

MECHANICAL AND THEORETICAL ENGINEERING

E. N. Eremin, G. N. Minnekhanov, R. G. Minnekhanov

Improving the quality of cast metal of pipeline valves by modification of dispersed inoculators

The problem of improving the steel casting quality of pipeline valves made by electroslag casting is considered. An integrated approach to the melt preparation in electroslag casting is proposed including its deep deoxidation with a rare earth metal agent and introducing a modifying complex containing nanodispersed pyrocarbon particles, which forms a fine ferrite-pearlite structure with small globular nonmetallic inclusions located in the dendrite axes. This permits to produce castings made of wide class of steels with a high cold resistance level.

Keywords: pipeline accessories, electroslag casting, nanodispersed particles, modification, structure, mechanical properties, cold resistance.

P. V. Litvinov, V. R. Vedruchenko, V. A. Borisov, A. V. Shtib

The evaluation of serviceability of internal combustion engine with diagnostic criteria for testing modified pistons in laboratory conditions

Diagnostic practice shows that the design of an engine and its systems is complicated in order to improve its environmental safety. In this case, the diagnostics and tests necessary in this case, often, can't be carried out on an automobile engine in conditions of its actual operation. This includes the testing of pistons modified with catalytic coatings. The conditions of their testing and the criteria for diagnosis and performance are discussed in this article.

Keywords: diagnostics, catalytic coatings, reliability, errors, internal combustion engine.

D. D. Primak, I. A. Volkov, V. B. Masyagin

The application of geometric models for analysis of dimensional parameters of joint based on direct kinematics problem of robots

Modeling the assembly process is an important stage in the development of the product and assembly of the model, which is basic in the analysis of properties and the design of the product. The purpose of this study is to obtain quantitative characteristics of the dimensional parameters of joint with reference to the coordinate system in modeling of the assembly process and subsequent visualization of geometrical models of details and their joints in the Excel program, by adapting the mathematical apparatus used in the kinematics of robots to solve problems of relevance in the modeling and analysis assembly process.

Keywords: dimensional analysis, geometrical model, direct kinematics problem of robots, assembly.

ELECTRICAL ENGINEERING. POWER ENGINEERING

S. V. Biryukov, A. S. Kolmogorov, S. S. Kolmogorova

The interaction of conductive surface of cylindrical sensor with electric field of uniformly charged rectilinear filament parallel to axis of cylinder

The article gives the calculation of the surface density of the electric charge induced on the conductive surface of the shell or the sensitive electrodes of the electrical induction electric field intensity sensor of cylindrical shape. The expressions found in the scientific literature for charge density are aimed at solving electrotechnical problems and require adaptation to the solution of problems in the calculation of electroinduction sensors. Therefore, the task of this article is to obtain suitable for calculation electroinduction sensors dependences of the charge density induced on the conductive cylindrical surface of the sensor body from the geometrical parameters of the electric field and the sensor. The mathematical investigations carried out made it possible to establish the dependence of the surface density of the electric charge for the case of conducting cylinder in the field of linear charge. These dependencies are analyzed and their reliability is confirmed. The result is a new form of representation of the surface electric charge density induced on the lateral surface of a conductive cylinder.

Keywords: electric field of linear charge, linear charge, image method, charged thread, electric charge density, sensor, sensitive electrode.

V. S. Klimash, A. V. Petukhov

Electric drive with common rectifier and individual inverters of wood processing line of Amur timber processing plant

In the article the power supply system of the electric drive of a woodworking line is considered. A special feature of the electric drive is the method of connecting the autonomous inverters to the direct current source through a common link of a constant voltage. The result of using the power supply system is the saving of electricity by eliminating braking resistors from the circuit and normalizing the thermal regime in the electronic control system. The results of a study of physical processes obtained in the process of simulation modeling are presented.

Keywords: frequency converters, Autonomous voltage inverters, induction motors, rectifier total, individual stand-alone inverters for each motor, motor modes and the generator braking and the total DC voltage.

V. V. Kharlamov, Yu. V. Moskalev, V. S. Lysenko

Increasing efficiency of three-phase induction motors at power supply from single-phase electrical network

The article discusses the scheme of inclusion of three-phase induction motor to single-phase electrical network. The scheme provides a symmetrical three-phase voltage system on the stator winding. The purpose of the study is to determine the laws of changing the currents of two reactive elements that provide voltage symmetry depending on the slip of the asynchronous motor. The article presents the calculation expressions for determining the conductivity of reactive elements on the known parameters of the electric machine. As a result of the calculation, it is determined that the current of one reactive element should have a capacitive character in the entire range of the slip of the induction motor, the other-capacitive or inductive.

Keywords: three-phase induction motor, single-phase network, phase-moving element, three-phase voltage, reactive current.

A. A. Komyakov, A. V. Ponomarev, V. V. Erbes

Development of software package for determining efficiency of energy saving devices and technologies in production process of enterprise

The article is devoted to the development of a software module that allows continuous monitoring of the energy efficiency of the production process, as well as to determine the actual efficiency of the implemented electrical installations, modern energy saving devices and technologies based on fuzzy neural network models of the production process. The software module implements statistical processing of data on power consumption and the amount of work performed and convenient mechanisms for working with neural network models of the technological process.

Keywords: energy efficiency of the production process, energy saving, fuzzy neural networks, correlation analysis.

A. G. Mikhailov, O. V. Vdovin, E. N. Slobodina

Heat exchange processes in volume of fire-tube boiler with non-water heat transfer fluid

The article proposes a solution to problems associated with high-temperature heating. The main advantages of high-temperature heat transfer fluid are given. A description is given of the design of a fire-tube boiler and its main components (furnaces and a convective bundle). The process of operation of a fire-tube boiler is considered. The method of thermal calculation of the boiler in accordance with the normative method is described. The characteristic of free and forced convection and criteria describing these processes are given. There is presented criterial equation describing the heat transfer in forced and free convection for a fire-tube boiler. Based on the results of the calculated experiment, the graphs of dependence of dimensionless magnitude at free and forced convection on the heat transfer fluid temperature are constructed.

Keywords: high temperature heat transfer fluid, fire-tube boiler, natural convection, forced convection, Nusselt criterion, non-water heat transfer fluid.

D. Yu. Rudi

The problem of quality of electric power functioning of ship electric power systems

The article describes the problems of the quality of electric power functioning of ship electric power systems. The urgency of this problem is given. The importance of this problem increased directly together with the development of water transport. The objects of the technical fleet of marine power systems are particularly susceptible to the effect of conductive electromagnetic interference. Comparative analysis, given in the article, on the indicators of the quality of electricity of various standards has shown the existence of differences in requirements, which leads to downtime in work, the violation of the scientific and technical process, the marriage of products. The issue of solving the scientific and technical problem for improving the quality of electric power functioning of ship electric power systems is still not solved, which causes certain difficulties in finding the problem in a timely manner.

Keywords: problems of ship electric power systems, electromagnetic compatibility problem, conductive electromagnetic interference, power quality indicators.

A. D. Dubkova, S. Yu. Dolinger, D. S. Osipov

Methods of spectral analysis in the control system of an arc extinguishing reactor

In this article the method of automatic setup of the adjustable arc-suppressing reactor using a surge characteristic of a circuit of the zero sequence of a distributive network for determination of natural frequency and parameters of a circuit is considered. In this method it is used wavelet conversion and the nonparametric analysis for determination of natural frequency of a circuit of the zero sequence. In the article results of operation of a method of automatic setup of the arc-suppressing reactor when using different algorithms of the nonparametric analysis in case of determination of natural frequency are provided.

Keywords: control system, Petersen Coil, wavelet analysis, algorithm Berg.

V. A. Kopyrin

The technical and economic rationale embedding downhole compensators in the oil field

The purpose of the article is a discussion of economic considerations of the feasibility of incorporating downhole compensator of reactive power in oil fields with active high-debit wells. Actual and calculated parameters of power consumption of electric centrifugal pumps under consideration are given before and after compensation of reactive power inside well. It has been found that the positive energy effect of the downhole compensators varies from 3,2 to 8,2 % by reducing the loss in the electrical engineering complex of the plants. The positive economic effect varies from 174,3 to 284,1 thousand rubles for the oil wells under consideration.

Keywords: downhole compensator of reactive power, oil well, energy.

N. M. Zaytseva

Model of asynchronous motor taking into account its magnetic system saturation on basis of Takagi–Sugeno method

At present asynchronous motors are controlled by means of microprocessors. Modern microprocessor equipment makes it possible to implement any algorithm of electric drive functioning. This is why the paper examines a model of a short-circuited asynchronous motor taking into account nonlinearity of its magnetization parameter. The algorithm implementing saturation of the engine magnetic system is developed with help of Takagi-Sugeno fuzzy inference. The work describes the suggested membership functions to the intervals of the magnetization vector module and patterns of the functions describing a magnetization curve for each interval. Modeling is done using a MATLAB Simulink system. The paper offers a graphical interpretation of time-superimposed models of a short-circuited asynchronous motor taking into account saturation of asynchronous motor magnetic system realized by means of a sextic polynomial and Takagi-Sugeno fuzzy logic. The algorithms used to describe the saturation are realized using C programming language.

The obtained new scientific result can be used in programming microprocessors controlling asynchronous electric drives due to simplicity of its implementation. It is shown that energy-efficient control of modern asynchronous drives must be based on a more adequate model taking into account saturation of the engine magnetic system, which can be done using Takagi-Sugeno fuzzy inference.

Keywords: model, asynchronous motor, magnetic system saturation, membership function, fuzzy logic, fuzzy inference.

**INSTRUMENT ENGINEERING, METROLOGY
AND INFORMATION MEASURING EQUIPMENT AND SYSTEMS**

V. V. Bolotov, K. E. Ivlev, E. V. Knyazev, I. V. Ponomareva

Formation and structural studies of integrated membranes based on channel silicon

A method for obtaining structures for integrated membranes based on channel silicon is proposed. In this work features of the formation of through channels in electronic silicon are considered depending on the composition of the electrolyte, the concentration of charge carriers and anode etching regimes. It is shown that porous structures in the form of «bottlenecks» are formed under the used regimes. It has been established that in the electrolyte based on HF: C₃H₇OH, to obtain porous layers with a thickness of more than 100 μm, it is necessary to interrupt the anodic etching process, which is due to the feature of pore formation. For the electrolyte based on HF: (CH₃)₂CO, the duration of etching may be longer, which is associated with a higher solubility of hydrogen in acetone than isopropanol. The average pore diameter in this electrolyte grows more slowly with depth compared to the use of the HF: C₃H₇OH electrolyte. This effect can be explained by facilitating diffusion in the structures of not only hydrogen but also fluoride ions.

Keywords: porous silicon, scanning electron microscopy, membranes.

V. V. Bolotov, V. A. Sachkov

The influence of Van der Waals interaction on electronic structure of coupled graphene planes

The work is devoted to the study of the influence of the Van der Waals interaction on the electronic properties of the distance of paired graphene planes. Calculations are made of the «ab initio» the width of the band gap as a function of the van der Waals interaction, which is varied by shifting one plane relative to the other. The conditions for the formation of a forbidden band in the band structure of coupled graphene planes with the help of Van der Waals interaction are investigated. The results obtained are applicable for the analysis of the band structure of multi-walled carbon tubes containing defects.

Keywords: nanosensoric, carbon nanotubes, two-layer graphene, band structure, point defects, «ab initio».

N. A. Davletkildeev, D. V. Sokolov, V. V. Bolotov

Gas sensitivity of individual nanostructures based on functionalized multi-walled carbon nanotubes and metal oxides

Using the methods of scanning force microscopy, the gas sensitivity properties of individual composite nanostructures based on CNTs, functionalized by argon ions and coated with tin and titanium oxides are investigated. The Fermi level shift and the change in longitudinal conductivity upon absorption ammonia and nitrogen dioxide are determined. It is shown that the change in conductivity of the composite nanostructures to the correlates with the Fermi level shift under gases exposure as a result of charge carriers concentration changing in the metal oxide surface layers upon adsorption of gas molecules.

Keywords: carbon nanotubes, tin oxide, titanium oxide, composite nanostructures, conductivity, Fermi level, gas sensitivity.

N. A. Davletkildiev, D. V. Sokolov, E. A. Zimbovich, E. Yu. Mosur, I. A. Lobov

Study of charge transfer process in system of «hemoglobin-electrode» at level of individual molecules

The process of electron transfer through an individual hemoglobin molecule (Hb) has been studied by conductive atomic force microscopy. It is shown that the current through the Hb molecule arises at applied force equal 45 nN. According to estimates, the height of the deformed molecule is 4,5 nm. Based on the analysis of the experimental I-V characteristic of the probe/Hb/substrate contact using of the non-resonant tunneling transport model, the parameters of tunnel electron transport through the individual Hb molecule are determined.

Keywords: hemoglobin, conductive atomic force microscopy, electronic transport, non-resonant tunneling.

S. N. Povoroznyuk, V. E. Roslikov

Modification of porous silicon using pulsed ion beam of nanosecond duration

The effect of a pulsed ion beam of nanosecond duration on the morphology, chemical composition, and electronic structure of porous silicon is studied. The gas sensitivity of the initial and irradiated samples is studied under exposure to NO₂ and degassing in air. Its degradation is assessed over time. It is established that both the initial and irradiated samples have a sensitivity to NO₂. In the case of the initial porous silicon, it disappears after 6 months, and in irradiated silicon it decreases after 3 months and then remains practically at the same level. This is a consequence of the formation of a passivating film, which prevents the degradation of the composition and properties of porous silicon when it comes into contact with the environment. The presence of such a film, represented by a SiO₂, is confirmed by X-ray photoelectron spectroscopy (XPS) data.

Keywords: porous silicon, X-ray photoelectron spectroscopy, pulsed ion beam, gas sensitivity.

E. V. Knyazev, K. E. Ivlev, V. E. Kan

The impact of ion beams and thermal annealing on the structure and electrophysical properties of individual multi-walled carbon nanotubes and their ensembles

The effect of irradiation with argon ions and thermal treatments on the formation of a defect structure and the electrophysical properties of multilayer carbon nanotubes (MWNTs) is studied. The methods of transmission electron microscopy, Raman spectroscopy and electrophysical measurements establish the formation of stable topological defects, which determine a sharp decrease in the conductivity of MWCNT after irradiation and thermal annealing. The possibility of using a set of ion irradiation and temperature annealing methods to change the conductivity of nanotubes is shown.

Keywords: functionalization of carbon nanotubes, carbon nanotubes, ion irradiations, thermal annealing, transmission electron microscopy, raman spectroscopy, density Functional Theory.

E. V. Knyazev, V. E. Kan, V. A. Sachkov

The influence of vacancy defects on the structural properties of single-walled carbon nanotubes

The work is devoted to the theoretical substantiation of the directional change in the structure of SWCNTs under ion irradiations of Ar⁺⁺. It is shown that the introduction of vacancy defects in the structure of the graphene sheet leads to a significant change in its geometric characteristics. The

values of the bends of graphene sheet are given depending on the number of vacancy defects. The data of theoretical calculations are confirmed by experimental studies of SWCNT using the methods of Raman spectroscopy and transmission electron microscopy.

Keywords: Nanosensorics, Carbon Nanotubes, Ion Irradiations, Transmission Electron Microscopy, Raman Spectroscopy, Density Functional Theory.

P. M. Korusenko

Ion-beam modification of composite based on multi-walled carbon nanotubes and tin dioxide

Using the methods of transmission electron microscopy (TEM), energy dispersive X-ray analysis (EDA), and X-ray photoelectron spectroscopy (XPS), there are analyzed changes in the morphology, phase composition, and chemical state of a composite based on multiwalled carbon nanotubes and tin oxide (SnO₂/MWCNTs) modified by pulsed ion beam of nanosecond duration. It is shown that irradiation of the composite leads to a change in the chemical state of nanoparticles of tin oxide, their redistribution and fixation on the surface of MWNTs. A significant decrease in the average size of tin oxide nanoparticles from ~120 nm to ~15 nm is established, which is explained by the heating, dissociation and evaporation of SnO₂ under the action of an ion beam, followed by vapor deposition on the surface of carbon nanotubes.

Keywords: multiwalled carbon nanotubes, composite, tin oxide, ion beam irradiation.

P. M. Korusenko, S. N. Nesov, S. N. Povoroznyuk

The change in electronic structure of oriented multilayer carbon nanotubes under action of pulsed ion beam of nanosecond duration

Using the equipment of the Russian-German channel of the RGL station (BESSY II, Germany), the Kratos Axis Ultra DLD laboratory spectrometer and the transmission electron microscope, data are obtained on the chemical state of MWCNTs and their structure after irradiation with a pulsed ion beam of nanosecond duration. It is shown that pulsed ion irradiation leads to the formation of new structural formations: thin nanotubes with an outer diameter of ~5 nm, structures up to ~20 nm in size, consisting of encapsulated iron clusters in a graphite shell, and also of a onion-like carbon with a characteristic size of ~5 nm. The formation of new structures is one of the reasons for the increase in the fraction of carbon atoms in sp³-hybridized in the surface layer of MWCNTs.

Keywords: multilayer carbon nanotubes, pulsed ion beam, X-ray photoelectron spectroscopy, X-ray Auger-electron spectroscopy, Onion-like carbon, sp³.

I. A. Lobov, I. K. Shulus

The effect of synthesis time on morphology and electronic structure of polyaniline

The paper investigates the morphology and electronic structure change of polyaniline as a function of the synthesis time. It is shown that the band gap of a polymer decreases with increasing duration of the synthesis time due to a change in the number of electronic states in a growing molecular coil. It is shown, that a longer synthesis provides a large amount of work function as a result of an increase in the protonation degree of polyaniline.

Keywords: polyaniline, synthesis time, atomic force microscopy, spectrophotometry, band gap, work function.

S. N. Nesov

The use of ion-beam treatment to activate the surface of multi-walled carbon nanotubes in the formation of nanocomposites with tin oxide by chemical gas-phase deposition

The possibility of activation of the surface of multi-walled carbon nanotubes by irradiating them with a beam of 5 keV argon ions in the formation of composite with tin oxide ($\text{SnO}_x/\text{MWCNT}$) by gas-phase chemical deposition is studied. The analysis of the structure and chemical state of the formed composites is carried out using synchrotron radiation by X-ray photoelectron spectroscopy (XPS) and X-ray absorption spectroscopy (XANES). The results obtained showed that the preliminary treatment of MWCNT by argon ions leads to the formation of oxygen-containing functional groups on their surface that act as interphase interaction centers during the subsequent formation of the $\text{SnO}_x/\text{MWCNT}$ composite.

Keywords: multi-walled carbon nanotubes, tin oxide, ion-beam treatment, X-ray photoelectron spectroscopy.

E. A. Roslikova, V. E. Roslikov, K. E. Ivlev

Gas-sensitive properties of por- $\text{SiO}_2/\text{SnO}_x$ multilayer structures

Multilayer structures based on macroporous silicon and tin oxide with platinum are obtained. By scanning electron microscopy (SEM), it is found that tin oxide uniformly covers the surface of macroporous silicon. The EDA data shows the existence of platinum in the nanocomposite. Investigation of gas sensitive properties shows that the obtained test structures with platinum have a higher sensitivity to CO and CH_4 gas molecules at a temperature of 150 °C than structures with tin oxide without platinum.

Keywords: porous silicon, multilayer structures, tin oxide, gas sensitive properties.

V. E. Roslikov, E. A. Roslikova, Yu. A. Stenkin, S. N. Povoroznyuk

Formation of nanocomposite structures based on irradiated nanotubes and metal oxides and investigation of their chemical sensitivity

Nanocomposite structures based on irradiated Ar + ions of multiwalled carbon nanotubes (MWNTs) and metal oxides (SnO_x and TiO_{2-x}) are obtained. By scanning electron microscopy (SEM), it is found that metal oxides uniformly cover MWNTs. The study of electrophysical and gas sensitive properties shows that the resulting test composite structures have a higher sensitivity to the molecules of gases NO_2 and H_2S at room temperature than the layers of MWCNs not modified by metal oxides.

Keywords: multiwalled carbon nanotubes, nanocomposite structures, tin oxide, Titanium oxide, ion beam irradiation.

D. V. Sokolov, N. A. Davletkildiev, I. A. Lobov

Determination of electrical parameters of individual multiwalled carbon nanotube using scanning probe microscopy techniques

Based on the combination of conductive atomic force microscopy (C-AFM) and electrostatic force microscopy (EFM), the electrical parameters of undoped, nitrogen- and boron-doped individual multiwalled carbon nanotubes (CNTs) have been determined. The longitudinal electric resistance of CNTs is obtained using C-AFM. The determination of diameter, length and work function in CNT

is based on the analysis of EFM data. Using two techniques of scanning probe microscopy, electrical conductivity, free carriers concentration, carriers mobility of individual multiwalled CNT are evaluated.

Keywords: carbon nanotubes, conductive atomic force microscopy, electrostatic force microscopy, electrical parameters, work function, conductivity.

INFORMATION TECHNOLOGY

A. V. Myshlyavtsev, M. D. Myshlyavtseva

Transfer matrix simulation of hard-core lattice gases on triangular lattice with up to third-neighbour exclusion

The hard-core lattice gas on a triangular lattice with up to third-neighbour exclusion has been simulated by the transfer matrix method. To calculate the transfer matrix a special algorithm for generating rings is used. The algorithm is based on the selection of admissible states of rings directly in the process of their construction. This approach allows us to increase the available sizes of rings. Isotherms have been constructed for all three models. For the first and second models, the previously obtained results are reproduced. For the third model, it is found that there is a first-order phase transition and the unit cell size of the ordered phase is equal to seven.

Keywords: phase transitions, transfer matrix method, triangular lattice, hard-core lattice gas.

A. V. Myshlyavtsev, M. D. Myshlyavtseva, V. F. Fefelov

Adsorption model of non-additive binary gas mixture on square lattice: attraction between molecules of different types

Adsorption of binary gas mixtures on the lattice of solid is of considerable interest both from the practical and the theoretical points of view. The simplest theoretical model taking into account the lateral interactions between adsorbed molecules is a lattice gas model with nearest-neighbor interactions. We have done complete analysis of the ground-state phase diagram for this model on a square lattice taking into account nearest-neighbor attraction between molecules of different types and arbitrary interactions between one type molecules. Regions of phase stability are determined using the principle of grand potential minimum. As a result we have constructed a partition of the model parameter plane into 14 regions differing by the type of the phase diagrams.

Keywords: adsorption, binary gas mixtures, lattice gas model, phase transitions, ground state.

E. Yu. Andieva, E. M. Guryeva, V. A. Mikhailov

About problem analysis of sufficiency of technology stack for solution development in field of industrial automation

The problem of forming effective «digital» organization of the base of engineering knowledge of IT-projects specifies objective to form special environment for accumulating the base of the best engineering practices. The article contains extensive analysis of technology platforms used to provide the ecosystem of forming the base of engineering practices in field of digital solutions I4.0. The article is devoted to main problems in provision of ecosystem of solution development of industrial automation taking into account features of the global changes in the field of digital engineering practices. It is revealed in studies that there are number unsolved challenges related to being far behind in provision of ecosystem's development of integral solutions at industrial

automation. Solutions that encompassed majority of system life cycle processes are foreign and proprietary.

Keywords: Industry 4.0 (I4.0), ecosystem, systems engineering, engineered system, digital engineering practices.

N. R. Storozhenko, A. I. Goleva

The development of mathematical model of process of information system monitoring

In our time, the development of information networks requires high availability, performance and fault tolerance. To achieve the best performance of these parameters there is a need in monitoring them. The article proposes the most relevant states in the process of network monitoring. With the help of the Markov chains there is developed a mathematical model that considers the dependence of probability of events on time and describes the process of monitoring the faulty parameters of network equipment. The method of probabilistic forecasting of the state of total network failure is proposed.

Keywords: probabilistic prediction, information system, mathematical model, monitoring of network parameters, reliability of network resources.

L. G. Varepo, A. V. Panichkin, O. V. Trapeznikova, M. D. Myshlyavtseva, I. V. Nagornova

Modelling of viscous incompressible fluid transfer with computer-generated graphics of the deformation in contact zone

The results of numerical modelling including computer-generated graphics of deformation within a viscous incompressible fluid layer at the transfer process onto a substrate between contacted cylinders are presented. The modelling is performed using developed algorithm of numerical calculation of Navie-Stocks evaluations for the viscous incompressible fluid on a two-dimensional mesh grid by finite-difference methods with additional computation of moving borders taking into account fluid splitting, fluid microdrops formation and contacting surfaces deformation due to pressure difference. A laminar type of the viscous incompressible fluid flow at a surfaces contact point in case of a permanent cylinder rotation is considered. It is noted that the program implementation of the developed algorithm as exemplified by a printing system allows to automate ink transfer coefficient estimation and also to predict printing system parameters.

Keywords: algorithm of numerical calculation, computer-generated graphics, Navie-Stocks evaluation, finite-difference methods, surface, deformation, viscous incompressible fluid.