a rotating shallow water [1] and more general model, which takes into account piecewise-constant stratification of a liquid. The derived symmetries are used to generate new exact solutions of the multilayered stratified shallow water equations. With use of the known stationary rotationally symmetric solution the class of time-periodic solutions is obtained. These solutions describe nonlinear fluctuations of the multilayered stratified liquid in a circular paraboloid with closed and quasi-closed (ergodic) trajectories of the liquid particles. The constructed solutions are used for modeling lenses and rings in a rotating stratified liquid. The obtained results are generalized for the case of more complicated long-waves model of the multilayered stratified rotating liquid. This model [2] includes dependence of horizontal velocity from vertical coordinate and can be used for modeling flows with recirculation zones.

This work was supported by Integration grant of SD RAS No. 65 and the RFBR (grant No. 10-01-00338).

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TWO-PHASE FLOW IN MICROCHANNELS

E.A. Chinnov, O.A. Kabov

The tendency to device miniaturization in various fields of technology, including aerospace industry, electronics, transport, power engineering, and medicine accounts for a growing interest in the hydrodynamics of gas-liquid flows and heat exchange in microsystems and microchannels. A review of investigations devoted to two-phase flow regimes in channels of various geometries [1] demonstrated that most of the published results refer to relatively long channels. Experimental investigation of two-phase flow in a short horizontal rectangular channel with a height from 0.1 mm to 0.5 mm has been made.

Two-phase flow patterns and transition between them are studied. The flow patterns map is constructed in the conventional coordinates of superficial gas and liquid velocities (U_{SG} versus U_{SL}, respectively), which are determined as the volume gas or liquid flow rates divided by the area of the channel cross section. The classical regimes of two-phase flow in the channel included bubbles, slug, stratified (film) and annular were detected. New two-phase flow regimes (gas jet, churn and droplet) were discovered in short horizontal rectangular channels. The instability of liquid flow near the sidewalls essentially influents on transition between regimes of two-phase flow in the short rectangular channels. With increasing of superficial liquid velocity, the stratified flow transforms into the annular regime because of increasing of ripple frequency and liquid emission from the side parts to the top wall of the channel.

It was found two type instabilities of two-phase flow in microchannels: lateral (gas-liquid interaction near the sidewalls) and frontal (gas-liquid interaction near liquid entrance for channel with height 100 m). These instabilities essentially influent on transition between regimes of two-phase flow in the short rectangular channel.

The work was supported by SB RAS (interdisciplinary project N 64) and RF (GC N 14.740.11.0103).

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THE ROLE OF THERMAL EXPANSION IN THE DESTRUCTION OF POLYMER IN THE NEIGHBORHOOD OF HOT PARTICLE

Yu.A. Chumakov, A.G. Knyazeva

The thermal destruction of hydrocarbons is complex process consisting of sequence of parallel and consecutive chemical reactions with generation a lot of products. The direction and maximum equilibrium conversion degree of initial products are defined by energy characteristics of reactions. The model of hydrocarbon destruction in the neighborhood of a particle heating by microwave radiation with allowance for thermal expansion (leading the substance melting), gas cavity formation in the neighborhood of a particle is studied. The particles in the reactant (hexadecane) are suspected to receive energy by microwave radiation. The reactant is transparent for microwave radiation. As reactant heat conductivity is low compared to particle, the initiation of the reaction in the neighborhood of a particle occurs without reference to other particles.

The mathematical formulation of the problem includes the equations of heat conduction for the particle and reactant, equation for concentration of reaction product in the neighborhood of a particle, motion equation with allowance for viscous force. The reactant density is considered to be inversely temperature. The considerable density local variations are supposed to induce generation of gas cavity. The problem is symmetrical, that is all values depend on radial coordinate. The symmetry condition satisfies in center of particle. The condition of thermal and mass flux absence is satisfied in the boundary of domain.

As investigation shows, the thermal expansion of hexadecane in the neighborhood of a particle caused by high temperature gradients influences on initiation of the reaction and removing of reaction products.

NUMERICAL ANALYSIS OF THE WAVE EFFECTS ACCOMPANYING THE HEAT SHOCK

V.N. Demidov

Many technology processes (plasma-enriched deposition, surface treatment using laser or electron beam, welding, surfacing etc.) are connecting with intensive heat action on the material under study. In these conditions rapid temperature change of the surface occurs – heat shock. In this paper the problem on heat shock is studied in generalized formulation taking into account the coupling between the heat and mechanical processes. In this case, the interrelation between various effects stipulated by various phenomena is included: 1) thermal conductivity, 2) dynamic (inertia) terms in motion equation, 3) coupling of strain and temperature fields, 4) heat inertia (finiteness of heat transfer rate) and 5) dissipative processes due to the plasticity. The mathematical model includes the motion, discontinuity, heat transfer equations, generalized Fourier law and governing equation of elastic plastic deformation connecting the change rates of stresses and strains. Together with full statement, the simplified problem formulations are studied, that allows to use known analytical solutions of thermal elasticity and thermal conductivity theories for debugging of numerical algorithms. The problem is solved numerically using finite-difference scheme of Godunov S.K.

THE INFLUENCE OF SURFACTANT PROPERTIES ON THE DEVELOPMENT OF THE MARANGONI CONVECTION ON THE FREE SURFACE

M.O. Denisova, K.G. Kostarev

The onset of the solutal Marangoni convection on the free surface is related to the appearance of the surfactant concentration gradient. The structure of the flows and concentration fields and their evolution are defined by physico-chemical properties of the surfactant.

The paper presents the results of experimental investigation of two problems. The first problem is concerned with the Marangoni convection on the free surface, which occurs due to local injection of a micro-drop of an aqueous surfactant solution. The second problem considers the development of the oscillatory solutal convection near the gas bubbles in a horizontal channel filled with inhomogeneous surfactant solution.

Visualization of the flow patterns has shown that the motion occurring in both cases develops in a threshold manner. In experiments, the monatomic alcohols were used as the surfactants, which allowed us to estimate the influence of such properties as surface activity and surfactant solubility, on the flow structure and its variation in time. The results of tests were used to define the threshold values of the concentration difference and the order of magnitude of the critical Marangoni number, which was found to be $Ma \sim 10^7$.

The work was financed by RFBR (project N 09-01-00484) and joint research project of SB, UB and FE B of RAS N 116/09-T-1-1005.

MATHEMATICAL MODELING OF PROCESSES OF A MUD VOLCANISM

A.V. Domanskii

In work modeling of activity of mud volcanoes on the basis of the equations of the non-stationary gas seepage and two-phase gas-mud flow through the conduit of a volcano is executed. Forward modeling is performed with reference to the pressure and temperature dependence of the gas viscosity and compressibility.

The inversion for the depth to the mud column base is formulated and its unambiguous solution is received. According to the modeling results, the depths to the mud base and to the gas reservoir are controlled mainly by conduit permeability, while the interval between two successive eruptions events depends on the gas/mud viscosity ratio. The model gryphon fields is offered and estimations of the subsurface thickness of a volcano and rate of the outflow of gas from it are received.

The model, allowing to explain increase of debit and free gases chemical compound change in gryphons of a mud volcano observed after earthquakes, is offered. Seismic impact is modelled by the flat longitudinal monochromatic wave, thus arising change of pressure influences processes of a seepage and solubility of gases in conduit of a volcano.

The work was supported by grant of FEB RAS 09-III-A-08-439.

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CONVECTION OF SUPERFLUID LIQUID IN A PLAIN LAYER WITH A FREE BOUNDARY

V. Donskay, M. Zhukov

Convection onset of superfluid liquid in plain 'free-free' boundary layer is investigated. Instead of tradition description of two-components mixture (normal fluid component and superfluid component, see, for example, [1]) a superfluid is presented by single-fluid model. To characterize the liquid we use the single-fluid velocity $\mathbf{v}$, density ρ and an additional potential field $\mathbf{c}$ (field of 'excitation', [2]). For the field $\mathbf{c}$ motion equations and constitutive relations are obtained in terms of the Onsager's theory. The form of constitutive relations provides invariance of model's equations. The variables $\mathbf{v}$ and $\mathbf{c}$ are presented as one-forms and motion equations are obtained in terms of Lie derivative. Note, that liquid incompressibility is not assumed. The liquid state of He^4 is obtained on basis of the experimental data (see, [3]) for temperature range from $0,5°K$ to $1,3°K$ (temperature of λ-transition is approximately $\approx 2,17°K$). To investigate mechanical equilibrium of liquid the linear hydrodynamical theory of stability are used (see, [4]).

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A LOSS OF STABILITY OF HIGH-PRANDTL NUMBER THERMOCAPILLARY CONVECTION

M.K. Ermakov

A goal of the paper is an extention of stability analysis for small and moderate Prandtl numbers [1] to a region of high Prandtl numbers, which correspond to modern experiments with silicone oils. As the IMA-2 conference benchmark has demonstrated, stability analysis of thermocapillary flows even for small Prandtl numbers represents essencial difficulties [2]. A well-tested linear stability analysis technics [3] is used for stbility study of thermocapillary convection in liquid bridge at high Prandtl numbers. Dependencies of critical Marangoni number and critical frequency upon Prandtl number within 4–200 range for striaght liquid bridge with aspect ratio H/R=0.5 are investigated. It is obtained that the change of critical azimuthal wave number from two to one occured at Prandtl number equals to 28. Approximation of neutral curve for high Prandtl number is compared with experimental one. The loss of stability reason is evaluated by aposteriory energy balances. Neutral curve for thermocapillary flow for spacial experiments MEIS-2 (Japan, 2009) for 5 cSt silicone oil (Prandtl number 68) and aspect ratio within H/R=1.4 range is deternimed by linear stability analysis. The linear stability analysis fits well to experimental data for aspect ration larger than 1.7 and describes change of critical disturbance type, critical frequency and non-monotonic behaviour of the neutral curve near aspect ratio 2.5. For the aspect ratio smaller than 1.7 where is essencial divergence of of experimental and modelling data, the reasons of which are discussed and as well as the possible ways of its ellimination.

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STABILITY OF A TWO-LAYER QUASI-INCOMPRESSIBLE BINARY-FLUID SYSTEM WITH A DIFFUSE INTERFACE

O.A. Frolovskaya, A.A. Nepomnyashchy

A system of two layers separated by a diffuse interface, which is created due to a phase separation in a binary liquid in the gravity field, is considered. The system is bounded by a planar solid substrate from below and by a gas phase from above. The deformable liquid-gas interface is considered as a sharp boundary. The dependence of the density on the mass fraction is taken into account, which is significant under the action of gravity.

The goal of the present work is the investigation of the linear stability of two-layer base solutions with respect to long-wave disturbances. The influence of gravity, solutocapillary effect at the free boundary and Korteweg stresses inside the diffuse interface on the stability is studied.

FREE LAMINAR CONVECTION IN A VERTICAL SEMI-CIRCLE DUCT

V.G. Gasenko

A few exact solutions of the follows equations $\Delta u = -a - b\theta$, $u_s = 0$, $\Delta\theta = 0$ for free convection in a vertical semi-circle duct with isothermal and adiabatic walls was found by the method of complex functioning and conformal mapping. The coefficients a and b are the known functions of Reynolds and Rayleigh numbers [1]. The temperature problem was solved by Keldysh-Sedov method, the velocity problem was yielded to Dirichlet problem. The solution for the isothermal walls case

$$u = \frac{b(1-z\overline{z})}{2\pi i}\left[\left(1+\frac{1}{z}\right)\ln(1+z) - \left(1-\frac{1}{z}\right)\ln(1-z)\right] + \\ + \frac{a}{2\pi i}\left[\frac{(1-z)^2}{z} + \frac{(1-z^2)^2}{2z^2}\ln\frac{1-z}{1+z}\right] - \frac{ay^2}{2}$$

with $a = 4$ and $b = 7$ are shown on Fig.1.

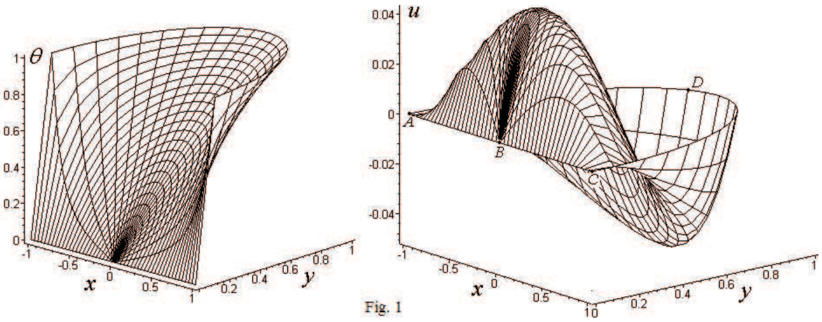

Fig. 1

The work was supported by Russian Federation Government grant N 11.G34.31.0035 for leading scientist Zakharov V.E.

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ON LARGE EDDY SIMULATION OF COHERENT STRUCTURES OVER PLANT CANOPY

K.A. Gavrilov

The Large Eddy Simulation (LES) is performed to reproduce the turbulent dynamic inside and above forest canopy [1]. The parallelepipedal computational domain with periodic lateral boundaries contains vegetation in its lower part, which homogeneous in vertical and horizontal directions. The drag force (additional term in equation of motion) induced by the elements constituting the canopy (foliage, branches, twigs) slows down the wind flow inside the vegetation layer.

First, since the profile of mean streamwise velocity contains an inflection point the Kelvin-Helmholtz instability occurs. The growth rate of the mixing layer instability and wavelength of Kelvin-Helmholtz structures is proportional to the magnitude of the shear length.

The second stage is the clumping of the vorticity of the Kelvin-Helmholtz waves into transverse vortices connected by braid regions of highly strained fluid. These rolls spread through domain at the canopy top level with ambient fluid velocity.

Third, due to the secondary instability the transverse rollers transform from two dimensional patterns into three dimensional ones.

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NEAR SHORE DYNAMICS OF LARGE-AMPLITUDE SURFACE AND INTERNAL WAVES: THEORY AND EXPERIMENT

V. N. Gavrilov, V.Yu. Liapidevskii

Propagation of high amplitude internal waves in a shelf zone is the very important physical mechanism of coastal water ventilation in view of the ability of such waves to transport cold water, lift up sediments, to intensify mixing processes in shallow waters etc. Such high-energetic mechanisms of the shelf ventilation can effectively intensify the biological and hydrological processes in coastal waters. In particular, they can redistribute the waste waters and influence the water quality in near shore area. Nonlinear internal waves generated by tides as well as by interaction of flows with topography play the important role in the energy transfer from the large-scale motion to small-scale mixing.

The evolution of large amplitude internal solitary waves propagating towards the shore as the subsurface waves of depression or the bottom waves of elevation is studied. The mathematical model describing solitary waves propagating, interaction and decaying is derived. It is a variant of the Choi-Camassa equations for two-layer and three-layer flows. It is shown that in laboratory experiments such flows could be simulated by internal symmetric solitary waves of mode 2 ("lump-like" waves) [1-2]. The exact solution representing the waves of permanent form for sharp interfaces is found. It is shown by the comparison between experimental data and numerical results that the rate of wave decay before and after interaction can be predicted by the model to a high accuracy. It is demonstrated that the numerical scheme developed for the open channel flows could be applied for description of large amplitude internal waves over a shelf [3].

The work was supported by Russian Foundation for Basic Research (grant 09-01-00427), by RAS Programs 20.4 and 14.14.

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MHD JET FLOWS WITH FREE BOUNDARY

S.V. Golovin

Exact solutions describing jet flows in ideal infinitely electrically conducting fluid with frozen-in magnetic field are investigated. Classes of exact solutions with constant total pressure were obtained in papers [1,2]. In particular, it was shown that in stationary flows with constant total pressure the free boundary of the jet, spanned by magnetic lines and streamlines of the flow, is necessary a translational surface. In present work the complete classification of such solutions is given, properties of flows determined by the solutions are investigated.

New examples of non-stationary solutions with constant total pressure are presented. Functional arbitrariness of solutions allows significant varying of the described picture of flows. Possibilities of generation of singularities due to 3D structure of magnetic lines are discussed. Generalizations of the methodology adopted in this work to another models of fluid mechanics containing frozen-in vector fields are investigated.

The work was supported by the Program of RAS No. 2.14.1, by the Program of Support of Leading Scientific Schools (N.Sc.-4368.2010.1) and Young Doctors of Science (MD-168.2011.1).

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THE DYNAMIC OF LIQUID DROP ON SUBSTRATE UNDER HIGH FREQUENCY VIBRATIONS

A.O. Ivantsov

The effect of high frequency vibrations on a droplet behavior placed on oscillating solid plate. The axis of vibration is normal to the substrate plane, the amplitude of vibration is supposed to be small compared with the equilibrium radius of the droplet. It is assumed that the drop is surrounded by gas medium whose density is negligible and the influence of gravity is ignored.

The acoustic oscillations of hemispherical drop are studied and the eigen frequencies of hemispherical drop are obtained. The analytical solution of the problem of forced vibrations of a hemispherical drop is obtained. The analysis is performed for situations then the surface forces can be neglected (the frequency of vibration of the plate is much larger then the natural frequencies of the drop), and taking into account surface tension.

The average form of an incompressible droplet in the case of high vibration intensity is found out using variational principle [1]. The problem of pulsation motion of drop with non-spherical average shape is solved by the boundary elements method. It is shown that the vibrations tend to reduce the height of the drop and the area of drop base increases. Average contact angle decreases with increasing of vibration intensity. The results are in good agreement with the analytical solution found for a drop whose shape is close to hemispherical.

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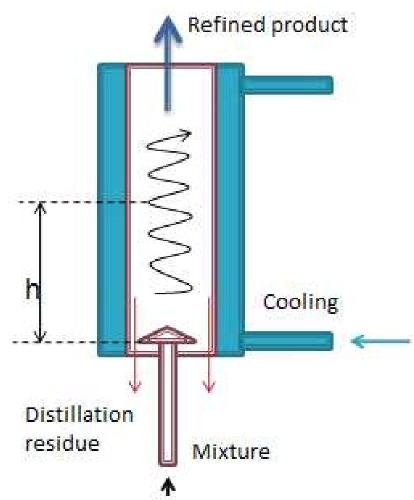
CONTROL OF SEPARATION PROCESSES OF A BINARY MIXTURE IN A VORTEX TUBE

Su Man Kan, N.I. Yavorsky

In work the results of separation of ethanol and water in a vortex rectifying apparatus of new type are presented. At present time the rectification columns are widespread and have good reputation [1]. At separation of components the size of the surface of interaction of a steam and a reflux plays the key role and the majority of improvements of process of rectification is related to magnification of a surface of contact of phases. A deficiency of such apparatuses is big metal consumption and flowrate restriction as a result of instability of uniformity of a stream that breaks homogeneity of flow on cross-section and leads to a column flooding. There are apparatuses in which for separation the rotating stream of an intermixture is used. Among them popularity was got by a three-line Ranque tube for separation of natural gas [2,3], however efficiency of similar devices is sufficiently low. In this work is made the attempt to use the physical phenomena playing a negative role in usual separating columns for raise of productivity and efficiency of a separation process of a binary intermixture. We use considerably higher rates of flow, herewith the hydrodynamic instability are used for magnification of an effective surface of contact of phases. Besides that the high relative travelling speeds of phases considerably increment a transfer coefficient that promotes raise of productivity and efficiency of the dividing device. The swirled stream of the binary intermixture, which are vapour-phase, is inducted from below into a vertical pipe chilled from the outside. On an interior surface of a pipe the condensate with the developed dynamic interface is formed. Magnitude of boundary surface is considerably incremented thanks to development on it of hydrodynamic instabilities, thus the surface is constantly updated that leads to essential magnification of a transfer coefficient. The vertical arrangement of a vortex tube leads to origination of a counter-flow of low-boiling and higher-boiling components that is a bottom of high performance of operation of all dividing devices.

In Figure the rectifying vortex tube, in which the swirled gas two-component stream interacts with moving in the opposite direction fluid flow (reflux), is depicted. The rectifying column construction consists of a vertical pipe in which the swirling stream of a water alcoholic steam intermixture is input from below at center at a small angle upwards concerning a horizontal. The turning stream in a pipe is divided into a distillation residue, which drains off on wall downwards, and a finished product, which comes up upwards in a form of steam and further condenses and goes on the analysis. The pipe has chilling housing. In experiments with a vortex separator the control parameters were the flowrate on an entry of the apparatus and flowrate of cooling. The original stock flowrate was controlled by power of heating elements (alcohol and water were boiled separately and were immixed vapor-phase). It is positioned that cooling plays a key role in the course of rectification. Stability of cooling strongly influences quality and quantity of the product on exit and in a distillation residue. The great influence on character of separation is rendered by geometrical performances of a pipe (a length and diameter relationship), hydrodynamic and thermodynamical parameters on an entry in a pipe. Guidance in these parameters allows to receive a high productivity and efficiency of separation process. Following regimes of separation are attained: 1) on an entry concentration of alcohol of 22% at the charge 3kg/hour - on a yield concentration of alcohol of 92,5% and the discharge of 0,22 kg/hour, the cooling discharge (water) made 14 kg/hour (the best effect on separation extent), 2) on a yield of 0,67 kg/hour 79% intermixtures at a 3,5kg/hour and 35% of concentration on an entry and cooling of 10,7 kg/hour (the best effect by quantity of a yield). These effects say that the swirling stream repeatedly reinforces mass transfer process in comparison with usual distilling.



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MATHEMATICAL MODELLING OF BREAKING PROCESSES AND THE SUBSEQUENT DISTRIBUTION NONLINEAR SOLITARY WAVES IN A COASTAL ZONE

S.N. Karabtcev

For acceptance of optimum decisions at designing sea and coastal constructions the extensive information on possible influence on these objects of various external factors among which the most significant is breaking waves which can cause movement of sedimentary breeds, change of the form of a bottom, destruction of designs is necessary.

Not so long ago experimental [1] and computing hydrodynamics [2] have concentrated the efforts to the better description of breaking waves processes, dissipation of energy, formation of two, three-dimensional whirlwinds, involving of air by a crest of a wave, and also modelling of wave impacts and hydrodynamical processes in a coastal zone. In the present work carries out complex research of breaking waves processes and the subsequent distribution of nonlinear solitary waves a coastal zone. Mathematical modelling of the given processes is carried out within the framework of model of an ideal incompressible fluid flow in full nonlinear statement on the basis of Euler's equations.

By virtue of significant deformations of free boundaries application of classical mesh methods becomes impossible. For numerical modelling in the given work the modified method of natural neighbours (NEM) is used.

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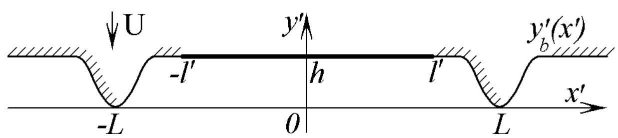
AIR-CUSHION EFFECT IN THE PROBLEM OF ELASTIC PANEL IMPACT

T.I. Khabakhpasheva, A.A. Korobkin

The problem of fluid impact onto an elastic panel is of importance in many engineering applications. For example, sloshing in LNG (liquefied natural gas) tanks can be so violent that the LNG may hit the walls and ceiling of the tank with strong force.

Initial stage of incompressible liquid impact onto a corrugated elastic panel with account for a compressible gas trapping between the corrugations is studied. The liquid free surface is flat and parallel to the panel before impact. The corrugations are modelled as rigid structures on the surface of the main panel. Part of the panel between two corrugations is elastic. During the initial stage the liquid closes the gas cavity between two corrugations and compresses the gas before the fluid comes in contact with the elastic part of the panel. The elastic deflection of the plate and bending stresses due to impact are determined accounting for the presence of the gas between the corrugations.



The problem is treated as a coupled problem of hydroelasticity, where the hydrodynamic loads and elastic deflections of the containment system are determined simultaneously. The hydrodynamic part of the problem is solved within the Wagner approach. The effect of gas compressibility on the elastic behaviour of the corrugated elastic plate is investigated.

The work was supported by the program of RAN No. 14.14.2.

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EVALUATION OF OPTIMAL CONDITIONS AND MODES OF ACOUSTIC EFFECTS ON THE VISCOUS AND DISPERSIVE MEDIUM

V.N. Khmelev, R.N. Golykh, S.S. Khmelev, R.V. Barsukov, A.V. Shalunov

The effectiveness of ultrasonic influence on liquid media of various technological processes is determined by properties of the cavitation area.

The theoretical studies aimed at identifying opportunities for implementation of an advanced cavitation mode and maximize a size of cavitation area in limited technological capacities in process of ultrasonic influence on a technological medium that has a high viscosity or dispersibility.

The mathematical modeling of cavity medium dynamics has been implemented for evaluation of optimal conditions (geometrical sizes and shape of technological capacity) and modes (power per unit area) of ultrasonic influence on different viscosity and acoustic properties liquids. The modeling approach is based on numerical analysis of a system of equations of hydrodynamics of heterogeneous bubble-liquid medium. The system of equations was developed on the basis of well known models of the microscopic process of expansion and collapse of single cavitation bubble.

These experimental studies for various liquids in various technological capaticies have allowed evaluating these optimal intensities of ultrasonic influence that differs little from the theoretical values.

These theoretical and experimental studies have shown effectiveness and determined optimal modes of ultrasonic cavitation processing of viscous and dispersive liquids. An ultrasonic technological devices constructions were developed, and a series of specialized devices was manufactured.

PRESSURE DIFFUSION EFFECT DURING ELEMENTS REDISTRIBUTION AT THE CONDITION OF ION IMPLANTATION

A.G. Knyzeva

In the media of different properties and at the different conditions, the role of transfer mechanisms as thermal diffusion and pressure diffusion (or the diffusion under stress gradient) is varied. The role of these phenomena, as any cross effects ones, growths in the irreversible conditions, for example at the conditions of ion and laser implantation. One can extract several causes: high temperature gradients and initiated by their mechanical stresses; specific action of particle beams on the material leading to properties change; the admixture presence and defects generation. The mechanical stresses play a special function in the admixture and defects redistribution: all connecting with them effects are the part of radiation-enhanced diffusion. In this paper, the models of admixture redistribution at the condition of ion implantation are suggested on the base of continua mechanics for deformable multicomponent body taking into account of interrelation between mechanical and diffusion processes. The dynamics effects and the analogy with hydrodynamic transfer models are analyzed.

The work is supputed by State contract N 16.740.11.0122 (Federal special-purpose program "Scientific and educational professional community of innovation Russia" for 2009-2013)

FREE-SURFACE SEPARATION FROM MOVING VERTICAL WALL

A.A. Korobkin

Initial stage of the flow with a free surface generated by a vertical wall moving from a liquid of finite depth in a gravitational field is studied. The liquid is inviscid and incompressible, and its flow is irrotational. Initially the liquid is at rest. The wall starts to move from the liquid with a constant acceleration. The problem of the vertical plate moving into the liquid was studied in [1].

It is shown that, if the acceleration of the plate is small, then the liquid free surface separates from the wall only along an exponentially small interval. The interval on the wall, along which the free surface instantly separates for moderate acceleration of the wall, is determined by using the condition that the displacements of liquid particles are finite. The flow scheme with separation of the free surface is similar to that studied by L.I. Sedov [2] for a vertical floating plate which starts to move impulsively. During the initial stage the original problem of hydrodynamics is reduced to a mixed boundary-value problem with respect to the velocity field with unknown in advance position of the separation point. The solution of this problem is derived in terms of complete elliptic integrals. The initial shape of the separated free surface is calculated and compared with that predicted by the small-time solution of the dam break problem. It is shown that the free surface at the separation point is orthogonal to the moving plate.

This study was carried out within the project "Separation effects in water impact problems" supported by The Royal Society of London.

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DIFFUSION OF A SURFACTANT FROM A DROP CONNECTED TO A RESERVOIR

K.G. Kostarev, A.V. Shmyrov, C.A. Bushueva

The character, intensity and duration of the soluto-capillary convection largely depend on the intensity of the surfactant source and its location in a multi- fluid system with the interface. As an example we refer to the case of surfactant diffusion from a drop of the binary mixture to a surrounding liquid under microgravity conditions [1]. The drop is coupled with the reservoir filled with the source mixture through a long thin tube (needle). A decrease of surfactant concentration in the drop was found to provoke its diffusion from the needle. The ejection of the surfactant initiated a capillary flow, which, in turn, contributed to the formation of a large-scale structure of the fluid motion in the drop.

The paper presents the results of studying the interaction between the capillary and gravitational mechanisms of motion in a similar problem treated under terrestrial conditions. Visualization of the flow patterns and concentration fields has shown that surfactant diffusion from the needle in the normal gravity leads to the onset of the oscillatory mode of the capillary convection in the drop. It has been found that the frequency of the Marangoni convection outbursts, the lifetime of the oscillatory flow modes and the amount of the initial mixture involved in the process of mass transfer depend on the drop size and initial concentration of the surfactant. The obtained results are compared with the case of surfactant diffusion from the secluded drop. We also consider the case of surfactant diffusion from the solution to the drop, which is connected with the reservoir filled with source fluid.

The work was supported by RFBR under the project N 10-01-96028, Federal Target Program (contract N 14.740.11.0352) and the program of the Department of Power Engineering, Mechanical Engineering , Mechanics and Control Processes of RAS N 09-T-1-1005.

BIFURCATION OF THERMAL CONVECTION IN VISCOELASTIC FLUID IN A CLOSED CAVITY

K.V. Kovalevskaya, T.P. Lyubimova

We study heat convection of viscoelastic fluid in a horizontal cylinder heated from below. Free boundary conditions and square cross section of cylinder are considered. To describe rheological properties general Odroyd model is used. The study of bifurcations is carried out by the means of two methods. 1. The problem solution is approximated by the series of trigonometric functions containing coordinate dependence with time-dependant amplitudes. Using weakly-nonlinear analysis the analytical expression which describes the boundaries dividing the plane of rheological parameters into areas with different type of bifurcations (super- and subcritical) is obtained. 3. Full nonlinear equations are solved numerically with applying finite differences method and the behavior of integral characteristics is observed. The results are shown to be in good correspondence with each other. Separately for the regions of exchange of stability and overstability, in the plane of rheological parameters (Debora number — dimensionless retardation time) the boundaries dividing areas with different types of bifurcation are built.

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VIBRATIONAL RIMMING FLOWS AND THEIR STABILITY

V.G. Kozlov, D.A. Polezhaev

We summarize the results of an experimental study of vibrational rimming flows in centrifugal fluid layer in a rotating cylinder. The transversal cylinder vibration creates the traveling azimuth wave in the fluid layer which generates phase inhomogeneous oscillations in the viscous Stokes layer near the cylindrical wall. It brings fluid outside the viscous boundary layer to the averaged motion in the direction of the wave propagation [1]. Depending on the velocity of liquid motion different flow regimes are available: two-dimensional azimuth flow, spatially periodic vortical flow in the viscous boundary layer near the solid boundary and the chaotic flow. The intensification of the averaged flow makes the two-dimensional azimuth flow unstable to the appearance of the vortices similar to Gortler flow. The vortical flow excitation is determined by the instability of the oscillatory fluid motion in the viscous Stokes layer near the solid boundary. The spatial period of the vortex cell is determined by the thickness of the viscous boundary layer and depends on the dimensionless rate of rotation [2]. The regime change occurs at critical Reynolds number based on the velocity of the averaged motion in the viscous boundary layer and does not depend on the direction of the fluid motion with respect to the cylinder. The collapse of the regular vortical flow occurs as a result of centrifugal instability of the averaged flow throughout the bulk of the liquid. The centrifugal instability (so-called Taylor instability) develops if close to the axis of rotation liquid layers rotate faster than the peripheral ones. This requirement is satisfied for prograde averaged fluid flow: vortical flow becomes irregular and chaotic in the overcritical domain. The transition to chaotic flow occurs at critical Reynolds number based on the averaged flow velocity on the fluid free surface.

The work is supported by Rosobrazovanie (Templan N 01201058898)

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THE PLANKTON COMMUNITY OF THE LENA DELTA IN RELATION TO HYDROGRAPHIC CONDITIONS

A. Kraberg, I. Bussmann, M. Loeder, K. Wiltshire

The Lena River is one of the largest rivers in the world annually discharging an average 400 tons of water and 15-20 Mio tons of sediments into the Laptev Sea, particularly during spring ice melt. Hence the Lena Delta is a very complex hydrographical region with difficult conditions for aquatic biological communities, particularly with respect to light conditions, salinity, temperature and turbidity. As the focus had previously been on physic-chemical aspects, a first cruise in 2009 started to investigate the biological characteristics and processes in the water column, including zooplankton and phytoplankton as well as methane distribution. Here we concentrate on phytoplankton data from the Lena Delta in relation to water chemistry and hydrography.

These data reflect the complex regime in the river and delta. All samples were completely dominated by freshwater plankton assemblages, with the exception of a few coastal sites, which had a mixed assemblage of freshwater and marine species. A striking difference between the coastal and riverine sites was the species abundance with cell numbers in the river proper, far exceeding cell numbers in the coastal region.

The concentration of sediment in the samples followed no obvious pattern but even in the most turbid samples phytoplankton remained abundant. Despite the high phytoplankton counts, chlorophyll concentrations were particularly low, possibly also influenced by the amount of organic matter and Gelbstoff in the samples. Methane distribution within the Delta was highly variable, with hot spots in certain channels and at sites with melting permafrost. Temperature and conductivity were uniformly distributed within the delta, but steep gradients occur outside the Delta proper.

COATING GROWTH IN ARC VAPOR DEPOSITION CONDITIONS: THEORY AND EXPERIMENT

M.V. Kripakova, A.G. Knyazeva, I.M. Goncharenko

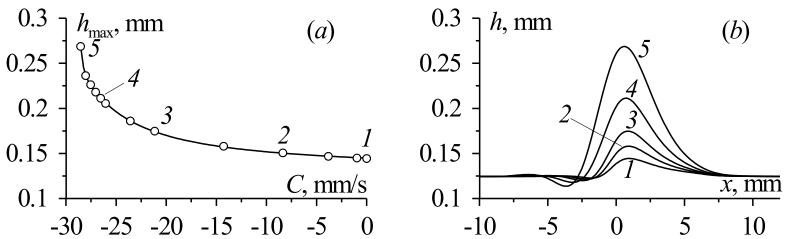
World experience in the field of functional coatings production in vacuum shows, that simultaneous ions deposition of different elements on the surface of a wide variety of substrates and their quantitative correlation in plasma flux, gives coatings with unique properties. Therefore, modeling of wear-resistant coating growth process is of great scientific and practical interest. According to the experiment data, the growth rate of nitride coating corresponds to predetermined parameters of a vacuum-arc device. Device parameters for mathematical model construction are considered to be given. It is assumed that the rate of coating growth is determined by technological parameters due to the directed flux of aluminum and titanium positive ions from the cathode. Interstitial impurities penetrate plasma coating, thus nitride coating synthesis runs in the diffusion mode. Coating growth dynamics is described by one diffusion equation with different coefficients for the coating and the substrate. In more complicated cases there is a system of diffusion equations with fluxes traverse and coefficients depending on the concentration of all elements. The task with a travelling boundary is calculated numerically and a time step is chosen according to external boundary hit into the block of a spatial grid. Consequently, both element concentration distribution and coating thickness are obtained at any time moment.

INERTION AND THERMOCAPILLARITY EFFECTS IN NON-ISOTHERMAL FILMS

P.A. Kuibin, O.V. Sharypov

The effect of moving heat source on the flow structure in gravity-driven thin liquid film is studied theoretically. The 2-D steady-state conjugated hydrodynamic and thermal problem is solved in long-wave approximation [1]. The equations for film thickness and temperature in finite-difference form are solved numerically with iteration method.

A series of simulations is done from the regime of flow along vertical substrate with resting heat source to the regime with moving heat source and horizontal liquid layer. It is shown numerically that changing of the velocity profile (connected with increase of heat source velocity it C and slope decrease under other equal conditions: fixed flow rate, film thickness and heat release) leads to dramatic amplification of thermocapillary deformation of the film (see Figure).



Maximum film deformation (a) and free surface (b) under constant flow rate condition, but at different C and inclination angles

The work is supported by Ministry of Education and Science (Program "Development of high school scientific potential" and FTP "Scientific and scientific-teaching personnel of innovation Russia") and RFBR (project N 10-08-01093-a).

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PARALLEL COMPUTING ON GRAPHICS PROCESSING UNITS FOR SIMULATIONS OF TWO-PHASE SYSTEMS USING LBE METHOD

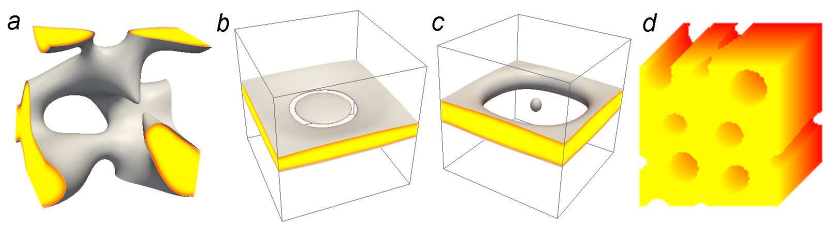
A.L. Kupershtokh

The Lattice Boltzmann Equation method (LBE) [1,2] was used for computer simulations of systems with interfaces between liquid and vapor phases. This method is widely used now for simulation of two-phase and multicomponent flows with complex topology. The variant D3Q19 of LBE method was used for three-dimensional simulations with phase transitions. The evolution equations for distribution functions of each component s and σ have the form

$$N_k^{s,\sigma}(\mathbf{x} + \mathbf{c}_k \Delta t, t + \Delta t) = N_k^{s,\sigma}(\mathbf{x}, t) + \Omega_k(N^{s,\sigma}(\mathbf{x}, t)) + \Delta N_k^{s,\sigma}.$$

The parallel computing were produced on Graphics Processing Unit (GPU) GTX-580 with 512 stream processors. Moving main parts of computations to GPU, we achieve 70 - 90 folds of speedup. The results of several three-dimensional simulations are presented in Fig. 1: a spinodal decomposition (a), a rupture of liquid film due to effect Marangoni (b,c), an anisotropic instability of initially uniform dielectric liquid under the action of strong electric field (d).

This work was supported by grants of RFBR (N 10-08-00805), DOEMMC of RAS (N 14.14.3), and Siberian Branch of RAS N 116-2009).



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BIFURCATIONS FOR SOLITONS OF INTERNAL WAVES

E.A. Kuznetsov

This talk represents a brief review of recent works devoted to bifurcations of solitons, both supercritical and subcritical. The main attention in the talk will be paid to the universality of behavior of solitons and their stability near supercritical bifurcation. On the example of solitons of internal waves propagating along the interface between two ideal fluids it is shown that near the supercritical bifurcation point solitons transform into the envelope soliton for the nonlinear Schrodinger equation. The soliton amplitude vanishes by the square root law while approaching the bifurcation point. Transformations of the solitons are analyzed for the density ratios close to the critical one $\rho_1/\rho_2 = (21 - 8\sqrt{5})/11$, when the supercritical bifurcation changes into the subcritical one. Upper and below this transition solitons have different behavior. For density ratio less the critical value solitons undergo supercritical bifurcation (it is also valid for surface waves in the deep water case). Such solitons are stable in the Lyapunov sense relative to the one-dimensional perturbations. At the density ratio larger the critical value solitons undergo subcritical bifurcation. They turn out to be unstable. The nonlinear stage of this instability results in their collapse - the complete destruction. Near the collapse time the soliton amplitude and its width demonstrate self-similar behavior with weak anisotropy on the soliton tails due to self-steepening.

The work was supported by the RF Government Grant (the contract no. 0035, November 25, 2010 with Ministry of Education and Science of RF), RFBR (grant no. 09-01-00631) and by the Program of RAS Presidium "Fundamental problems of nonlinear dynamics".

MOTION OF LIQUID FILM IN FISSURAL MICROCHANNEL

V.V. Kuznetsov

There's constructed a mathematical model for simulation of motion of liquid film together with gas flow in a microchannel, which takes into account mutual influence of vaporization processes, heat transfer, transfer of gas by gas flow, formation of thermocapillary surface structures and alternating gravity. Flows are assumed to be non-stationary and three-dimentional.

There are done calculations for fields of velocity, temperatures in liquid and gas phases, concentration of vapour and the shape of the interface for the flow in microchannel. Analysis of temperature fields has shown that in contrast to streaming down films, here the temperature below the heater along the flow is constant throughout the depth of the channel. This is explained by smoothing of temperature in phases by the processes of vapourization-condensation, which play a key role in the interphase heat transfer in the presence of gas flows. At that if there's vapourization of liquid near the heater, then condensation is possible below along the flow. Since the velocity of gas is bigger than liquid's by order, the redistribution of heat comes to be significantly faster than for streaming down films. Heat tranfer is expressed heterogeneous. On the leading edge of the heater the heat transfer is the highest and then it falls fast. There is also some intensification of heat transfer on the trailing edge, which was not noticed in the streaming down films. This intensification is connected with high intensity of vapourization near the trailing edge of the heater.

The work is supported by the Interdisciplinary Integration Grant SB RAS No. 64, RFBR Grant No. 10-01-00007 and Federal Goal-oriented Program "Scientific and scientific-educational personnel of innovative Russia" governmental contract 14.740.11.0355 of September 20, 2010.

DEFORMATION OF COMPOUND DROPS DURING THERMOCAPILLARY MIGRATION

O.M. Lavrenteva, L. Rosenfeld, A. Nir

Compound drops are comprised of two or more immiscible phases. One phase of such an aggregate is completely or partially engulfed by the other one. A compound drop with partial engulfment has three interfaces between the components of the aggregate and facing the ambient fluid. At equilibrium, all three interfaces are segments of spheres. The angles at the three-phase contact line are determined solely by the ratios of the interfacial tensions, and the resulting configuration of the aggregate depends on the relative volumes of the drop's components. Exact analytical solutions describing creeping motion of such a hybrid drop in an infinite viscous domain under the influence of Marangoni effect due to various temperature distributions are constructed in [1] and [2]. However, when the drop moves in a non-isothermal ambient medium, the interfaces are deformed due to viscous stresses and to the non-homogeneous surface tension. We assume that the capillary numbers associated with all 3 interfaces are relatively small, i.e. that surface tension changes weakly at the interface, and construct corrections of the solutions obtained in the undeformable case making use of a regular perturbation technique following [3]. The cases of spontaneous thermocapillary migration and the motion in an externally imposed temperature gradient are considered. For the former case the deformations are steady, while for the latter one, the the interfaces evolve when the drop propagating to hotter region. An extreme cases this evolution may result in a complete engulfment of one phase by the other one or in a break up of the agregate and separation of the phases.

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THE UNIDIRECTIONAL MOVEMENT OF THE THREE VISCOUS LIQUIDS IN FLAT LAYERS

E.N. Lemeshkova

The joint movement of the three viscous liquids under the influence of pressure gradient in a layer restricted by solid walls was researched. The analysis of the movement is reduced to the decision of the conjugate initial-boundary value problem for three parabolic equations. During this research work the following results were given:

1. The exact stationary decision of the problem has been constructed;

2. The decision of the direct and inverse non-stationary problem has been given in the form of the final analytical formulas using the method of Laplas transformation;

3. It has been proved that if a gradient of the pressure in one liquid has a final limit, then the decision is located on a stationary mode;

4. For the problem about the "the flooded layer" movement it has been shown that velocities converge to the different constants with the time growth;

5. The integral Fridrichs' type inequality for the areas consisting of three segments has been proved. Also the aprioristic estimations of the general problem have been received.

The research was fulfilled with support of the RFBR grant N 11-01-00283.

ABOUT THE POSSIBLE CONTRIBUTION OF EFFECTS OF ROTATION OF THE EARTH TO GEODYNAMICS

B.W. Levin, E.V. Sasorova, A.V. Domanskii

Processing of real observations over seismicity of the Earth [1] has shown that latitudinal distributions of seismic events have the bimodal form with maxima around $\pm 30^0 - 50^0$. The work aim is to present the model describing development of two for equator symmetric zones of hydrodynamic instability in middle latitudes of a planet, caused by its rotation, and to show displays of this instability on materials of last geophysical observations [2]. The problem of a finding of a variation of the moment of inertia of a rotating planet as functions of geocentric latitude for homogeneous, and also for the layer-uniform on density Earth has been for this aim considered. On the basis of the problem solution values of critical latitudes which were calculated as a point of an excess for the graph of dependence of the moment of inertia from latitude are received. The received dependences at qualitative level coincide with the available natural data of distribution of quantity of seismic events and energy of earthquakes on latitudinal belts.

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RAYLEIGH-BENARD-MARANGONI INSTABILITY IN A FLUID LAYER WITH DEFORMABLE INTERFACE

D.V. Lyubimov, T.P. Lyubimova, N.I. Lobov

Stability of a conductive state of plane horizontal fluid layer with free deformable upper surface is considered. The layer is bounded from below by isothermal rigid plate. On the free surface the Biot heat transfer condition is imposed. The fluid is assumed to be isothermally incompressible, i.e. its density depends only on temperature. Dynamic viscosity, thermal conductivity and specific heat are considered as constant. In contrast to the conventional Boussinesq approximation the density variations are taken into account not only in the buoyancy force, but also in the inertia terms of the momentum equation and in the continuity equation, since it is known that the conventional Boussinesq approximation is incompatible with the assumption of deformability of the free surface. In the conditions indicated above the conductive state is possible where the fluid is quiescent, the free surface is flat and horizontal, the temperature is linear function of vertical coordinate, the density distribution is defined by the state equation and the pressure distribution - by the hydrostatics equation. The linear stability of the conductive state is studied for linear, gaseous and exponentional state equations. Stability maps in the parameter space of the problem are obtained. The calculations show that even in the case of very high surface tension, at not too large Galileo number and not too small Rayleigh number, the accuracy of the Boussinesq approximation is not sufficient. It is found that at zero Marangoni number the critical Rayleigh number increases with the decrease of Galileo number and at some value of Galileo number Rayleigh instability vanishes.

THE DYNAMIC OF GAS INCLUSIONS IN POROUS MEDIA SATURATED BY NATURAL HYDRATE

T.P. Lyubimova, D.V. Lyubimov, A.O. Ivantsov

Methane hydrate is an ice-like substance in which methane molecules are located in the space between water molecules. Importance of hydrates investigation is caused by the possibility of the development of technique that will allow using natural hydrates as the alternative source of fuel [1]. According to some estimates [2], the total content of natural gas in hydrates is twice the total amount of its deposits in all other form.

We deal with the processes in a porous medium saturated with hydrate, gas and water. In particular the behavior of a vertical channel, penetrating the layer of stable hydrate is studied numerically. Calculations show that the channel in hydrate can exist for a long time. The estimates show that considerable amount of gas might stream through the channel into the environment.

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ONSET OF CONVECTION IN A TWO-LAYER SYSTEM WITH DEFORMABLE INTERFACE AND FIXED HEAT FLUX AT THE BOUNDARIES

T.P. Lyubimova, Ya.N. Parshakova

Onset of thermal convection in a two-layer system of superposed horizontal layers of immiscible fluids subjected to vertical temperature gradient is studied for the case of fixed heat flux at the boundaries. The case of fluids of close densities is considered. In this case it is possible to apply generalized Boussinesq approach [1] allowing to take into account the interface deformations in a proper way. It is found that there are two long-wave instability modes: monotonic and oscillatory. Moreover, there are two different types of monotonic perturbations. For the first type of monotonic perturbations the onset of convection in each layer is typical such that the interface remains nearly undeformed. The second type of monotonic perturbations is substantially related to the interface deformations. The boundaries of the conductive state instability to the long-wave perturbations are determined analytically and to the perturbations with finite wave length - numerically. It is found that the perturbations of the first type are most dangerous at sufficiently large absolute values of the Galileo number. At the intermediate values of the Galileo number, an intensive exchange of energy between two types of perturbations leads to the onset of the oscillatory instability. The effects of the temperature dependence of the surface tension and of the variations of the layer thicknesses are analyzed.

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UNSTEADY MOTION OF THE ELLIPTIC CYLINDER UNDER FREE SURFACE

N.I. Makarenko, V.K. Kostikov

The problem on nonlinear non-stationary surface waves in deep ideal fluid generated by submerged elliptic cylinder is investigated. The method involves the reduction of basic equations to the integral-differential system for the free surface elevation, as well as for normal and tangential fluid velocities at the free surface. Small-time solution asymptotics is constructed in the case when the cylinder moves with constant acceleration from the rest. Several wave regimes are considered (vertical rising and vertical submersion of the cylinder, horizontal- and combined motion), the wave pictures are compared for different eccentricity values and initial submergence depthes.

PROGRAM SYSTEM FOR BIFURCATING SOLUTIONS WITH THEIR STABILITY DETERMINATION IN CAPILLARY-GRAVITY WAVES THEORY

O.V. Makeev, B.V. Loginov, A.N. Andronov

The construction of branching equation (BEq) general form by group analysis methods is based on the theorem about inheritance by it symmetry of original nonlinear problem. If a_j, $j = 1, 2$ are basic vectors of planar crystal lattice and l is a vector of inverse lattice, then the zero-subspace $N(B)$ of the linearization has the basis $\{e^{2\pi i\langle l_j,q\rangle}\}_1^n$ with enumeration: if the vector l has an odd number, then the vector -l has the subsequent even. The group G is a semidirect product of continuous shifts group, preserving periodicity, and point reflection-rotation group of the lattice. Real BEqs construction is made in complex variables.

Input data of the program are formed by infinitesimal operators of the relevant Lie algebra in coordinate space Ξ^n. Algorithm of the exhaustive search of all possible combinations of variable indices for the finding the monomial solutions M_k to the DE system $X_\nu(M_k) = 0$, $\nu = 1, 2$ in the ascending orders is created. The quantity of obtained invariants exceeds the number of functionally independent ones. The second part of the program determines the connections between used invariants. Factorization of BEq decomposition on degrees of used invariants is realized in third part.

The determination of families stability in group-theoretical simulation is based on the linearized stability principle for the ODE system with right-hand side in the form of BEq operator. A stable solution family of the nonlinear problem is the parameterized by the group action family of reduced stable solutions. The dimension of zero-subspace of Frechet derivative of nonlinear operator on bifurcated solution coincides with the number of zeros of BEq Jacobian matrix on its solution. The signs of real parts of other eigenvalues, determinated by the physical parameter grid, give the areas of reduced stability of the bifurcating solution families.

DETERMINATION OF SURFACE TENSION AND CONTACT ANGLE FROM BUBBLE AND DROP PROFILES

I.V. Marchuk

Numerical algorithms for solution of the Young-Laplace equation describing shapes of steady bubbles or drops attached to a horizontal flat plate [1-2] has been developed and tested for different types of initial conditions setting. Set of inverse problems are solved on determination of the capillary length and contact angle from measured values of bubble/drop sizes: height, diameter, diameter of wetted spot or square of vertical axial drop section. The suggested method of determination of the capillary length and contact angle is a modification of well known Drop Profile Fitting Method [3]. The main advantage of proposed approach is its simplicity and reliability. Drop profile is uniquely defined and calculated by three parameters which are easily measured on a bubble or drop photo. Inaccuracies of the capillary length and the contact angle evaluation are definitely calculated from known inaccuracies of drop sizes measurements. Results obtained give a base for developing advanced method of contact angle and surface tension measuring on bubble and drop shapes.

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COATING-BASE DIFFUSED ZONE FORMATION IN THE CASE OF ISOTHERMAL ANNEALING UNDER LOADING

M.A. Mikolaichuk, A.G. Knyazeva

Coupled two dimensional problem of diffusion under external loading Two dimensional problem of one-axis loaded plate admixture saturation was considered. Mechanical part of problem was formulated under the Bernoulli-Euler hypothesis. Lateral displacements are negligible. We are supposed that axial deformation is an linear function of coordinates in the cross-sectional plane. Stresses was obtained as functions of deformations which was expressed in terms of displacements. Relation between deformations and stresses described with Duhamel–Neumann Law. In the defining relationship we have volume changing function which depends on admixture concentration. Thereby, without external loading plate stressed state depend on concentration stresses. Unknown functions from axis displacement definition was obtained from system of linear algebra equations which was written as result of conditions of equilibrium for resultant forces and torques.

Two possible influence mechanisms of starins and stresses on diffusion were analyzed for diffusion part of problem. First of them related with diffusion activation energy change by lattice deformation. To relate activation energy with stress and strains, which presence in the system, we need introduce some notion, such as activation volume. Activation volume is difference between local volumes of the system in the ground and activated states. Ultima analysi, we can say that the work of stresses, which are presence in the local volume, is explicitly influence to diffusivity. We have used this diffusivity in the our model. Second mechanism consist in a mass transfer of impurity under stresses. It like pressure diffusion mass transfer in a liquids.

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CONVECTIVE FLOWS INDUCED BY INHOMOGENEITY OF SURFACTANT DISTRIBUTION

A.I. Mizev, R.V. Birikh

Development and stability of a convection flow caused by a presence of a localized inhomogeneity of a soluble surfactant distribution located nearby a free liquid surface is studied experimentally and theoretically. There were examined two cases: source and sink of surface-active substance (SAS). For the case of SAS source it was found that either an oscillatory or steady flow state can be obtained depending on the ratio of intensity of buoyant and solutocapillary convection. It is shown that concentration dynamic Bond number which can be described on the analogy of the thermocapillary case is the analogy parameter of the problem which defines the flow state. Only oscillatory regime can be found under relatively small values of Bond number (relatively small contribution of the buoyancy in comparison with that of solutocapillarity). At that the period of oscillations normalized by the Bond number is the same for all surfactants used in the experiments. An increase of the Bond number gives rise to appearance of steady state flow existence range of which becomes wider under further increase of this parameter.

Development of a convection motion in the presence of a surfactant sink located near a free liquid surface was studied experimentally. It is shown that from the experimental point of view this situation is similar to the case of a source of surface-inactive substance. Appreciable difference in the system behavior for the cases of a source and a sink of SAS is found. In the latter case a surface-inactive substance does not penetrate into an interface (that is just unfavorable from the thermodynamic point of view) remaining in the liquid volume. Solutocapillary convection does not develop in this case.

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INTERACTION OF CAPILLARY FLOW WITH AN ADSORBED FILM OF A SURFACTANT

A.I. Mizev, D.A. Bratsun, A.I. Lutsik

A presence of surface tension gradient or a viscous entrainment of a liquid surface by a volume flow results in appearance of a surface (or capillary) flow. A structure of such flows is as rule easily predictable and can be simply modeled in theoretical and numerical investigations. However there are a few experimental studies where the structure of observed surface flows is much altered from that predicted by a theory or followed from symmetry considerations. The most probable cause of the obtained discrepancies is a presence (often uncontrolled in experiments) of surface-active impurities which form an adsorbed layer at an interface. In this case the surface flow develops under boundary conditions which are different from those at a free liquid surface. From this point of view the additional study of development and stability of the surface flows in presence of surfactant films is needed for the formulation of the boundary conditions suitable for such problems.

The results of the study of interaction between a solutocapillary surface flow and an adsorbed film of an insoluble surfactant are presented in the presentation. The main problem of such class of studies is a creation of a "zero" free surface with controllable and reproducible properties which is initially free of any surface-active contaminations. A way to solve this problem and results of preliminary experiments are presented in the presentation. It's shown that a solutocapillary surface flow induced by local mass source become unstable breaking axial symmetry under relatively low surface concentration of a surfactant.

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HYDRODYNAMICAL CHARACTERIZATION OF BALL

A.B. Morgulis, V. Vladimirov

We present the characterization of ball that arise itself from the classical Björkness problem concerning the effect of vibrating fluid upon a submerged solid body. We restrict ourselves within most simple model: we consider inviscid, incompressible and homogeneous fluid whose pulsations are forced by pointwise immobile source of fluid. Its intensity $\varkappa = \varkappa(t)$ is supposed to be given. We assume that the fluid flow around the body is irrotational and the fluid stays in rest on the infinity. The described system obeys Least Action Principle of Hamilton where the configuration space represents a submanifold in the group of orientation-preserving motions of $\mathbb{R}^3$; the Lagrange function has the natural form $\mathcal{L} = K + \Lambda - \Pi$ where K is positively defined quadratic form in velocities; Π depends on the displacement only while Λ is linear in the velocities. The linear term determines 1-form on the configuration space. More explicitly,

$$\Lambda = \varkappa(t) \int\limits_{S(t)} G(0, y|t) v_b^n(y,t)\, dS_y,$$

where $S(t) = \partial D^b(t)$, $D^b(t)$ stand for the solid body, $v_b^n(y,t)$ — projection of the body velocity on the normal filed on $S(t)$ directed inward the fluid, $G = G(x, y|t)$ — the Green function for the Neumann problem in the exterior of $D^b(t)$. This representation presumes that the source of fluid is considered as the origin that does not lead to the losses in generality.

Theorem. *Assume the Pfaff form Λ is exact. Then the solid body represents a ball. The converse statement is true as well.*

PROBLEM OF STABILITY OF A SUBMERGED JET

R.I. Mullyadzhanov, N.I. Yavorsky

The work is dedicated to the study of the stability of axisymmetric steady flow in an incompressible viscous fluid, which was described analytically by Slezkin [1], Landau [2], and Squire [3]. The flow is generated by $\tilde{\mathbf{P}}$ pulse source located at the origin of (R, θ, ϕ) spherical coordinate system. The solution of the problem corresponds to the submerged jet and belongs to the class of conical flows, where the velocity is inversely proportional to R spherical radius.

The work presents a linear analysis of the stability to axisymmetric perturbations that also belong to the class of conical flows, which corresponds to the study of the stability in the point at infinity. In this case, the velocity vector of infinitesimal perturbations is $\nu\tilde{\mathbf{f}}(\theta,\xi)/R$, where $\tilde{\mathbf{f}}$ – nondimensional vector of the velocity perturbations, ν – kinematic viscosity of the fluid, θ – spherical angle measured from the symmetry axis, $\xi = R/\sqrt{4\nu t}$, t – time. The perturbation equations are a system of differential equations in the partial derivatives with two dimensionless variables of ξ and $x = \cos\theta$. At the Reynolds number of $Re = \sqrt{\mid \tilde{\mathbf{P}} \mid /\pi\rho\nu^2} = 0$ it is possible to divide the variables in the equations. In this case, the solution that depends on x represents Legendre polynomials, while the solution for ξ – hypergeometric functions. Hence, all eigenfunctions of the linear stability problem have been found analytically for the class of conical flows at rest. In case of $Re > 0$, the problem has been studied in the asymptotic limit of $\xi \to 0$, which corresponds to $t \to \infty$ limit, i.e. the asymptotic stability. In this case, the dependence on ξ variable is power-like, i.e. ξ^λ, where λ is a spectral parameter determined when solving ordinary differential equations. The flow is stable if $\lambda(Re) > 0$. The study has shown that the flow corresponding to Slezkin-Landau-Squire solution is asymptotically stable to infinitesimal axisymmetric eigenperturbations at all Reynolds numbers. This result correlates well with the known experimental data for the far field of the submerged jet [4]. At the same time, theoretical studies of the submerged jet stability that consider streamlines curvature reveal the loss of the jet stability at relatively low Reynolds numbers [5]. In the plane-parallel approximation the submerged jet is stable to axisymmetric perturbations at all Reynolds numbers [6,7]. Unlike work [5], this work studies the initial stage of the development of linear perturbations. It is shown that in some time perturbations unstable at the initial stage of the development turn into decaying ones. This property is typical of eigensolutions in the form of hypergeometric functions. Therefore, initially unstable linear perturbations are, however, asymptotically stable.

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SPECIFICS OF WATER AND WATERED-ALCOHOL DROPS EVAPORATING ON THE HEATING SURFACE

V.E. Nakoryakov, S.Ya. Misyura

A new experimental method namely measuring the current mass of the drop with the use of electronic scales was developed to study the dynamics of evaporating drops. The wall temperature was measured by a thermocouple, and the surface temperature of the drop was determined by infrared imager. The measurements were performed within the wall temperature range from 80 to 250°C at the test sections made of various materials (copper, aluminum, stainless steel, and gold plating). Surface roughness and heated wall thickness were variables (0.001-0.02 m). Liquid drops were generated by means of "Lenpipet" batch meter within the range of 2-100 mkl.

Formerly the most thorough study on influence of various factors on the evaporation process was conducted just for large balks of water. Boiling of the water drop within broad temperature range was investigated previously just for the drop of a specific size [1].

It has been revealed that the nature of evaporation depends on drop's shape (volume) and is nonlinear. Critical boiling temperatures TCR1 (early cessation of nucleate boiling) and TCR2 (steady film boiling) practically do not depend on the size of the drop. Critical temperatures and the ratio of TCR1/ TCR2 significantly depend on the surface conditions (oxide film and surface roughness) as well as on the heat diffusivity and wall thickness. On the thin walls at the same TCR different modes of evaporation were observed during the change in volume of the drop, such as mode without boiling, nucleate boiling, and film boiling. A decrease in wall thickness less than 0.01 m and application of the material with high thermal resistance and high surface roughness lead to significant drift in the heat transfer crisis of the drop. Measurements of wall temperature in the vicinity of the drop showed existence of cooling zone with the temperature equal to 5°C. In order to eliminate the effect of oxide film and minimize the influence of surface roughness, the experiments were conducted on the copper polished test section with gold plating. Nature of the drop boiling on the polished wall differs significantly from the evaporation of the drop on a rough surface.

We have measured the heat flux of the drop and heat transfer coefficients at a constant TCR. In nucleate boiling mode the time of drop evaporation on the polished surface increases by 5-6 times, and the heat transfer coefficient, respectively, decreases by several times. At the final stage of evaporation accompanying by a decrease in the droplet surface, capillary waves were observed, as well as reduction in temperature at the top of the interfacial area by 5-7°C. Measurements carried out by thermal imager, revealed that the temperature field of the drop was significantly nonisothermal, three-dimensional, and axially asymmetrical. Besides the water was subcooled and the degree of subcooling could reach up to 30°C. Such essential subcooling effects the character of bubble growth and its collapse as compared with that in pool boiling.

During the boiling of water-alcohol drops we have observed the delay of boiling crisis, at which the transition region increased significantly.

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METHOD OF SUCCESSIVE APPROXIMATIONS FOR THE RIEMAN PROBLEM WITH A SMALL AMPLITUDE DISCONTINUITY

V.V. Ostapenko, P.E. Karabut

The Riemann problem for hyperbolic systems of conservation laws [1] is one of the most typical problems concerning the derivation and qualitative analysis of self similar weak solutions. In this paper, we propose a method of successive approximations for constructing the solution of the Riemann problem with a small amplitude discontinuity. The linear approximation of this method yields the Cauchy problem for a linear hyperbolic system. Its solution represents discontinuity lines divided by domains in which the solution is constant. Primary attention is given to the first and second approximations of the method, in which discontinuities obtained in the linear approximation are divided into stable shocks and rarefaction waves. As an example, we analyze qualitatively different flow regimes developing in the dam break problem for the model of two layer shallow water with a free boundary [2].

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ON REAL ACCURACY OF SHOCK CAPTURING DIFFERENCE SCHEMES

V.V. Ostapenko, O.A. Kovirkina

A convergence of high order shock capturing difference schemes is analyzed. Notions of weak finite difference approximations which conserve a sense on discontinuous solutions are introduced [1]. Necessary and sufficient conditions of these approximations are obtained. It is shown that among the explicit two-layer in time conservative difference schemes there are no schemes which can have high order of weak approximation. A compact scheme of the same third order of classical and weak approximations is constructed [2]. There is demonstrated an advantage of this scheme in comparison to TVD Harten scheme at shock-capturing computations. A difference approximation of Rankine-Hugoniot (RH) conditions is investigated [3]. It is shown that TVD type schemes (in contrast to non-TVD schemes, whose numerical fluxes are smooth enough) can approximate RH-conditions at most with the first order. Given examples show that non-TVD schemes (in contrast to TVD schemes) can have the second order of integral convergence through the smearing shocks and as a result can conserve a higher accuracy in the post shock regions [4].

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FILTRATION OF A COMPRESSIBLE FLUID IN VISCOELASTIC ROCK

A.A. Papin, M.A. Tokareva

Isothermal motion of a compressible fluid in a deformable porous medium is described by the following system of equations [1,2]:

$$\frac{\partial(\rho_f \phi)}{\partial t} + div(\rho_f \phi \vec{v}_f) = 0, \quad \frac{\partial(\rho_s(1-\phi))}{\partial t} + div(\rho_s(1-\phi)\vec{v}_s) = 0,$$

$$\phi(\vec{v}_s - \vec{v}_f) = k(\phi)(\nabla p_f + \rho_f \vec{g}), \quad \frac{1}{1-\phi}\frac{d\phi}{dt} = -a_1(\phi)p_e - a_2(\phi)\frac{dp_e}{dt},$$

$$p_e = (1-\phi)(p_s - p_f), \quad \phi p_f + (1-\phi)p_s = p_{tot}(x,t).$$

Here $\phi, \rho_f, \rho_s = const, \vec{v}_f, \vec{v}_s, p_f = p_f(\rho_f), p_s$ – respectively the porosity, true density, velocity and pressure of the fluid and porous medium; $\vec{g}$ – density of mass forces; p_e – effective pressure; $k(\phi)$ – permeability; $a_1(\phi)$, $a_2(\phi)$ – the parameters of the rock; $d/dt = (\partial/\partial t + \vec{v}_s \cdot \nabla)$. Results of solvability of initial boundary-value problems for given equations are presented at this report [3].

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LONG-WAVE INSTABILITY OF THE THIN FILM DOWNFLOW OF A FLUID WITH NON-LINEAR VISCOSITY

A.V. Perminov

The paper discusses the flow down an inclined plane of the thin film of the Williamson fluid. Given certain choice of rheological parameters, the Williamson rheological equation allows the modeling of visco-plastic fluids with rigid spatial structures, capable of resisting external shear stress not exceeding some threshold stress τ_0. Stable quasi-solid zones can be found near free surfaces of thin films. In Newtonian fluid [1] the steady-state thin film flow loses stability with respect to long wave planar perturbations for Reynolds numbers $\mathrm{Re} > 1.25\mathrm{tg}\alpha$, where α is an angle between vertical ort and inclined plane ($\alpha = 0$ corresponds to the case of vertically aligned layer). There is a transition of the rheological Williamson model to the Newtonian model which permits the aforementioned relation.

For $G \leq 1$, a visco-plastic film is in a stable quasi-solid state ($G = \rho gh/A$ where ρ is density of fluid, g is gravity coefficient, h is film width, A is a rheological parameter - $A = \tau_0$ in the case of visco-plastic fluid). The increase of the gravity force leads to the onset of a shear motion within a film which quickly becomes unstable with respect to long-wave oscillatory perturbations of the free surface. The flow of visco-plastic fluid may regain stability when gravitational parameter $G > 6.5$. The increase of the angle poses a significant stabilization effect of the fluid motion for the case of $G < 6.5$ but destabilizes it for greater G's.

No quasi-solid zone forms during the flow of pseudo-plastic fluid. There exists a certain critical gravity force magnitude when motion within the thin film becomes absolutely unstable. This magnitude is zero in case of vertically-aligned layer and approaches infinity for horizontally-aligned layer.

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THE COALESCENCE AND RESONANT BREAKUP OF PULSATING GAS BUBBLES IN FLUID

A.G. Petrov

The convergence and coalescence of pulsating gas bubble in fluid can be explained by the Bjerknes force. However, the experiments show that the coalescence of bubbles is not always observed. The condition of coalescence can be obtained by taking into consideration the forces of viscosity. The case of two pulsating bubbles with equal radii was considered. A period-mean force between pulsating bubbles and the Lagrange function were obtained with the help of the method of reflections.

The condition of coalescence was obtained. This condition is in accordance with the experiment and the previous works on this topic (Boshenyatov 2009). The coalescence can be obtained by increasing the radii of bubbles or by decreasing the viscosity coefficient (Petrov 2010).

One of possible mechanisms of bubble breakup is one due to shape instability. The resonance of radial and arbitrary deformational oscillation mode frequencies 2:1 was examined using the Zhuravlev's method of invariant normalization of Hamiltonian systems and the complete analytical solution was obtained. It has been shown the problem is fully analogical to that of the swinging spring (Petrov 2006). The exact expression for energy transfer period was obtained. The maximal magnitude of deformational mode due to energy transfer from radial mode has been shown to grow with the growth of n linearly. For example the relation of magnitudes in case of n=7 is about 20 (Vanovski, Petrov 2011).

The resonant energy transfer and huge growth of deformational mode magnitude on big n could be the explanation of bubble breakup due to shape instability.

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MATHEMATICAL MODELLING OF WAX CRUDE OIL FLOW IN SUBSEA PIPELINES

A.G. Petrova, A.A. Korobkin

Some part of pipelines are submarine where the temperature is rather low. Waxy crude oil pumped into a pipeline contains dissolved paraffin. Lowering the temperature leads to phase segregation in the domain with temperature less than WAT (wax appearing temperature). The part of waxes deposits on the pipe walls as a gel, which is subject to aging and becomes immovable under the temperature low than PP (pour point). That can lead to compleat stop up of a pipeline.

Analysis of different approaches to mathematical modelling of physical processes is conducted, the main of which are: heat and mass axial transport due to flow of liquid oil pumping into pipeline and wall deposition; radial heat transport caused by the difference in the liquid oil and the pipe walls temperature; deposition of an immovable gel on the walls when the temperature is lower than PP; phase segregation, appearance and growth of wax crystals when the temperature is between WAT and PP and the liquid is saturated; gelification process; evolution of the velocity field (which has the parabolic velocity profile of fully developed Poiseuille flow at the entry) due to the changing of geometry caused by wall deposition and to the changing if media properties; the aging process driven by diffusion mechanism; pipe vibration.

We consider the multiscale problem for a general model and propose an approach, based on specification of two time scales: "fast", determined by axial transport of and "slow" time of heat and mass diffusion. The problems of zero and first approximation with respect to a small parameter connected with the inverse characteristic time of diffusion processes are formulated and study.

CALCULATION OF THE DROPS MOTION IN A PLASTIC MEDIUM

Yu. V. Pivovarov

Stebnovskii [1] considered the behavior of drops of various oils in an alcohol-water solution (matrix) and found that, if the distance between two drops is of the order of their sizes, they slowly approach each other, independent of the system scale.

In present work the point of view, according to that the complete force, acting on the drop, is calculated by the formula

$$G_z = \xi(z)F_{z1} + (1 - \xi(z))G_{z1} + G_{z2}$$

is substantiated, where F_{z1} is the force component, limited by normal stresses in the rest state, G_{z1} and G_{z2} are the force components, limited by normal and shear stresses in the hydrodynamic flow round the drop, $\xi(z)$ is linearly decreases weighting function of the distance z, passes by the drop, receives the values from unit to zero and turns into zero by $z \geq \Delta z$. It means the part of the non-destroyed molecular bonds in matrix, thanks to which the latter one acquires the properties of solid body. The matrix is considered as a Bingam liquid. The drop moves cyclicly with the average velocity in order of 10^{-6}m/s and with the cycle time in order of 10^{-2}s. Hydrodynamic influence of the second drop is not taken into account.

The optimal parameters: the ratio of shear modules of the drop and the matrix G_1/G_2, the matrix yield point $k_0 = 10^{-4}$Pa and $\Delta z = 4 \cdot 10^{-10}$m was found by conducting of calculations. Under this parameters the experimental and calculating dependencies of overage velocity from the time are differed only on final stage of rapprochement. It can be explained by non taking into account of hydrodynamic influence of second drop.

The work was supported by the program 14.3 of power engineering, machine-building, mechanics and government processes Department of RAS.

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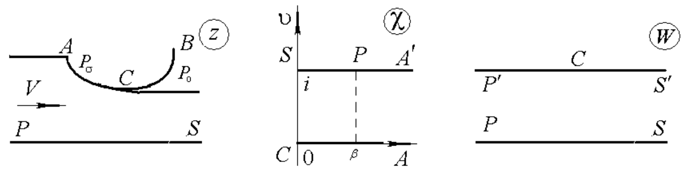
SOFT SHELL SHAPING IN THE FLOW CLOSE TO THE SCREEN

M.Yu. Podymova, M.A. Timofeeva

In this problem fluid is considered ideal, incompressible and weightless. Soft shell with two fixed points A and B are streamlined. Flow separation occurs at point C. PS – the screen, P_σ, P_0 – pressure inside the shell and ambient pressure.



We use the Bernoulli equation $P + \rho V^2/2 = P^*$. On the free boundary *CS'* $P = P_0$, and hence $V = V_0$. Let P_σ – the pressure inside the shell P_∞, V_∞ – pressure and velocity at infinity, P^* – Bernoulli constant, ρ – fluid density. Laplace condition $T = R\,(P_\sigma - P) = const$ must be satisfied on the surface of the shell, where R – radius of curvature of the shell.

On the complex potential plane the domain corresponding flow is a band. We use the parametric plane $\chi{=}\sigma{+}i\tau$ in the form of a half-strip width 1 to solution.

The mapping of χ on W

$$W = iQ + \frac{Q}{\pi}\left[\ln\left(ch^{-2}\pi\chi/2 + sh^{-2}\pi\beta/2\right) - \ln\left(1 + sh^{-2}\pi\beta/2\right)\right].$$

Part of shells CB represents the circular arc of radius $R_0 = 2T/\left(\rho V_\infty^2\right)$.

The problem reduces to the definition function of Zhukovsky, the real part is zero at the PA and PS and satisfies Laplace condition at the AC.

Function mapping the plane χ on the physical, sought in the form of a sum . Function maps conformally the strip of plane χ on the strip of plane ω.

As a result we obtained the shape of the shell for different ratios of geometrical and physical parameters.

LYAPUNOV INSTABILITY AND STRUCTURAL INSTABILITY OF MOLECULAR DYNAMIC PROBLEM

G.M. Poletaev, A.M. Sagalakov, P.S. Stenchenko

The theory of dynamical systems is applied to concern the molecular dynamic modelling of process of superswift amorphous metal solidification. The amorphous nickel, copper and aluminium formation is simulated. The Morse potential is applied to simulate atom interaction. The computation that structural chaos of liquid state is considerably inherited by solid state. It is shown, that one necessary has to take into account Lyapunov instability side by side with structural instability. Considered set of atoms is Pontryagin structurally instable. Both instabilities involve that the concrete atomic structure of amorphous metal is unreproductable neither in simulation nor experiment. Hydrodynamic analogies are concerned.

ON THE MODELING OF FLUVIAL PROCESSES IN RIVERS WITH SANDY BOTTOM

I.I. Potapov

In the work of the 2D tasks carried out mathematical modeling of hydrodynamic processes and channel of the Amur River near Khabarovsk. The hydrodynamic part of the problem is formulated within the framework of shallow water equations, the task of reshaping the riverbed is formulated using the original equation of channel deformations constructed on the basis of a family of sedimental models [1,2] does not contain a phenomenological parameters.

For the proposed mathematical model using the finite element method developed method for calculating the hydrodynamic and channel processes. Numerically investigated the process of retreat of the coastal slope of the Amur River in the confluence of the Amur flow, compared the results with field data.

This work was supported by the Federal Program "Research and scientific-pedagogical cadres Innovative Russia" State contract N 02.740.11.0626.

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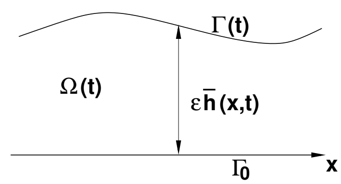
JUSTIFYING THE THIN FILM APPROXIMATION: A RIGOROUS LIMIT RESULT FOR STOKES FLOW DRIVEN BY SURFACE TENSION

G. Prokert

For $\varepsilon \in (0,1)$ we consider the moving boundary problem of Stokes flow driven by surface tension in a layer geometry (see Figure), given by

$$\begin{aligned} -\Delta u + \nabla p &= 0 && \text{in } \Omega(t), \\ \nabla \cdot u &= 0 && \text{in } \Omega(t), \\ T(u,p)n &= \kappa n && \text{on } \Gamma(t), \\ V_n &= u \cdot n && \text{on } \Gamma(t), \\ u &= 0 && \text{on } \Gamma_0, \\ \bar{h}(\cdot, 0) &= h_0. \end{aligned}$$



Here u and p denote the velocity and pressure fields of the liquid, $T(u,p)$ its Newtonian stress tensor, and κ and V_n the curvature and normal velocity of $\Gamma(t)$, respectively.

We show that as $\varepsilon \to 0$, the rescaled film profiles $h(x,t) := \bar{h}(x, \varepsilon^{-3} t)$ approach the solution of the well-known Thin Film equation

$$\partial_t h + \tfrac{1}{3} \nabla_x \cdot (h^3 \nabla_x \Delta_x h) = 0.$$

While this is straightforward on the level of formal asymptotics, a rigorous analysis has to deal with the degeneracy of the limit which is reflected e.g. in the fact that a first-order evolution equation is replaced by a limit problem of order four. Our main techniques are uniform energy estimates in appropriately scaled Sobolev norms of sufficiently high order, based on parabolicity. This is joint work with M. Günther, Leipzig.

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LINEAR STABILITY ANALYSIS OF NONPARALLEL FLOW

A.V. Proskurin, A.M. Sagalakov

The authors investigate numerical method for solving problems of non-parallel flows stability in a channel with respect to small perturbations. The hydrodynamic stability theory in this case reduce the linearized Navier-Stokes equations to boundary eigenvalue problem for partial differential equations system. Perturbation of the steady flow submit by [1] in form

$$\psi = v(x, y)\exp^{iCt},$$

where ψ – stream function, v – disturbance amplitude, x, y – coordinates directions, C – complex phase velocity. Small perturbation can be expanded in Chebyshev series $\psi = \sum a_{ij}T_i(x)T_j(y)$. On the set of collocation points we obtain an algebraic eigenvalue problem that was solved by the standard algorithm, provided by $LAPACK$.

Computations show that modern personal computers can solve such stability problems at Reynolds numbers of order 10^3, required amount of memory depends of accuracy and algorithm optimization, but still have gigabytes volume. The increasing Reynolds number requires expanding in the number of terms N, memory volume grows as N^4.

The work was supported by Federal Special Program ¡¡Scientific and scientific-pedagogical staff of advanced Russia¿¿, contract 14.740.11.0355.

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STABILITY OF POISEUILLE PLANE FLOW IN LONGITUDINAL MAGNETIC FIELD

A.V. Proskurin, A.M. Sagalakov

The small perturbations stability of electrically conductive fluid plane flow in the presence of longitudinal magnetic field are investigated at high Reynolds numbers. Complete linearized magnetohydrodynamics system is considered. This problem is classic, but it is difficult to investigate: still absent simple and effective methods for studying instability of Tollmien-Schlichting waves in linear approximation at high Reynolds numbers and arbitrary magnetic Prandtl numbers. Efficient solution of hydrodynamic stability problems is possible only numerically and requires special techniques [1,2].

The dependence of critical Reynolds numbers by magnetic Prandtl number have studied well. Eigenvalue problem has been solving using the collocation method and the method of differential trial[1,2]. We have discovered the new branch of instability at high Reynolds numbers and the jump change of the critical Reynolds numbers.

The work was supported by Federal Special Program "Scientific and scientific-pedagogical staff of advanced Russia" contract No 14.740.11.0355.

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ON A ONSET OF VIBRATIONAL CONVECTION IN A FLUID LAYER WITH A NON-DEFORMABLE FREE BOUNDARY

O.A. Prozorov

Onset of convection in a horizontal layer of weakly non-isothermical fluid under high-frequency vibration is studied. Two models for free boundary behaviour are used namely non-deformable at the mean and on the whole. In both cases averaging procedure analogous to [1] is applied and quasi-equilibrium monotonic and oscillatory stability is studied. The dependence of neutral stability curves upon vibrational number is analyzed. Oscillatory instability is found when fluid layer is heated at the top (with negative Rayleigh number) as it's known in a system without vibration [2], where surface and internal waves were found. Also comparative studies of the models concerning free boundary behaviour are provided.

The work was supported by Russian Foundation for Basic Research, grant No. 09-01-00658-a.

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EXACT SOLUTIONS OF THERMOCAPILLARY EQUATIONS SOLUTIONS

V.V. Pukhnachev

We consider exact solutions of the Navier-Stokes and heat equations, which satisfy conditions on a free boundary, subjected the thermocapillary effect. Well known examples of such solutions (Birikh, 1966; Napolitano,

1980) detect a group-theoretical nature. Systematical search of exact solutions for equations of thermocapillary convection is based on the invariance theorem of boundary conditions on a free surface, which is unknown a priory (Pukhnachev, 1972; Andreev and Pukhnachev, 1983). Obtained solutions describe convective motion of a two-layered liquid in a rotating tube under action of longitudinal temperature gradient (Birikh and Pukhnachev, 2001), equilibrium of a vertical non-isothermal liquid film in the gravity field (Burmistrova, 2011), and deformation of liquid layer by thermocapillary forces in weightlessness conditions (Pukhnachev, 2002; Kuznetsov and Pukhnachev, 2009). In the last case, we describe different scenario of the problem solution destruction in a finite time.

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MODELING THE DYNAMICS OF ICE-RICH COASTS IN THE LENA DELTA AREA UNDER UNSTEADY CLIMATIC CONDITIONS

S.O. Razumov, M.N. Grigoriev

Rapid erosion of ice-rich, fine-grained sediments is documented in many locations along the sea shorelines and channel banks in the Lena Delta area. The coastal dynamics is related to the changes in the hydrologic and climatic characteristics: mean summer air temperature t_a, drift ice limit x, ice-free period k_b, wind wave regime (the sum of horizontal parts of tidal and nutational forces f_Σ, and average storm wind velocity u) in the coastal areas and the hydrologic regime in the estuary. Erosion rates also depend on the permafrost and morphometric characteristics along the coasts and in the shoreface (ice content L and temperature t_p of sediments, cliff height h, and sea depth z at fetch line).

A physico-mathematical model of ice-rich coastal dynamics under unsteady climatic conditions has been developed at the Permafrost Institute. This model takes into account the above driving factors and the temporal changes in coastal processes τ and outcomes in the predictive equation:

$$v_e(\tau) = \varphi(t_p, L, h) \cdot \psi(\tau, k_b, t_a, x, u, z, f_\Sigma).$$

The first function (multiplier) in the right-hand part of the equation describes the coastal resistance to external impacts, while the second part defines the erosional capacity of the water area.

ON THERMOCAPILLARY INSTABILITY IN A LIQUID COLUMN

I.I. Ryzhkov

The dynamics of fluid systems with interfaces remains a challenging problem of modern physics. In such systems, the variation of surface tension due to thermal or compositional gradient along the interface can cause convective flows in the bulk fluid. Thermocapillary effect essentially affects the process of crystal growth by floating-zone method. To study the motion of melt in the full floating zone between the feed material and crystal, the so-called liquid bridge model is often used. In this model, the fluid is placed between two cylindrical rods (hot and cold) with a common axis. The surface tension gradient due to temperature variations along the free surface drives thermocapillary flow from hot to cold rod near the free surface and in the opposite direction at the central axis. This flow is stationary for small temperature differences between the rods. When temperature difference reaches some critical value, the instability sets in as a standing or axially running hydrothermal wave (characterized by the azimuthal wave number m). Similar instability in the floating zone essentially affects the quality of the growing crystal.

The solution describing steady thermocapillary flow in an infinite liquid bridge (liquid column) was derived in [1]. Linear stability analysis of this stationary flow was performed in the subsequent work [2]. The free surface of the column was assumed to be non-deformable. Heat transfer through the free surface was characterized by the Biot number. The authors determined the critical Marangoni number Ma for modes $m = 0$ and $m = 1$. It was found that the critical Ma is increasing with the increase of Prandtl number Pr. When $\mathrm{Pr} < \mathrm{Pr}^*$, the mode $m = 1$ is critical, while for $\mathrm{Pr} > \mathrm{Pr}^*$, the critical mode is $m = 0$. The value of Pr^* depends on the Biot number. The described results are well known in the area of liquid bridge studies and the corresponding papers [1,2] are highly cited in the literature.

In this work, the linear stability analysis of steady thermocapillary flow in an infinite liquid column is revisited. The previous results [2] for the mode $m = 1$ are confirmed in the range of low Prandtl number. However, for large Pr, the true stability boundary on the plane $(\mathrm{Pr}, \mathrm{Ma})$ lies below the previously reported one. We have shown that the neutral curves on the plane (k, Ma) have two local minima (k is the axial wave number). One of these minima was known previously, while the global minimum is determined in this work for the first time. A comparison with the experimental results [3] shows that the corrected stability boundary lies closer to the experimental values. In contrast to work [2], we have shown that the mode $m = 1$ is always critical and there is no transition to $m = 0$ in the considered range of parameters.

The work is supported by Interdisciplinary project of SB RAS No. 116, and of the RFBR grant No. 11-01-00283.

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WEAKLY NONLINEAR ANALYSIS OF AN OSCILLATORY INSTABILITY OF A FLAT LAYER WITH A FREE SURFACE

A.E. Samoilova

The instability of a flat inhomogeneously heated liquid layer with a deformable surface is investigated numerically. The model proposed by D.V. Lyubimov in [1] is applied here for the purpose of correctly buoyancy consideration. The liquid is considered to be isothermally incompressible. The density dependence on temperature is included not only in the buoyancy force term but everywhere in the Navier-Stokes equation, the continuity condition and boundary conditions. The equation of state is considered to be exponential. Two-dimensional perturbations with various wavelenght is examined.

The linear analysis of instability revealed an additional oscillatory instability mode with zero Marangoni number and zero gravity.

Weakly nonlinear analysis detected the parameter region of soft instability excitation. It is showed that instability onsets in the form of traveling or standing wave.

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MODELING OF FREAK WAVES: QUALITATIVE RESEARCH AND PREDICTION

R.V. Shamin

Freak waves are studied by means of modeling of the full nonlinear equations, describing dynamics of a perfect liquid with a free surface. Theoretical and numerical studying of these equations is based on use of conformal variables [1].

During scale computing experiments qualitative characteristics of waves-murderers are received. Also stability of the decisions describing these freak waves is established. Estimations of probability of occurrence of freak waves depending on initial parameters are received. It can be used for a prediction of occurrence of freak waves [2].

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ION DISTRIBUTION IN PLASMA AT THE CONDITION OF REQUIREMENTS MAGNETRON COATING DEPOSITION

S.A. Shanin, A.G. Knyazeva

At drawing of coverings by a vacuuming-arc method by an important problem the finding of distribution of ions in a vicinity of a growing covering is. The information on distribution of the ions generated in plasma of the vacuum arc category, and on the factors influencing this distribution, has great value both for understanding of processes of formation of plasma, and for definition of a range of parameters of the ionic-plasma dusting providing reception of coverings with set properties. In the present work process of distribution of ions in the chamber magnetron installations in approach weakly ionized plasmas is modeled.

The chamber represents the cylinder of radius R_1 in which center the manipulator or a detail of radius R_2 which rotates with angular speed w is located. The stream of ions arrives the chamber from one or several sources located at level of external radius. Generally distribution of ions follows from the decision of system of the equations of indissolubility, movement, and diffusion with corresponding initial and boundary conditions.

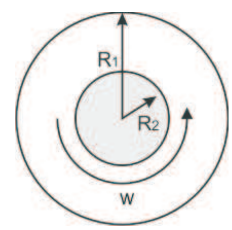

Figure 1: illustration

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ACTION OF THERMOCAPILLARY EFFECTS ON WAVY MOTION OF FALLING LIQUID FILMS

E.N. Shatskiy, E.A. Chinnov

It is known that the hydrodynamic two-dimensional waves in isothermal liquid films are unstable to three-dimensional perturbations. It was established that the wavelength of the instability to transverse three-dimensional perturbations decreases with increasing Reynolds number [1].

Except for the hydrodynamic instability that leads to the development of three-dimensional waves, there have also thermocapillary instability, when the falling film is heated. It resulted in formation of stationary three-dimensional structures: vertical rivulets separated by thin film regions of a certain width Λ on the film surface.

In [2] an experimental study of the evolution of hydrodynamic disturbances into thermocapillary-wave in a locally heated water film with a high-speed infra-red camera was performed. It was shown that temperature inhomogeneities appear on the three-dimensional hydrodynamic wave front, which through the action of thermocapillary forces lead to deformation of the liquid film and formation of rivulets.

This paper presents the results of an investigation of the evolution of the temperature field on the surface of the heated water films. It was established that temperature inhomogeneities arise in the residual layer. A characteristic wavelength of the instability corresponding to the distance between the thermocapillary-wave structures. It was shown that action of thermocapillary forces on a hydrodynamic wave leads to deformation of the liquid film, which results in the formation of rivulets.

The work was supported by youth research project IT SB RAS.

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STABILITY ANALYSIS OF BIOCONVECTION IN A FLUID POROUS MEDIUM WITH VARIABLE PERMEABILITY

E. Shchekinova, A. Kraberg, I.Bussman, M. Boersma, K. Wiltshire

Bioconvection is the phenomenon of spontaneous pattern formation by swimming microorganisms in concentrated suspensions [1]. Bioconvection patterns are observed in laboratory in shallow suspensions of upwardly swimming micro-organisms that are denser than the water [2]. Such organisms are found in Nature in saturated river sand floors, snow fields, fluidized soils.

Continuum models are set to analyze the collective hydrodynamic behavior [2]. The importance of permeability parameter on the stability of bioconvection has been postulated [2], namely it was shown that for a constant permeability not exceeding a threshold the bioconvection is stable.

In natural marine sediment the soil permeability is not constant but it decreases with the depth. Theoretical treatment of the variable permeability in a binary mixture of a saturating porous layer has been addressed recently in [3]. It was shown that with the variable permeability the thickness of the convective cell progressively confined to the top layer of a porous medium.

We will investigate the effect of the variable permeability on the stability of bioconvection in a shallow porous layer using the Darcy model with the Boussinesq approximation.

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FREE BOUNDARIES IN THE WELL-DRILLING PROBLEM WITH PROPER ACCOUNT FOR STRESSES IN A SATURATED POROUS MEDIUM

V.V. Shelukhin

During the borehole drilling, the pressure within the wellbore is higher than that within the pores of the formation. This is why the mud-filtrate invades the formation and a mudcake grows near the borehole surface. Both the invasion front and the mudcake surface are free boundaries to be determined. The study is motivated by the electromagnetic logging problem; the invasion should be taken into account to treat correctly the data of electric resistivity measurements. In earlier publications, the invasion front propagation was considered under the assumption that no deformations occur within the rock. However, rock stress affects permeability and the mud-filtrate invasion provided the borehole pressure is great enough.

A mathematical model is developed to determine both the dynamics of the rock-stresses and the fluid flows. We study the invasion front and clear up the rock elasticity effect.

HEAT AND MASS TRANSFER IN THAWING SNOW

K.A. Shishmarev

In this paper is studied the problem of heat and mass transfer in thawing snow, which is considered as the three-phase continuous environment consisting of water, air and ice. The basis of the mathematical model is based on the equation of mass conservation for each of the phases with phase transitions, equation two-phase filtration Musket-Leverett model for water and air, energy conservation equation for thawing snow [1],[2]. For this system of equations is investigated initial-boundary problem.

This work was supported by the analytical departmental target program "Development of Scientific Potential of Higher School (2009-2010)" (project N 2.2.2.4/4278), and with program "The scientific and scientific-pedagogical cadres Innovative Russia" in 2009-2013 years.

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COMPOSITION AND STRUCTURE OF MATHEMATICAL MODELS FOR RIVULET FLOWS AND PROCESSES IN SIBIRIAN RIVER ESTUARIES

V.A. Shlychkov

Physical and mathematical modeling seems to be most promising in solution the tasks of inland water formation in conditions of the Siberian North. This is due to very poor information coverage of northern territories, where hydrological stations are extremely rare. The length of time series observations is also too small to obtain statistically meaningful conclusions. Physical and mathematical models, however, serve to assess the missing information, and their structure is oriented to the available measured data.

It should be noted that development of adequate mathematical river runoff models is one of the great challenges in hydroinformatics. This is due to the complexity and diversity of processes occurring in the watershed, considerable spatial heterogeneity of Siberian territories, and high sensitivity of runoff characteristics to variations of natural factors, particularly to weather conditions.

Calculation of a substance outflow from the river channel system into the estuary should be preceded by correct reproduction of hydrodynamic parameter part of a water stream, that is, velocities, discharges, water surface slopes, bottom stresses, etc. This will provide a basis for adequate calculation of secondary process dynamics - pollution transport, dispersion, and physical and chemical transformations.

Description of hydrodynamic processes on the basis of modern concepts must rely on the complex of models, including:

- thermodynamics of snow cover;
- mass-energy exchange in soils including permafrost;

- surface slope runoff in the catchment;
- groundwater motion in water-saturated layer;
- water motion in the channel system; and
- hydrophysics of interaction between channel and sea waters in the estuary.

DYNAMICS OF SUPPORTS OF SOLUTIONS TO ANISOTROPIC PARABOLIC EQUATIONS WITH NONSTANDARD GROWTH

S.I. Shmarev

The talk addresses the question of propagation of disturbances from the data in solutions of anisotropic parabolic equations with nonstandard growth conditions. The prototype of such equations is furnished by the equation $u_t = \sum_{i=1}^{n} D_i \left(|D_i u|^{p_i(x,t)-2} \nabla u \right) + c_0 |u|^{\sigma(x,t)-2} u + f$. The anisotropy and the variable nonlinearity of the diffusion part lead to certain properties intrinsic for the solutions of equations of this type. We prove that unlike the case of isotropic diffusion the solutions vanish in a finite time even in the absence of absorption (i.e. if $c_0 = 0$), provided that the diffusion is fast in only one direction. It is shown that in the case of slow anisotropic diffusion the supports of solutions display a behavior typical for the solutions of equations with strong absorption terms: the support does not expand in the direction corresponding the slowest diffusion. For certain ranges of the nonlinearity exponents the supports are localized both in space and time. We also discuss the influence of anisotropy on the blow-up of solutions and show that for equations with variable nonlinearity the effects of finite vanishing and blow-up may happen even if the equation becomes linear as $t \to \infty$. The results were obtained in collaboration with Prof. S. Antontsev. The presentation follows the papers [1–4].

The work was supported by the Research Project MTM2010-18427 MICINN, Spain.

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DYNAMICS OF A RUPTURE OF A FLUID LAYER ON A LIQUID SUBSTRATE

A.V. Shmyrov, K.G. Kostarev

Considerable attention in studying the behavior of liquid films is given to the problem of their deformation under the action of the locally applied external force. However, investigation of this process finishes as soon as the film breaks down. Difficulties in the mathematical treatment of the resulting effects are caused by disturbance of the film continuity, whereas in experiments the problems are associated with the necessity of increasing the speed of video recording with the appearance of fast-growing rupture. The fact that the film interacts with a solid substrate adds complexity to treatment of this problem. In the case when a substrate is not used, there is still a need to take into account a contribution of the gravitational force to film deformation.

The paper presents the results of experimental studying the process of rupture of a liquid film on a liquid substrate. It has been shown that a liquid substrate eliminates the gravitational effect and slows down the propagation of rupture due to viscous friction introducing no changes in the character of the process.

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ON THE MOTION OF A BINARY MIXTURE AND A VISCOUS FLUID IN A THERMALLY ISOLATED CYLINDRICAL TUBE

N.L. Sobachkina

The invariant solution to the problem of joint motion of a binary mixture and viscous fluid with a common interface in a thermally isolated cylindrical tube is investigated. The motion is induced by longitudinal pressure gradient in a mixture. The problem reduces to solving a conjugate initial-boundary value problem for parabolic equations. Stationary solution of problem is determined and it is shown that this solution is the limiting one at $t \to \infty$ if a pressure gradient has a finite limit at $t \to \infty$. Using Laplace transformation properties the exact analytical solution was obtained [1].

We assume that the motion of a cylindrical jet of a binary mixture in an unbounded fluid is induced by longitudinal pressure gradient. It is shown that the flow is not limiting one at $t \to \infty$, because there is no inhibitory effect of a solid wall. Thus, there is an evolution of a flooded jet of a binary mixture under a pressure gradient. It also generates the unsteady motion of the surrounding liquid.

Some examples of numerical reconstruction of the velocities, temperatures and concentration fields depending on geometric and physical parameters were considered. Numerical calculations confirm theoretical conclusions [2].

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THE IMPACT OF A BOX ONTO SHALLOW WATER UNDER SMALL ANGLE

L.A. Tkacheva

Two-dimensional problem of the impact of a box onto shallow water under small angle is solved. A box falls vertically down without deformations. Initially liquid is calm, a box touches liquid surface at a single point. The rest part of liquid surface is free. Liquid is ideal, incompressible, its flow is potential. At the initial moment a box begins to penetrate the liquid layer with some velocity and liquid is displaced and flows by two jets along the box surfaces.

We suppose that the thickness of liquid layer is much smaller than the length of a box and the angle of incidence is small. Nonlinear equations of the shallow water theory are used. The flow field is divided into four regions: I is the region under box, II is the region of flow turning and jet formation, III is main part of liquid and IV is the region of the spray jet. The method of matched asymptotic expansions is used to determine liquid flow in domains I and II.

Liquid flow in the region II is built in the quasi-stationary approximation based on the conservation laws: mass and momentum and the Bernulli's equation. Flows in regions I and II are analysed and matched to each other and to the state of the rest in the region III. Then we obtain necessary relations for for the pressure and velocity determination in dependence on the box coordinates: vertical displacement and angle of incidence. As a result we have the system of nonlinear ordinary differential equations that is solved by the fourth-order Runge-Kutta method.

Numerical results are presented which show that all parameters of the problem: mass, dimensions, angle of incidence and velocity of the box, the thickness of liquid layer influence significantly on the box motion.

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STABILITY OF ELASTIC PLATE IN A GAS SHEAR LAYER

V. V. Vedeneev

Asymptotic study of elastic plate stability in a uniform supersonic gas flow [1] led to discovery of a new instability type, which has been called single mode flutter. Later a series of analytic, numerical, and experimental studies has been conducted, which confirmed existence of this flutter type [2].

In this paper influence of the gas boundary layer (of thickness δ) on the plate stability is studied as $\mathrm{Re} \to \infty$. Solving compresible Rayleigh equation (under assumption that the wave length $\lambda \gg \delta$), expressing pressure through the plate deflection and substituting the pressure into equation of the plate motion, we obtain dispersion equation:

$$\mathcal{D}(k,\omega) = (Dk^4 + M_w^2 k^2 - \omega^2) - \\ - \mu \left(\left(\frac{(M_\infty k - \omega)^2}{\sqrt{k^2 - (M_\infty k - \omega)^2}} \right)^{-1} + \left(\int_0^\delta \frac{T_0(\eta)d\eta}{(u_0(\eta) - c)^2} - \delta \right) \right)^{-1} = 0$$

The first term expresses the plate dynamics, the second one expresses the gas flow dynamics. Boundary layer is described by velocity $u_0(\eta)$ and temperature $T_0(\eta)$ profiles. Influence of these profiles and boundary layer thickness on stability boundaries of an infinite plate and of a plate of large but finite length is studied.

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METHOD OF COMPUTATION OF THE PROBLEMS OF CONVECTION ON THE BASIS OF SPLITTING INTO PHYSICAL PROCESSES

A.F. Voevodin, O.N. Goncharova

The Oberbeck - Boussinesq equations are used for study of the thermal gravitational convection in the closed domains with a fixed impermeable boundary. For numerical investigations of the flows in the 3D domains and in the 2D domains with curved boundaries a method of splitting into physical processes (Voevodin, Protopopova, 1999-2005; Voevodin, Goncharova, 2001-2009) is developed. The numerical algorithms make it possible to fulfill the no-slip and no-flow conditions on the fixed walls exactly and to guaranty the properties of solenoidality and energetic neutrality of the velocity field.

The convective and diffusive transfers are naturally extracted in the motion- and heat transfer equations. Separation of the stage of convection allows to avoid calculation of the pressure gradient and to provide correctness of the splitting for fulfillment of the boundary conditions. On the stage of diffusion the variables "vorticity - stream function" and "rotor of velocity - vector potential" are considered for the 2D- and 3D problems respectively. To realize the stage of diffusion a special variant of the sweep methods with parameters (Voevodin, Shugrin, 1981) is constructed. The second order finite difference schemes are presented. The principal order of calculations relative to the directions is established. A problem of statement of the boundary conditions for the auxiliary functions on the inner stages of the finite difference scheme is solved.

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MATHEMATICAL MODELLING OF THE ICE-THERMAL REGIME OF WATER BODIES AND SALINES

A.F. Voevonin, T.B. Grankina

One-dimensional three-layer model that describes snow-ice cover growth in different mineralized water bodies is review.

$$H > z > s(t): \quad \rho_w c_p \Big(\frac{\partial \omega T_w}{\partial t} + \frac{\partial w \omega T_w}{\partial z} \Big) = \frac{\partial}{\partial z} \omega k_w \frac{\partial T_w}{\partial z};$$

$$\frac{\partial \omega C}{\partial t} + \frac{\partial w \omega C}{\partial z} = d \frac{\partial}{\partial z} \omega \frac{\partial C}{\partial z}; \quad w = \frac{ds}{dt};$$

$$s(t) > z > 0: \quad \frac{\partial T_{ic}}{\partial t} = a^2 \frac{\partial^2 T_{ic}}{\partial z^2};$$

$$0 > z > -l_{sn}: \quad \rho_{sn} c_p \frac{\partial T_{sn}}{\partial t} = \frac{\partial}{\partial z} k_{sn} \frac{\partial T_{sn}}{\partial z};$$

$$k_w \frac{\partial T_w}{\partial z}\Big|_{z=s(t)} - k_{ic} \frac{\partial T_{ic}}{\partial z}\Big|_{z=s(t)} = \lambda \rho_w \frac{ds}{dt}, \quad T_w\big|_{z=s(t)} = T_{ic}\big|_{z=s(t)} = T_f;$$

$$C_f \frac{ds}{dt} = -d \frac{\partial C}{\partial z}\Big|_{z=s(t)}, \quad T_f = T^* - \gamma C_f;$$

$$k_{ic} \frac{\partial T_{ic}}{\partial z}\Big|_{z=o} = -k_{sn} \frac{\partial T_{sn}}{\partial z}\Big|_{z=0}, \quad T_{ic}\big|_{z=0} = T_{sn}\big|_{z=0};$$

$T_{w,ic,sn}(t,z)$ - temperature, $C(t,z)$ - salinity, $T_f(t)$, $C_f(t)$ - freezing-point and value of salinity in moving boundary of phase transformation, l - is the thickness of layer, w - velocity, $\omega(z)$ - sectional area, $s(t)$ - moving boundary of phase transformation, γ - coefficient of equilibrium, k - heat-conductivity.

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EQUATION FOR SURFACE WAVES MOVING IN ONE DIRECTION

V.E. Zakharov

Simple equation describing evolution of 1-D water waves is derived. This new equation is based on the important property of vanishing four-wave interaction for water waves. It is much more applicable then the nonlinear Schrodinger equation or the Dysthe equation.

ON THE AVERAGED EQUATIONS OF VIBRATIONAL CONVECTION AND SOME VIBRATIONAL EFFECTS

S.M. Zen'kovskaya

The term "vibrational convection" originated after the appearance of [1], where the problem of influence of high-frequency vertical oscillations of container with solid boundaries on the onset of thermal convection was formulated. In [1] the averaging method was applied to Oberbeq–Boussinesq convection equations (OB) was applied. This method allows to separate slow and fast components of unknown variables, with fast components being explicitly expressed in terms of slow components. As the result, in [1] the vertical vibrations were shown to have stabilizing influence. The approach, applied in [1], was later used in a series of works on vibrational convection. Different vibrational effects, which can allow to control convection with the help of vibration, were discovered as the result. In the case of domains with free boundaries and interfaces, with weakly nonisothermic heterogeneous fluid, the averaging method should be applied to the generalized OB equations. Then, a transition to classical OB approximation can be done. This approach was suggested by D.V. Luybimov. Vibration generated forces in equations of motion and vibration generated tensions in boundary conditions appear as the result of averaging [2]. The report will contain a short review of existing results, with explanation of new results, related to the problems of vibrational convection in areas with free boundaries.

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INFLUENCE OF HIGH-FREQUENCY VIBRATION ON THE ONSET OF THERMOCAPILLARY CONVECTION IN TWO-LAYER SYSTEM

S.M. Zen'kovskaya, V.A. Novosiadliy

The target of current research is vibrational thermocapillary convection in two-layer system of immiscible fluids with interface. In [1] averaged equations for the case of heterogenous fluids and deformable interface were derived. The spectral problem for normal disturbances was analyzed for the case of homogenous fluids. Vertical vibration was shown to smooth the interface. Current research is concentrated on the case of heterogeneous fluids, with undeformable or undeformable in average interface. These two different cases lead to different neutral curves and eigenfunctions behavior. A special attention is given to the case of heating from above.

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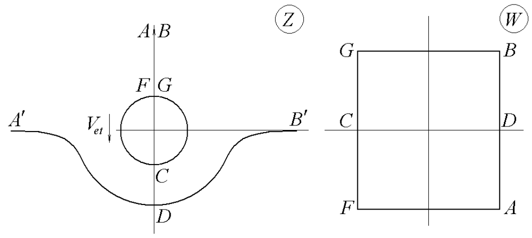
BOUNDARIES SHAPING IN NONSTATIONARY ELECTROCHEMICAL MACHINING BY ROUND ELECTRODE-TOOL

V.P. Zhitnikov, R.R. Muksimova, A.R. Salimyanov

Electrode-tool, which is a circle with a radius $R,$ is recessed into the workpiece with a rate V_{et} perpendicularly to the surface.



The problem is solved by methods similar to those which used in hydrodynamic. The interelectrode space domain on the complex potential plane $W = \varphi + i\psi$ is a rectangle, on the parametric plane is horizontal band $\chi = \sigma + i\upsilon$.

We take the function which conformally maps the band of plane χ on the IES domain of the physical plane as the sum $z(\chi, \tau) = g(\tau)\, sh\pi\chi + z_c(\xi(\chi), \tau) + z_a(\chi, \tau)$, where $z_a(\chi, \tau)$ – is a continuous on the boundary function, which defines the difference between the shape work surface from a rectilinear (in $\chi{=}\sigma{+}i$ $Im z_a(\chi, \tau) = 0$); $z_c(\xi, \tau)$ – is a continuous on the boundary function that is used to describe a form of ET (in $\xi{=}\upsilon{+}i0$ $Im z_c(\xi, \tau) = 0$).

We use the Schwartz and the Keldysh-Sedov formulas to restore the functions of $z_a(\chi, \tau)$ and $z_c(\xi, \tau)$. We find $z(\chi, \tau_j)$ and the partial derivative $\partial z/\partial\tau\,(\chi, \tau_j)$ at each time step τ_j as an analytic function of the complex parameter χ, which obey the boundary condition $Im\left[\frac{\partial z}{\partial\tau}\overline{\frac{\partial z}{\partial\sigma}}\right] + \frac{\partial\psi}{\partial\sigma} = 0$.

After the solve of system of equations and the determination of partial derivatives $\partial z/\partial\tau = q_m$ we do temporal step.

Solution's results are given as geometrical parameters dependences of processing surface on time.

EXPERIMENTAL INVESTIGATION OF THE EFFECT OF SiO_2 NANOPARTICLES IN FREON-21 ON PROPAGATION VELOCITY OF THE SELF-MAINTAINED EVAPORATION FRONT

V.E. Zhukov, A.N. Pavlenko, M.I. Moiseev

Experimental results on investigation of propagation velocity of the self-maintained evaporation front at free convection and stepped heat release on a horizontal cylindrical heating surface. Dynamics of front propagation was registered by a digital video camera with the recording speed of 15000 frames/s. According to experiments of [1] carried out on the pure liquid (Freon-21), a vapor cavity formed on the heating surface under the conditions of stepped heat release and the rate of surface heating of about 1000 K/s and higher, spreads along the heater with some acceleration. It was found out that there are two regions in the dependence of front velocity on temperature difference; these regions are characterized by different rates of a change in propagation velocity of self-maintained evaporation front. Transition to the region with stronger dependence of propagation velocity on temperature difference is connected with a loss of interfacial stability and development of fast-growing small-scale perturbations. Addition of 0.001 mole fraction of SiO_2 powder with particle size of 20-25 nm into the pure liquid increased significantly the velocity of evaporation front propagation at corresponding temperature differences.

The work was partially funded by the Integration project of SB RAS together with UB RAS (No. 68).

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LOADED COMPLEX EQUATIONS IN THE FREE BOUNDARY PROBLEMS

E.N. Zhuravleva, E.A. Karabut

The system of two linear equations

$$\frac{\partial}{\partial t}\begin{pmatrix} f_1 \\ f_2 \end{pmatrix} + A(\zeta)\frac{\partial}{\partial \zeta}\begin{pmatrix} f_1 \\ f_2 \end{pmatrix} + B(\zeta,t)\begin{pmatrix} f_1 \\ f_2 \end{pmatrix} = \vec{F} \qquad (1)$$

regarding the complex-valued unknown functions $f_1(\zeta,t) = \varphi_1 + \mathrm{i}\psi_1$, $f_2(\zeta,t) = \varphi_2 + \mathrm{i}\psi_2$ is being solved. The system is loaded, i.e. the vector of the right part $\vec{F}$ depends on the values of the unknown functions and their derivatives in the point $\zeta = 0$. In addition, it is supposed, that $f_1(\zeta,t), f_2(\zeta,t)$ are analytical functions of the complex variable ζ. This means, that besides the equations (1) also Cauchy-Riemann equations must be fulfilled. Thus we have an overdetermined system of eight equations with four real-valued unknowns.

This overdetermined system has a solution not for any matrix A. Cauchy problem for system (1) was demonstrated to be correct only in two cases: either the spur of the matrix A is equal to zero, or the ratio between $\det A$ and the second power of the spur is real-valued and does not exceed $1/4$.

The above mentioned conditions applied to the matrix A are fulfilled automatically, if the complex-valued system (1) possesses a physical meaning. Similar complex overdetermined systems naturally arise in different problems of mechanics. For example, in the problem of non-linear small amplitude gravity waves [1], or in the problem of a right angle being flowed around [2]. The new results of solving the system (1) will be produced in the report. These results describe the evolution of small perturbations on the free surface of some jet flows.

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DYNAMICS OF THE INTERFACE OF DIELECTRIC LIQUIDS IN AN ELECTRIC FIELD

N.M. Zubarev

The dynamics of the interface of two ideal dielectric liquids in an external homogeneous electric field is considered. It is shown that the special regime of motion can be realized where the velocity and electric field potentials are linearly related. Previously a similar regime of motion was studied for the initially flat interface in the normal electric field [1,2]. As it turns out, the reduction takes place in the more general case, when the initial interface and the direction of the external field are arbitrary. In particular, such an approach is used to study the behavior of a dielectric liquid drop deformed by the electrostatic forces. In the limit when the drop density is small with respect to the density of the surrounding liquid, the reduced equations are similar in shape to the equations describing the Laplacian growth process. In 2D-geometry, the equations of motion reduce to the finite number of ordinary differential equations. The surface evolution results in the appearance of a cusp in a finite time.

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EQUILIBRIUM CONFIGURATIONS OF THE SURFACE OF A CONDUCTING LIQUID IN THE MAGNETIC FIELD OF A CURRENT-CARRYING STRAIGHT CONDUCTOR

O.V. Zubareva, N.M. Zubarev

In the absence of an external magnetic field the simplest equilibrium configurations of the free surface of a conducting liquid are a plane, a cylinder with a circular cross-section, and a sphere. In the field the surface is deformed by the magnetic forces. Compensation of their destabilizing effect by capillary forces can lead to the appearance of a nontrivial equilibrium configuration of the surface. A number of similar solutions were numerically obtained in [1,2]. In the present work we have found the families of exact solutions for the equilibrium shapes of initially flat and cylindrical surfaces of the conducting liquid in the magnetic field of a set of current-carrying straight conductors which are placed along the boundary of the liquid. Our approach is based on the conformal mapping of the region above the liquid onto the upper half-plane, or onto the region exterior to the unit circle in the complex plane (previously the similar technique was used for the electrostatic problems [3]). In new variables a problem of a field distribution admits an exact solution, and the mapping function should be defined.

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