MECHANICAL AND THEORETICAL ENGINEERING

V. S. Serdyuk, A. M. Dobrenko, O. A. Tsorina, E. V. Bakiko
Management of production risk on objects of machine-building complex

In order to ensure safe working conditions in mechanical engineering, it is necessary to develop methods of production risks managing in the workplace.

The paper proposes an engineering approach based on the use of mathematical models for determining the probability of adverse events in the workplace to develop a methodology for quantitative assessment of production risks for specified processes (operations) at the facilities of the engineering complex. The use of mathematical models makes it possible to uniquely assess changes in the parameters of the technological process in terms of their impact on risk factors, and thus manage the safety of technological processes and improve safety in the workplace.

Keywords: production risks, risk factors, quantitative risk assessment, mathematical models for determining the probability of events, process safety management.

K. A. Vansovich, I. P. Aistov, A. A. Nakhlestkin, D. S. Beseliya
Assessment of crack growth development in main pipeline on the basis of elastoplastic model

A method for predicting the growth of surface cracks in the wall of the main pipeline under action of operational loads is proposed. The elastoplastic model of surface crack growth under biaxial loading is described on the example of steel 20. ANSYS developed an algorithm for modeling crack growth taking into account residual stresses. The forms and sizes of crack opening under varying loading cycles of the pipeline are determined. The dependence of the crack growth rate under varying loads on the stress state in front of the crack tip is established. The influence of overload cycles on crack growth is investigated. The technique of crack development prediction based on in-line diagnostics and pipeline loading monitoring is described.

Keywords: surface crack, main pipeline, finite element method, crack growth rate, overloading cycle, mean stress change coefficient, crack growth prediction.

N. A. Raykovskiy, V. A. Zakharov
Numerical calculation of heat transfer coefficient in cooled crescent gap of self-lubricating bearing

The paper proposes methods for numerically and experimentally determining the heat transfer coefficient of a self-lubricating bearing of a turbine unit brought to the surface of a crescent channel. The method of numerical research allows you to get the criterion heat transfer equations that are necessary in engineering methods for designing self-lubricating bearing assemblies. The results of an experimental study allow us to evaluate the adequacy of the proposed numerical method. The discrepancy between the values of heat transfer coefficients obtained by a numerical method using the thermal energy model and as a result of experimental studies on average does not exceed 7%. A significant effect of the mass flow rate of the cooling medium on the heat transfer coefficient is revealed. The values of the heat transfer coefficient in the range of studies ranged from 12 to 85 W/m^2K.

Keywords: numerical method, heat transfer coefficient, physical experiment, self-lubricating bearing, cooling system, crescent gap, temperature field.

N. A. Raykovskiy, V. L. Yusha, A. V. Tretyakov, V. A. Zakharov, K. I. Kuznetsov
Research of temperature deformations of self-lubricating tapered bearings of low-consumption rotor units

The use of self-lubricating bearing units of conical shape implemented according to the «rotaprint» lubrication scheme is promising in oil-free small-sized turbine units to provide a given resource. At the same time, an important issue, especially for microturbines, is to ensure the required temperature regimes and permissible temperature deformations. The paper proposes a numerical method for calculating the conical bearing units implemented under the scheme «rotaprint» with a different number of smearing elements, which takes into account the mutual influence of the operating modes of the turbine unit and the cooling system of the bearing. The method consists of two stages: the first one defines the temperature fields, then the results are transferred as the initial data for the second stage – the definition of the fields of thermal deformation. The results of the deformation calculation serve as the initial data for the thermal calculation of the adjusted geometric dimensions, thus an iterative calculation to the desired convergence. The approbation is performed and the results of the analysis of the temperature state and temperature deformations for different angles of the cone of the bearing unit with different number of smearing elements in relation to the bearings both on the compressor side and on the turbine side in their cantilever execution are presented.

Keywords: self-lubricating conical bearing, low-flow turbine unit, numerical method, thermal state, temperature deformation.

D. S. Rechenko, D. G. Balova, A. K. Aubakirova, R. U. Kamenov, D. E. Levin
Determination of geometry of cutting tool for small-size machining of parts made of titanium alloys

Requirements for the quality of manufacturing implants made of titanium alloys used in medicine are quite high. At the same time existing processing methods in their manufacture do not always provide the required quality of the treated surfaces, characterized by roughness and surface layer defects of the final part. The article proposes the constructions of carbide tools of various geometric shapes allowing to obtain different quality processing parameters. The aim of the research is testing new constructions of carbide end tools allowing to obtain the required quality parameters of fasteners of the screw for osteosynthesis ensuring the minimum defective layer. To achieve this goal in the work of the problem are solved: the manufacture of end carbide cutting tools of various geometric shapes; testing of cutting tools at recommended cutting conditions; control of roughness of processed surface. The results of testing metal-cutting tools in the processing of titanium alloy brand VT1-00, which is relevant from the point of view of the use of a new carbide end tool.

Keywords: small-size processing, carbide tools, implant, titanium alloy, roughness of the treated surface.

I. K. Chernykh, E. V. Vasil'ev, E. I. Tkachenko, A. S. Lukin, D. A. Proshutinskiy,
V. A. Valova, E. A. Savva
Design of device for gas shielding of joint during friction stir welding

Due to its characteristics, titanium alloys are widely used in industries such as shipbuilding, aircraft manufacturing, rocket production, etc. Friction stir welding of titanium alloys is a perspective method for manufacturing parts in these industries.
During the welding process, the temperature can reach more than 1200°C, while an active oxidation process occurs, which causes defects. To eliminate the formation of voids, it is necessary to use

special devices for gas shielding. The existing devices for arc welding are not intended for friction stir welding. The aim of the study is to design device for supplying a shield gas during friction stir welding of titanium alloys, which will allow eliminating these defects. Friction stir welding of titanium alloys experiments are carried out using the developed device. As a result of the experiment, sound welds with no oxidation markers are produced.

Keywords: friction stir welding, welding of titanium alloys, gas shielded welding.

ELECTRICAL ENGINEERING

V. L. Kodkin, A. S. Anikin, A. A. Baldenkov
Spectral analysis of rotor current of induction motor as indicator of its effectiveness

The article substantiates the effectiveness of the analysis of rotor currents of asynchronous electric drives with frequency control. It is proposed to use a spectral analysis of these currents, their main harmonics as the most accurate «display» of slip in an induction motor — as a method for assessing the quality of the motor torque generation. Modeling and experiments confirm the proposed theoretical propositions. These experiments demonstrating the operation of the drive at low loads corresponding to a slip of 3%, with a load close to the nominal corresponding slip of 8–10%, convincingly demonstrated that the torque generation algorithm implemented in standard frequency inverters (for example, ATV, Schneider Electric) is not the most effective, at the same time, a constructive solution is proposed that improves the dynamics of the drive by almost half, making it close to the dynamics of permanent magnet motors. This solution will allow the use of asynchronous electric drives in precision technology.

Keywords: asynchronous drive, rotor current, spectral analysis, torque formation.

V. V. Fedyanin, P. S. Yachmenev
Design and experimental studies of power source of arcjet thrusters for corrective propulsion systems of small spacecraft

The article describes a power source designed for arcjet thrusters of corrective propulsion systems of small spacecraft. The source is galvanically isolated and provides high energy efficiency at a consistent load. The design contains a push-pull converter with a midpoint, which is covered by the feedback circuit for the output current. The inductance connected in series in the circuit smoothes the current pulsations generated by a pulsewidth modulator. The absence of a storage capacitor in the output circuit allowed for a quick response to adjust the pulse width in accordance with changes in load resistance. The results of the experiments confirmed the theoretical calculation and simulation. In the current stabilization mode, the source output power is 40–120 W with an input voltage of 12–18V.

Keywords: pulse-width modulation, power electronics, arcjet thrusters, push-pull converter, chaotic pulse-width modulation, arc discharge.

A. A. Baldenkov, V. L. Kodkin, A. S. Anikin
Assessment of dynamics of asynchronous drive by nonlinear transfer function. Correction of nonlinearity of asynchronous electric drive

The article describes methods for analyzing dynamic processes in structures that form a mechanical moment in asynchronous electric motors with frequency control. For the first time, the nonlinearity of the mechanical characteristics of an asynchronous electric motor is taken into account in the

transfer function of the torque former, which is expressed in dependence of this function on sliding (lag of the rotor speed of rotation of the speed of rotation of the stator magnetic field) and on the frequency of the voltage at the motor stator. It is shown how dynamic positive feedback on the stator current «linearizes» an asynchronous electric drive without violating the stability of transients. This work is an example of how the initial complicated (but more accurate!) Interpretation of nonlinearity made it possible to find a new better solution to the problem of controlling a complex dynamic object.

A. V. Simakov, V. V. Kharlamov, V. I. Skorokhodov
Digital relay protection complex testing method development for electric power equipment

The article describes the digital relay protection devices features for electric power equipment. A technical description is given and the main conclusions of the test operation of the Digital Substation software and hardware complex are presented. A method for simulation modeling of a decentralized relay protection system with digital protocol communication is proposed. The presented model takes into account the layout of the real complex of protection. The model can be used when checking the correctness of the functioning of existing devices. The method can be used to build new digital protection algorithms that comply with IEC 61850.

B. A. Kosarev, V. K. Fedorov
Modeling power system with distributed generation

The article is devoted to the development of a simulation model of an electrical system with distributed generation on the example of power supply of residential buildings. Existing models of such systems have several drawbacks: not represented principal power consumers of the equivalent circuit of the individual power consumers is incorrect, the calculation of parameters of equivalent circuits of power consumers and other elements of electrical systems that are not described methods of measuring the main parameters of the electrical system. In this regard, there is a need to generalize the results obtained earlier and create a simulation model of the power supply system of residential buildings with distributed generation, taking into account the above shortcomings. The aim of this work is to develop a simulation model of the power supply system of residential buildings with distributed generation, including principal consumers, a description of the calculation of parameters of equivalent circuits of power consumers and other elements of electrical systems, review of methods of measurement of basic parameters of the electrical system. The result of the work is the creation of a simulation model of the power supply system of 6 residential buildings in the software package SimscapePowerSystems (Matlab). The model takes into account the main types of current-using equipment of a residential building. The paper describes the calculation of the parameters of the equivalent circuit of current-using equipment, electric transmission lines and power transformer. The method of measuring the basic parameters of the system using the blocks U, I, P Measurement and Powergui is considered. The results of measurements of the basic parameters of the system are showed.

D. S. Polozhentsev, D. J. Dzhukich, D. N. Zakharov
Control system of spacecraft solar array drive assembly actuator

This paper deals with the issues of developing a control system of a spacecraft solar array drive assembly actuator that meets strict requirements for operation at the set angular accelerations and rotation velocities, under the influence of payload and disturbance forces. The work consists of developing a control system, its mathematical description, simulation and fabrication of an assembly prototype that meets the defined technical specifications. In the work, methods of mathematical and experimental investigation are applied. System mathematical simulation was carried out using the Matlab/Simulink applied software. As a result of the work, a structural diagram is proposed of the control system of a spacecraft SADA actuator of an operating follow-up system based on the set angular position that is calculated as required for operation at the defined angular accelerations and rotation velocities. The article presents the results of mathematical simulation of actuator operation, the results obtained during operation at the defined angular rotation velocity by a prototype SADA, the analysis and comparison of theoretical and practical results. Experimental investigation shows the achievement of the goal when developing the actuator control system, as well as rather exact matching of simulation and experiment results. The proposed control system can be used when designing and developing devices with similar technical specifications.

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

V. A. Zakharenko, V. V. Zakharenko, M. Yu. Nikolaev, A. G. Shkayev
Electric pulse cleaning of cornices

Results of development of automatic devices for removal of ice and ice from eaves of buildings and constructions in which the technology of electroimpulsive transformations of electric energy in impulse mechanical force is realized are presented. In one of the variants, it is proposed to use a solar battery as a source of electric energy, while the presented circuit solutions ensure the autonomy of its operation in automatic mode. The results of field tests of the device confirmed the effectiveness its work are presented.

R. A. Akhmedzhanov, V. F. Chegodaev, A. I. Cheredov, A. V. Shchelkanov
Phase motion transducer

The principle of construction of a multipole phase transducer with a running field with the implementation of multiphase winding located in one plane is considered. This transducer has high operational reliability and can be mounted on curved surfaces.

E. V. Leun, A. I. Cheredov, D. V. Sergeev, V. K. Sysoev
Questions of design of jet-droplet optical measuring systems: control of electrification of metallized polymer films during automated laser perforation

The article is devoted to the use of jet-droplet optical measuring systems (JDOMS) for monitoring the electrization of products such as metallized polymer films during their laser perforation. The article shows that the main reason for the electrization of films is the removal of matter by a laser pulse with the formation in the microvolume of the plasma, a gaseous ionizing substance and its partial deposition on the edge of the perforated hole in the absence of contact with the metallization of the film. The JDOMS operating mode with the formation of a monodisperse coherent controlled charged droplet flow and video recording of the trajectory of charged droplets along the centers of perforated holes near the film is described based on the measurements of which electrization is controlled. The maximum charges of the perforated holes of the film and moving drops are determined. The displacements from their interaction and the JDOMS sensitivity limit for electrification control are calculated. The requirements to the means of video recording and processing of the obtained stroboscopic micrographs are determined.

Keywords: perforation, polymer film, electrostatic charge, electrization, charged drop, drip flow, video recording.

D. B. Ponomarev, V. A. Zakharenko, E. V. Abramova
Errors analysis in pyrometric measurements in industrial environment

The article presents the analysis of uncertainties associated with reliable accounting difficulties for the radiation coefficient in non-contact temperature measurement in industrial environment. Practical recommendations of methodological and instrumental nature to reduce such measurements errors are offered. On the Planck function and the aluminum reflection coefficient mathematical model basis the analytical aluminum radiation coefficient dependence on temperature and wavelength is obtained. Methodological errors estimates of low-temperature thermometers with a spectral sensitivity ranges equal to 7–14 and 3–5 μm are produced. Experimental studies are carried out using Optris CT LT15 pyrometer and Flir E60 infrared imager.

Keywords: pyrometer, emissivity, methodological error, instrumental error, calibrator, spectral ratio.

A. A. Fedotov, Yu. G. Malinovskiy
About probability of error detection of unauthorized impacts on pipeline with active vibroacoustic method of control

The scientific community has developed many ways to ensure the safety of transportation of petroleum products by automated means. An urgent task is to increase the efficiency of identifying the type of unauthorized impact on the pipeline and assess the errors probabilities in the detection of violations. The paper presents the results of an experimental assessment of the probabilistic characteristics of the detector based on the previously proposed active vibro-acoustic method of control. The values of informative features in vibroacoustic signals are obtained depending on the size of the local heterogeneity and the signal-to-noise ratio. The probability of recognition error and the required number of accumulated signals for system operation in the far zone are determined. The conclusion is made about the consistency of the proposed algorithm for identifying the type of unauthorized exposure.

A. A. Fedotov, R. A. Akhmedzhanov, A. A. Pyatkov
Model of pipeline vibrations during unauthorized exposure

The article presents a model for calculating elastic vibrations recorded on the surface of a pipeline as a result of impact. The use of an empirical refinement characteristic together with an analytical expression made it possible to synthesize a vibroacoustic signal corresponding to unauthorized impact to the pipeline. The adequacy of the proposed solution is estimated by comparing the calculated signal with the empirical one. Models can be used to develop and test algorithms for identifying impacts on the pipeline.

P. A. Vyatlev, E. V. Leun, D. V. Sergeev, V. K. Sysoev
Quality control of metallized polymer films after automated laser perforation

The article discusses the control of parameters of laser-perforated metallized polymer films used in the manufacture of screenvacuum thermal insulation (SVTI) mats of spacecraft. The design, operating principle and operating mode of the laser perforator are described. It is shown that the most important operational parameters of perforated SVTI films are strength and dust release. Experimental studies have shown that laser perforation leads to increased strength and reduced dispersion for different samples of films SVTI compared with similar indicators for manual mechanical or semi-automatic thermomechanical perforation. When measuring the profile of the edge of the perforated hole, the optimal geometric parameters of the carbon Deposit zone consisting mainly of carbon corresponding to the effective mode of laser perforation and the maximum strength are determined. It is also shown experimentally that laser perforation does not lead to an increase in the dust release of SVTI films.

V. I. Kirnos, A. V. Zubar', E. A. Geyntse
Improvement of internal target designation system for modern and advanced armored weapons samples

The article presents a brief analysis of the existing methods of internal target designation used on existing models of armored weapons. The authors propose the method of internal target designation and target indication based on the mathematical description of interrelation between coordinates of the image of an object in the visual field of a sight and its three-dimensional coordinates in world coordinate system.

A. S. Golosnoy
Hydrooptics for ecological monitoring of marine areas

The article describes a method for environmental monitoring of the sea area. The main indicator of environmental changes of water masses authors is considered to be a variation of its transparency. In the currently used method for measuring the transparency of water environment based on definition of depth visibility of white standard disc, which falls into the aquatic environment from the deck of a surface ship. This method for measuring the transparency has significant drawbacks, among them — the ability to determine the transparency of the water only in the surface layer dependent on weather conditions and the low accuracy of the measurement. To eliminate these drawbacks the authors propose another method of measuring the transparency of water environment based on the use of laser technologies.