CONTENTS

SUMMARY. KEYWORDS

MECHANICAL AND THEORETICAL ENGINEERING

P. D. Balakin
Systematics of means of vibration isolation in technogenic systems

Omsk State Technical University, Omsk, Russia

The periodic nature of natural and man-made processes, the parametric properties of objects and the physical laws of interaction of material bodies and media affect non-useful vibrations of mechanical systems. Vibrations of small amplitude and high frequency are called vibrations, the weakening or elimination of which form a system of vibration protection of machines, part of which is vibration isolation. Decomposition of the General problem of vibration isolation helps to choose technical and engineering solutions of vibration isolation devices for basic, inter-unit connections, and for personnel. The article is intended for developers of vibration isolation tools, students, postgraduates and researchers whose interests include machine dynamics, vibration protection and vibration isolation of machines.

Keywords: vibration protection of machines, criteria for the effectiveness of vibration isolation, the model of the vibration isolator, basic, inter-unit connections, vibration isolation of personnel.

I. N. Ganiev, A. E. Berdiev, N. A. Aminova, S. J. Alikhonova
Improving anticorrosive properties of coatings based on zinc alloy TsAMSv4-1-2,5 doped with strontium

Russian-Tajik (Slavic) University, Dushanbe, Republic of Tajikistan

The results of an experimental study of the effect of strontium on the anodic behavior of the Tsam 4-1-2,5 alloy in the NaCl electrolyte medium are presented. It is shown that strontium additives reduce the corrosion rate of the initial alloy Tsamsv4-1-2.5 by 10 %. With an increase in concentration of chloride ion in the NaCl electrolyte, the corrosion and pitting potentials shift to the negative region, and the corrosion rate increases.

Keywords: zinc alloy Tsam4-1-2,5, potentiostatic method, NaCl electrolyte, strontium, free corrosion potential, corrosion rate, pitting potential.

S. S. Kudryavtseva, M. V. Shinkevich
Evaluation of effectiveness of resource-saving technologies in machine-building industry

Kazan National Research Technological University, Kazan, Russia

The article analyzes the effectiveness of the use of resource-saving technologies in machine-building complex. With the transition of production and business systems to work in the context of the formation of the sixth technological order, issues of increasing the efficiency of production processes acquire special significance and relevance. The purpose of the article is to summarize the main trends in the implementation of resource-saving technologies at the enterprises of the machine-building complex of the economy and the development of a mathematical model to assess the effectiveness of the use of resource-saving systems. The presented results of the study are of great economic importance not only for the machine-building complex as a whole, but can also be used by individual enterprises in the real sector of the economy to assess the level of effectiveness of implemented and used resource-saving technologies expressed through the increase in added value.

Keywords: reduction of energy intensity of GDP, reduction of losses in factory electricity networks, energy consumption per worker, descriptive statistics of energy intensity of industrial complex, structure of electricity consumption by electrical balance, share of electricity consumption in total electricity consumption.

E. S. Gebel, E. A. Chigrinova
Optimization kinematic synthesis of four-link linkage mechanism in two preset positions

Omsk State Technical University, Omsk, Russia

The widespread use of flat articulated four-link mechanisms in various automatic devices and devices requires the further development of automated kinematic synthesis methods, which, based on modern mathematical approaches, will reduce the required amount of a priori information and obtain an exact solution. The approach of the best quadratic approximation of functions used in the article made it possible to formulate both the optimality criterion and the conditions for its achievement on the basis of the equation of closure of a vector contour.
The analysis of the model showed that on its basis it is possible to evaluate the presence of singular positions of the links at which a spontaneous change in the law of motion of the output link is possible. A numerical experiment in the MathCAD package made it possible to verify the synthesis methodology based on the results of solving the kinematic analysis problem and the graphical representation of the connecting rod curves.

Keywords: flat connecting rod mechanism, kinematic synthesis, quadratic approximation of functions, modeling.

I. A. Volkov, D. D. Primak, V. B. Masyagin, R. L. Artykh
The assembly sequences modeling using graph incidence matrix

Omsk State Technical University, Omsk, Russia

The article discusses the problem solution of computer aided determination of the precision axisymmetric products assembly sequence. The aim of this work is to consider the possibility of using a directed assembly graph, in particular, an adjacency matrix and an incidence matrix in the theoretical description of the construction and design of the assembly technology. This approach corresponds to solving the problem in mathematical form. The analysis of the features of mathematical modeling of the construction and the assembly process is performed. The method for constructing a graph that displays the relationships between parts and the assembly process is proposed. Implementation the task of automated formation the assembly process is performed using algorithms and a computer program based on the matrix representation of graphs. A comparative analysis of the results obtained theoretically and using computer in the framework of assembly processes design is performed. The obtained results makes it possible to quickly enter the necessary changes in assembly sequence, thereby possibility emerges of monitoring data and decisions when designing assembly processes.

Keywords: assembly simulation, assembly unit graph, graph tree links, algorithm, adjacency matrix, incidence matrix.

D. D. Primak, I. A. Volkov, V. B. Masyagin, R. L. Artykh
Development of methodology for geometric tolerances analyzing during assembly based on adaptation of mathematical apparatus of robot kinematics inverse problem

Omsk State Technical University, Omsk, Russia

Information about the assembly process is directly influenced to the product accuracy. A modeling technique based on the schematization of the assembly process information for predict the product accuracy is proposed. Information about assembly deviations is displayed by the geometry deviations in contact points, the propagation of deviations between parts and the direction of deviations propagation. A schematic connection is established between the assembly process information and the

deviations propagation information, a technique for precision assembly modeling include a method based on adapting the mathematical apparatus used in the kinematics of robots and a methodology for influencing of assembly deviations transitions.

Keywords: assembly process, dimensional parameters, geometrical model, geometry deviations, set of bases, form deviation.

ELECTRICAL ENGINEERING

A. A. Tatevosyan
Determination of conditions for optimal control of linear magnetoelectric drive of low-speed single-stage piston compressor

Omsk State Technical University, Omsk, Russia

During designing a linear magnetoelectric drive (LMEP), which includes a permanent magnet synchronous driver (SDPM) and the compressor stage, much attention is paid to reliability and efficiency while ensuring high rates of energy conversion processes occurring in various subsystems. One of the areas that increase the reliability of LMEP is to reduce the number of elements included in its composition, for example, transmission and converting mechanisms. However, in this case, nonlinear suction-discharge processes occurring in the compressor stage have a significant effect on the operation of the electromechanical converter. In this connection, the task of increasing the energy efficiency of LMEP can be solved in various ways. The article describes the control conditions for the LMEP of a low-speed single-stage reciprocating compressor obtained from solving the problem of optimizing the design of the SDPM magnetic system at which maximum efficiency is achieved. The relationship of the generalized parameters of the drive with the design features of the SDPM design is established.

Keywords: linear magnetoelectric motor, magnetic field, magnetic system, low-speed synchronous magnetoelectric machines, low-speed single-stage piston compressor.

O. V. Arkhipova
Principles and tools of research of regionally isolated electrotechnical complex from the standpoint of system analysis

Yugra State University, Khanty-Mansiysk, Khanty-Mansi Autonomous Okrug − Yugra, Russia

The article discusses the application of system analysis in research of regionally isolated electrotechnical complexes (RIEC) and electrical generation systems with common signs. For such aggregates from the standpoint of system analysis, the concept of a regionally isolated electrical complex is introduced. It is proved that the analyzed electrotechnical complex is a complicated technical system. In relation to a regionally isolated electrotechnical complex a meaningful interpretation of the following principles of the theory of system analysis is given: emergence, optimality and equifinality. Based on a system approach, an integral indicator of the average net present cost of electricity generation is proposed (levelized cost of electricity in the region — LCOER).
This indicator is directly applicable to the object considered in the article. On basis of the LCOER indicator, a methodology for the optimal design and operation of a regionally isolated electrotechnical complex is proposed. Its application reduces the total costs of a regionally isolated electrotechnical complex throughout the entire life cycle by $5-15$ %, while maintaining the given volumes, quality and reliability of electric energy production.

Keywords: system analysis, regionally isolated electrotechnical complex, complicated technical system, net present value of electricity generation, optimization.

G. A. Koschuk, K. I. Nikitin,
A. S. Tatevosyan, N. A. Tereshchenko
Procedure for optimization calculation of structures of suspended electromagnetic separators

Omsk State Technical University, Omsk, Russia

The article is devoted to the technique for optimizing the structures of suspended electromagnetic separators based on the minimum weight of active materials used for their manufacture. Optimization procedure is based on output of equations of relationship of design parameters of electromagnetic separators to specified criteria. During development of the optimization technique there is used the assumption of the plane-parallel nature of the magnetic field under the pole tips of the electromagnetic separator, thanks to which the formula for magnetic force at the middle of the inter-pole gap is derived. The effect on the maximum magnetic force of the length of the pole tips, the inter-pole gap and the height of the suspension of the electromagnetic separator has been investigated. Based on the developed optimization methodology, an algorithm for calculating optimal structures of suspended electromagnetic separators has constructed.

Keywords: magnetic force, inter-pole gap, pole tips, optimization ratios, minimum mass of active materials.

A. A. R. Rahim[1], S. N. Kladiev[1], S. Saeidi[2]
Comparative analysis of control methods with predictive models of six-phase permanent magnet synchronous motor

[1]Tomsk Polytechnic University, Tomsk, Russia
[2]SOBEK Drives GmbH, Rottenburg-Heilfingen, Germany

This article presents a comparison of the performance of the six-phase permanent magnet motor (PMSM) based on two control methods: continuous control set model predictive control (CCS-MPC) and a finite control set model predictive control (FCS-MPC). The basic concepts and principles of control systems for synchronous motors with permanent magnets are examined, their behaviors are studied to compare the effectiveness of these methods. The CCS-MPC method is studied on a simulation model of dual three-phase PMSM for the first time, unlike the previously used FCS-MPC control method. The simulation results are presented in the form of graphical dependencies. Analysis of the results shows that when using the CCS-MPC method, the state variables accuracy controlling of the drive is higher, dynamic errors are less, although the speed of the FCS-MPC method is higher.

Keywords: model predictive control, dual three-phase synchronous machine, voltage source inverter, transient characteristics.

INSTRUMENT ENGINEERING, METROLOGYAND INFORMATION MEASURING EQUIPMENT AND SYSTEMS

S. V. Biryukov[1], E. G. Glukhoverya[1], A. V. Tyukin[2]
Comparative analysis of flat multi-element electric field strength sensors with round base and various design features

[1]Omsk State Technical University, Omsk, Russia
[2]Siberian State Automobile and Highway University, Omsk, Russia

The article provides a comparative analysis of multi-element sensors of an electric field of a flat shape differing in various configurations of sensitive elements, each of which is determined by its design parameters. For this, a generalized mathematical model of the sensor is compiled taking into account its design parameters which affect the error from field inhomogeneity and the spatial range of measurement. Using a generalized mathematical model, graphs of the sensor error are constructed depending on the spatial measurement range and various design parameters of its sensitive elements. The change in design parameters allowed us to model sensitive elements in the form of quadrants and truncated quadrants of a circle. According to the error graphs, it is established that sensitive elements made in the form of quadrants of a circle provide the sensor with a lower error and a larger spatial range of measurement, therefore their use is more appropriate. The studies performed allowed us to obtain the following technical results. Sensors with sensitive elements in the form of a quadrant of a circle have a minimum of an error and a maximum of a spatial range of measurement at design parameters: $b = 0$ and $b_0 = 0,2$; $b = 0$ and $b_0 = 0.4$, for which, with a maximum spatial range of measurement equal to unity ($a = 1$), the errors are respectively minus 3 % and minus 10 %.

Keywords: multi-element disk electric field sensor, uniform field, inhomogeneous field, point source, electric field strength, sensing element, error from field inhomogeneity, spatial measurement range.

V. V. Bolotov,
K. E. Ivlev, I. V. Ponomareva
**Macroporous layers formation on n-Si substrates in
an HF-containing electrolyte adding HCl**

Omsk Scientific Center of Siberian Branch of Russian Academy
of Sciences Omsk, Russia

Adding an oxidizing agent to a solution of hydrofluoric acid significantly changes the process of electrochemical etching, because allows to accelerate the dissolution of electron silicon.
In this work, we studied the formation process and morphology of macropores in high-resistance n-Si depending on the concentration of HCl in the HF: C_2H_5OH electrolyte. It is shown that the presence of HCl leads to a more uniform pore diameter distribution both at the surface and in the layer depth, and the increase in etching rate. With an increase in HCl concentration, a narrower pore diameter distribution is observed; the main pores near the surface approximate in size to the pores in the depth of the porous layer.
The results are explained by the action of HCl as an oxidant.

Keywords: porous silicon, electrochemical etching, electron microscopy.

K. K. Kim[1],
A. A. Tkachuk[1], A. A. Kuznetsov[2]
**Stands for measuring losses and critical parameters of
superconducting samples in external magnetic fields**

[1]Emperor Alexander I St. Petersburg State Transport University,
Saint Petersburg, Russia
[2]Omsk State Transport University, Omsk, Russia

In the development of any superconducting magnetic system, an important role is given to the values of losses in the superconductor and its critical parameters (critical current density and induction) under real operating conditions (when the superconductor is exposed to alternating and constant magnetic fields). Due to the complexity of the physical processes taking place in a superconductor and the design of modern superconducting magnetic systems, this problem is difficult to solve. In this regard, two experimental stands have been developed that allowing to study the parameters of a superconductor under the influence of external factors.

Keywords: superconductor, critical parameters of superconductor, magnetic field, loss power measurement, calorimetric method for power determining.

I. A. Kirovskaya[1], E. N. Kopylova[1],
E. V. Mironova[1], A. O. Ekkert[1],
R. V. Ekkert[1], O. V. Kropotin[1],
V. I. Krasheninin[2], Yu. I. Matyash[3]
**New materials — primary converters of semiconductor
measuring cells based on InAs-CdTe system**

[1]Omsk State Technical University, Omsk, Russia
[2]Kemerovo State University, Kemerovo, Russia
[3]Omsk State Transport University, Omsk, Russia

Using the method developed with reference to the InAs-CdTe system taking into account its condition diagram and the primary bulk physical, physical and chemical properties of the initial binary compounds (InAs, CdTe), the new materials have been obtained — solid solutions $(InAs)_x(CdTe)_{x-1}$.
Based on the results of X-ray studies in combination with the results of micro-, electron-microscopic studies, the obtained solid solutions are certified as substitution solid solution with the cubic structure of sphalerite.
The acid-base properties of the surfaces of the InAs-CdTe system components have been studied: the pH values of the isoelectric state — pH_{iso} — have been found, indicating that the surfaces belong to a weak-acid region ($pH_{iso}<7$).
The interconnected patterns in changes with the composition of the studied bulk and surface properties, respectively, the relationship between them have been established. The experimentally confirmed forecasts have been made concerning the possibilities of a preliminary assessment of the nature of the ρ_r concentration dependence and the increased sensitivity of the components surfaces of the studied system to the main gases. The practical recommendations are given on the use of the obtained new materials as primary converters of measuring cells for trace impurities of main gases, in particular ammonia.

Keywords: new materials, solid solutions, crystal-chemical, structural, acid-base properties, interconnected patterns of changes of the studied properties, forecasts, practical recommendations, measuring cells.

L. O. Shtripling, V. V. Bazhenov,
N. S. Bazhenova, P. E. Nor
Improving air monitoring system in the city

Omsk State Technical University, Omsk, Russia

Despite the fact that the majority of large industrial enterprises in Omsk comply with environmental legislation, the problem of air pollution is acute in the city. The expansion of the network of air pollution observation posts allows us to improve the quality of determining background pollution, but it is not able to answer the question of who is to blame for excess air pollution. The article presents the development aimed at improving the existing monitoring system, which allows, on the one hand, to determine the level of pollution at any point in the area, and, on the other hand, to quickly respond to complaints from the population about the violation of atmospheric air quality and identify sources of excess emissions in the city.

Keywords: air pollution, atmospheric monitoring, search for the source of pollution, excess emission, localization of the source of pollution.

R. B. Burlakov
**Photocell with two Schottky barrier contacts Al-p-Siand ohmic
silicide contact**

Dostoevsky Omsk State University, Omsk, Russia

Way of the fabrication and results of studies of photoelectric features of photocell with two Schottky barrier opaque contacts Al-p-Si on one party of the silicon plate and ohmic silicide contact Ni_2Si-p-Si (or Pd_2Si-p-Si) situated on the opposite party of the plate are cconsidered. It is shown that explored photocell can be used for the transformation of the energy of the radiation in the electrical energy at room temperature in near infrared region of the spectrum $(0,8-1,4)$ micron. This characteristic of the designed photocell will allow to increase its application. Photocell possesses a simple structure and technology with a time of its fabrication in the interval $(2,5-3)$ hour.

Keywords: method of fabricating the photocell, p-type silicon, Schottky barrier contacts Al-p-Si, silicidecontact Ni_2Si-p-Si, silicidecontact Pd_2Si-p-Si.

E. V. Leun
**On construction of laser acousto-optical heterodyne
interferometers with push-pull measurement of product motions**

Lavochkin Association, Moscow region, Khimki, Russia

The article discusses the implementation of a differential push-pull measurement method using a phase interpolator and a phase meter in an acousto-optical (AO) heterodyne laser interferometer of displacements (in future — a laser interferometer). To reduce the noise level in the measuring signal, a phase locked loop system with a small jitter has been introduced. In the first measure at the beginning of the object's movement due to the high accuracy of the phase meter, so-called «slow precise» measurements with high resolution, up to $\approx\lambda/10000$, where λ is the wavelength of the laser radiation. For high-speed object motion the clock of «fast rough» measurements is used when the high-speed phase interpolator is running and the phase meter is locked. This push-pull principle of operation of the laser interferometer improves the dynamic and metrological parameters of object motion measurements.

Keywords: laser interferometer, adaptive interferometer, phase shift, phase interpolator, phase meter, a phase locked loop, signal noise, jitter.

S. N. Povoroznyuk, V. E. Roslikov
Morphology and gas sensitivity of nanocomposites based on porous silicon and tin oxide formed using nanosecond pulsed ion beams

Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia

For the first time, the morphology of the surface layers of porous silicon, as well as composites based on them formed using high-power pulsed ion beams of nanosecond duration (PIB) with different exposure ratios are analyzed. The results showed that a single radiation exposure is the most rational regime for both porous silicon and composites. With this modification, surface structures are characterized by higher por-Si and SnOx crystallinity and uniformity. The gas sensitivity of the structures formed using PIB to nitrogen dioxide as well as the process of its degradation over time is studied. It is found that the most promising of all structures is a por-Si/SnOx composite irradiated with a single PIB pulse. It has the best gas sensitivity after creation and, with time, is less susceptible to aging, thus, being the most stable.

Keywords: porous silicon, nanocomposite, scanning electron microscopy, pulsed ion beam, gas sensitivity.

Yu. A. Stenkin, S. N. Nesov,
D. V. Sokolov, P. M. Korusenko
Functionalization of multi-walled carbon nanotubes by oxidizing agents

Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia

The influence of an oxidizing solution on the structure and chemical state of multi-walled carbon nanotubes (MWCNTs) is investigated. The changes elemental composition of MWCNTs surface is studied by X-ray photoelectron spectroscopy. Quantitative and qualitative analysis of functional groups on the outer walls of MWCNTs under various oxidation conditions is carried out. It is shown that the use of various oxidizing agents for nanotubes treatment allows to effectively influence on the composition of the functional groups, and therefore to affect physicochemical properties of MWCNTs.

Keywords: multi-walled carbon nanotubes, X-ray photoelectron spectroscopy, functional groups.

Yu. A. Stenkin, D. V. Sokolov, V. V. Bolotov
Gas sensing properties of multicomponent systems based on oxides of manganese, copper and yttrium

Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia

The composites based on manganese oxide (MnO_{2-x}), copper oxide (CuO) and yttrium oxide (Y_2O_3) are obtained. The gas response and selectivity of multicomponent composites to toxic and hazardous gases are found. Enhanced gas response of MnO_{2-x}/CuO composite to hydrogen sulfide and methylcyan are observed as compared with as-grown manganese oxide. Doping of MnO_{2-x} by yttrium oxide instead of copper oxide leads to changes gas-sensing properties of the composite to hydrogen sulfide, formaldehyde and sulfur dioxide. The presence of copper and yttrium oxides in MnO_{2-x} increases the response to ethyl alcohol vapors.

Keywords: manganese oxide, copper oxide, yttrium oxide, gas response.

A. S. Golosnoy
Experimental determination of limiting range of vision for underwater laser system

VNIIOkeangeologia, Saint-Petersburg, Russia

Modern tasks of improving the quality of underwater research results require the use of innovative solutions. One of the modern directions is the development of informative channels based on laser systems for underwater vision. The objectives of the study, in the presented work, are: substantiation of the use of a laser informative channel for mapping the bottom surface; evidence of the calculation of the limiting range of visibility of the laser system through the transfer functions characterizing the contribution of each of the components of the multi-link system to the formation of the final image. The proposed laser systems can find practical application in the fields of oceanographic scientific research, underwater search, and in the equipment of deep-sea vehicles. The calculations and field tests carried out on the basis of the developed mathematical model in real conditions showed the correspondence of theoretical and experimental results.

Keywords: laser system, underwater search, hydrooptics, modulation transfer function.

G. A. Fofanov
Comparative analysis of microelectromechanical inertial measurement units of various manufacturers for human motor activity monitoring

Omsk State Technical University, Omsk, Russia

In this paper, we compare microelectromechanical inertial measuring modules that can be used to record the motor activity of a person. The comparison involved sensors with nine degrees of freedom of the lower price category. Such parameters as the value of noise at rest, the average deviation of the measured data from the true values, the average value of gyro drift under influence of external factors and without, built-in sensor capabilities, and ease of setup are evaluated. Based on the comparison data, the most suitable inertial measuring module for recording a person's motor activity is selected.

Keywords: average deviation, microelectromechanical systems, gyroscope, accelerometer, magnetometer.