MECHANICAL AND THEORETICAL ENGINEERING

E. N. Eremin, A. S. Losev, S. A. Borodikhin, A. E. Matalasova, I. A. Ponomarev
Using thermal treatment for hardening corrosion-resistant coatings surfaced with a flux-cored wire containing BN-TiB2-ZrB2 complex

This study explores the metal of coating deposited by a high-chromium flux-cored wire alloyed with a BN-TiB2-ZrB2 complex. We have investigated the changes in the durometric properties and fine structure of the coating after tempering and subsequent quenching. It is shown that the hardening of the metal of such a coating after quenching consists in formation of a complex composite structure with an iron-chromium martensitic matrix, a large amount of eutectic and particles of hardening complexes, which leads to an increase in hardness and wear resistance. It has been established that phase transformations in the metal of such coating are caused by the formation of an eutectic component based on chromium and iron borides, the framework structure and large number of dispersed titanium nitride particles up to 2,5 μm in size.

Keywords: surfacing, flux-cored wire, chromium steel, boride compounds, heat treatment coating, martensite, hardness of metal, coating structure.

V. I. Kuznetsov, O. A. Sharikov
A method of processing mechanical mixtures using vortex set of deep separation

There is described a new method of processing mechanical mixtures using a vortex set of deep separation – VCGS and experimental model of a new vortex separator in the form of cyclone nozzles. New method of processing mechanical mixtures using a vortex set of deep separation is that the compressed air from the supercharger (pump, fan, compressor, etc.), enters the swirler main process line, which creates an air vortex flow with peripheral, axial layer, and, simultaneously, a negative pressure in the axial layer. Vacuum, a flexible hose is supplied to the mechanical mass of the mixture to be processed. By a flexible hose, the mixture is drawn into the vortex tube of the swirler, where it is involved in the technological process of separation of mixture components according to their density. The method involves processing mechanical mixtures using the new physical process of the vortex effect of the confuser, the series cascade connection of technological units in the main processing line and an additional line machines: separator-constrictors, cyclones-constrictors, overpasses, separators exhaust air that drives the indivisible particles of the mixture of the overpass with the ejector, to reuse the exhaust air. Such decisions, and the device create technical conditions for continuous technological process with the first load operation, the mechanical mixture in the vortex chamber, its processing, move processing, to finished products with maximum use of wasted resources and minimal environmental damage. The method has no analogues in the world practice.

Keywords: separator-confuser, cyclone-the confuser, swirl, vortex flow, the tangential nozzle.

**G. N. Sokolov, A. A. Artem'ev, Yu. N. Dubtsov, E. N. Eremin, V. B. Litvinenko-Ar'kov,
A. S. Losev**
The influence of nitrogen and titanium carbonitride particles on structure and properties of metal Fe-C-Cr-Ni-Mo system deposited by flux wire

The influence of nitrogen and titanium carbonitride particles on the structure and properties of high-chromium steel deposited by flux cored wire has been studied. It has been shown that the quality

formation of the deposited metal and pore absence in it are achieved with nitrogen concentration in wire filler no more than 0,32 WT %. It has been found that in adding titanium carbonitride particles from 0,2 to 0,6 WT % to wire filler the effect of deposited Fe-C-Cr-Ni-Mo-N system metal modification is implemented and its operational properties increase. The developed flux cored wire has been recommended for oil and gas equipment surfacing.

Keywords: deposited metal, flux-cored wire, titanium carbonitride particles, metal modification, austenitic-martensitic structure, metal heat resistance, metal wear resistance.

ELECTRICAL ENGINEERING. POWER ENGINEERING

E. V. Ptitsyna[1], D. V. Ptitsyn[1], A. B. Kuvaldin[2]
Water heaters low-voltage electrode with current supply complex shape

At present, it remains urgent to develop effective electrode water heaters related to the need for more sophisticated technical means of electric heating of water for individual processes within enterprises.
In the article on the example of the physical model of the low-voltage electrode of the heater there is described in the experimental study of the influence of the electric mode with the current supply of complex shape in the process of heating water.
The aim of the work is to study the heating processes in electrode water heaters when changing the electrical modes (amplitude and frequency of the supply voltage (current)) to select the effective operating modes of the units. This required the solution of scientific problems in the development of research methods on the physical model of the water heater, obtaining regulatory characteristics that develops recommendations for the selection of effective operating modes required for the subsequent development of the algorithm of automatic control system. The solution of the tasks establishes the influence of the electromagnetic component, along with the temperature component, on the water heating processes: it is experimentally proved that at the same temperature rise speed, the value of the power factor of the plant increases from 0.67 to 0.975. The mode with a power supply of a complex shape causes an increase in the efficiency of the electrode water heaters.

Keywords: electric resistance furnace of direct heating, the current is of complex shape, the low-voltage electrode water heater.

V. V. Kharlamov, S. N. Nayden, A. S. Khloptsov, P. G. Petrov
The mathematical model and the method of temperature calculation at nodes of dump truck BelAZ traction drive's EDP-800 collector-brush assembly in stationary mode

The article presents a mathematical model of a dump truck BelAZ traction drive's EDP-800collector-brush assembly and the calculation of temperature rised in stationary mode. Using thermoimaging the temperature points at the nodes of the collector-brush assembly for nominal operation of the engine are obtained. The estimation of the mathematical model is done by comparison of experimental and calculated data.

Keywords: collector-brush assembly, the contact area, the thermal equivalent circuit, temperature rise, thermal resistance, heat flux, steady state mode.

A. A. Bubenchikov, T. V. Bubenchikova
Evaluation of use of no-load windscreens in body of flow accelerator for wind power plants with vertical axis of rotation

The article presents studies aimed at determining the design of a concentrator with the maximum airflow acceleration. In the course of the work, the tower-type installations with free blades in the body of the concentrator are investigated to determine the useful effect of their use. Analytical and experimental studies of the proposed structures and a version of their multi-tier design are carried out. Recommendations on the application of the proposed developments are given.

Keywords: wind power plant with a vertical axis of rotation, an air flow accelerator, multi-tier wind power plants, confuser.

A. A. Bubenchikov[1]**, T. V. Bubenchikova**[1]**, E. N. Eremin**[1]**, V. V. Kharlamov**[2]
Investigation of air-flow accelerators of tower type for wind power plants with vertical axis of rotation

The work is aimed at determining the geometric parameters of the concentrator for maximum acceleration of the air flow passing through it. The article presents design variants of a tower-type accelerator from a simple design to a complex one with the addition of additional structures allowing to exclude tearing and unwanted twisting of the air flow in the channel body.

Keywords: wind power plant with a concentrator, tower type accelerator of a turbulent flow, optimal geometry of a convergent channel.

S. S. Kolmogorova, A. S. Kolmogorov, S. V. Biryukov
Measurement of degree of non-uniformity of electric field

Examination of the degree of non-uniformity of the electromagnetic field assumes the estimate necessary for determining the type of the field and further standard classification, for the purpose of establishing dependencies and determining the applicability of existing and developed sensors in research of parameters of electromagnetic fields. The task of the study is to provide a methodology for determining field non-uniformity, since this problem has not been solved in the prior art. Classification and quantitative evaluation of degree of non-uniformity will allow to detect informative parameters necessary in designing new sensors of electromagnetic fields.

Keywords: electric field, inhomogeneity of electric field, methodology of inhomogeneity determination, the point charge, the intensity vector, the degree of non-uniformity of the electric field, the multi-component sensor.

A. I. Antonov, Yu. M. Denchik, D. A. Zubanov, N. V. Zubanova, A. A. Ruppel
Simulation of asymmetric modes of operation of electrical network and processing of results using computer program

The article describes the processes associated with the appearance of asymmetry of a three-phase voltage system. An active experiment on the selected object of investigation with asymmetric sharply varying loads is described. The results of the experiment are processed using a computer program and an analysis of the processing of the results data is carried out.

Keywords: power quality, voltage asymmetry ratio, electromagnetic interference, alternating load, electromagnetic situation, phases overload.

A. V. Ded, S. P. Sikorskiy, I. B. Daniukov
Processing of data of experimental measurements of electric power quality characteristics on example of voltage deviation levels

The article shows results of processing of data about deviations of supply voltage levels in electric networks of 0,38 KV of the Omsk State Technical University, obtained within the limits of obligatory energetic examination. At given probability value for each measurement point, value of deviation of voltages of each of phases from nominal value is calculated. It has been found that the average value of deviation of the supply voltage level does not exceed for each of the phases of the values of 7 %, which is less than maximum permissible value of 10 % of set GOST.

Keywords: quality of electric energy, deviation of voltage, asymmetry, quality characteristics, quality control of electric energy.

A. V. Ded, S. P. Sikorskiy, P. S. Smirnov
Results of measurements of electric power characteristics in power supply systems of enterprises and organizations

The article shows the results of measurements of electrical energy quality and their analysis carried out. Measurements are carried out at characteristic points of control of distribution network of 0,4 kV of enterprises and organizations of different branches of economy. It has been found that the parameters of the supply voltage according to a series of parameters of more than 30% have deviations from the permissible standards set in the standards documents. It is confirmed that the main indicator having the largest percentage of deviation from the boundary values is the steady-state voltage deviation.

Keywords: quality of electric energy, deviation of voltage, non-sinusoidal range, asymmetry, quality characteristics, quality control of electric energy.

**D. V. Kovalenko, L. A. Faifer, B. Yu. Kiselyov, A. O. Shepelev, P. S. Smirnov,
V. I. Surovtsev**
Modeling of resonance of currents on higher harmonics with non-stationary mode of power supply system operation

The article describes the simulation of the current resonance that occurs in the power supply system when the degree of reactive power compensation is varied in non-stationary operation modes and the presence of electric receivers having a nonlinear voltage-current characteristic. In addition to simulating the mode of parallel resonance arising at frequencies close to the frequencies of higher harmonics, the proposed algorithm determines all possible resonance frequencies at which the parallel resonance condition under different assumptions can be satisfied, as well as the relative error of calculation for different cases: when all the components of complex impedances are taken into account; without taking into account the active components of the resistance; taking into account the active component of the resistance of the transformer, but not taking into account the resistance of the loads; without taking into account the active component of the resistance of the transformer and without taking into account the resistance of the loads. The purpose of the proposed work is to show how the accounting (non-accounting) of the components of complex resistances affects the results of determining the resonant frequencies.

Keywords: resonance of currents, resonant frequency, non-sinusoidal non-stationary modes, static capacitor banks.

A. V. Radchenko, K. I. Nikitin, A. S. Tatevosyan, R. T. Tazhiyev
Visualization and research methodology of three-dimensional magnetic field of suspended electromagnetic iron separator with typesetting poles and pole tips

The mathematical modeling of three-dimensional magnetic field of the suspended electromagnetic iron separator intended for the separation of ferromagnetic objects from bulk non-magnetic materials presents the complicated problem for developers of the magnetic systems of iron separators, because without the acceptance of considerable simplifying assumptions it cannot be taken to the calculation of plane-parallel magnetic field in a piecewise homogeneous medium. The magnetic field of iron separator differs in sharp heterogeneity in a pole gap and under pole tips. The modeling of such field using software packages of FE analysis (for example, ANSYS) requires additional confirmation of reliability of results of mathematical modeling of electromagnetic iron separator the experimental data got at their physical modeling. Based on this, the article describes a test stand and a research method of the three-dimensional magnetic field of the electromagnetic iron separator using measuring a vector-component of magnetic induction by teslameter with Hall effect sensor. Based on the processing of experimental data the visualization of the spatial distribution of the module and vector-components of magnetic induction and ponderomotive (magnetic) force in Excel are presented. Visualization results of the three-dimensional magnetic field distribution of the suspended electromagnetic iron separator taken on the test stand are compared with the calculation results of the magnetic field of the separator in Elcut 6.0 programme but allowing plane-parallel magnetic field.

Keywords: physical modeling, test stand, suspended electromagnetic iron separator, pole gap, pole tips, three-dimensional heterogeneous magnetic field, magnetic induction, magnetic force.

D. Yu. Rudy, A. I. Antonov, T. V. Gonenko, V. I. Kleutin, A. A. Ruppel, E. Yu. Ruppel
Methods for reducing asymmetry in electrical networks of 0,4–10 kV

The article describes the processes associated with the appearance of asymmetry of the three-phase voltage system, the reasons why this phenomenon is undesirable are explained. The main reasons for the appearance of asymmetry in electrical networks and effects that asymmetrically stress the electrical equipment and the energy system as a whole are considered. The issues of lowering the voltage asymmetry ratio in reverse order by different methods are considered and the main recommendations are given, which allows improving the quality of electric power to meet the requirements of GOST 32144-2013. In conclusion, it is noted that at the moment the problem of voltage asymmetry requires an immediate solution, since the 0,4–10 kV electric networks are characterized by a considerable asymmetry of voltages.

Keywords: quality of electric energy, voltage asymmetry ratio, asymmetry, power losses, balancing device, low voltage electrical network.

V. A. Kopyrin, O. V. Smirnov, A. L. Portnyagin
Assessment of energy efficiency in use of downhole reactive power compensators

The article provides an assessment of the energy efficiency of the use of downhole compensators in the reactors as part of the installation of electric centrifugal pumps. A scheme for replacing the electrotechnical complex of an oil production facility has been developed. The energy efficiency curves have been constructed characterizing the positive effect of the introduction of downhole compensators for different cross sections and lengths of supply cables.

Keywords: downhole compensator, cable line, submersible asynchronous motor, transformer, electric centrifugal pump.

T. A. Novozhilov, A. N. Novozhilov, A. O. Yusupova, G. Zh. Assainov
Stand-alone power supplies for relay protection

At present, telemetry and relay protection devices, which are located directly on the protected element of the electric power system or inside it, are increasingly used in the electric power industry. To supply them requires an autonomous source of low power, which has a stabilized DC voltage. Existing devices are unreliable, expensive to manufacture and operate. In contrast to the well-known power supply devices, it is proposed to use Autonomous power sources to provide constant current for relay protection and diagnostics devices, which receive energy directly from the network by means of current or voltage transformers, as well as by means of an induction Converter located in the end zone of the electric machine. To implement this, the schemes of power supply and calculation of the parameters of Autonomous power sources have been designed.

Keywords: relay protection, diagnostic device, an autonomous power supply, stable voltage.

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

V. L. Khazan, M. N. Kovaleva
Communication channels with variable parameters

The theory of «paired echoes» is a universal mathematical apparatus for analyzing linear and nonlinear phenomena in radio engineering circuits and communication channels. In this paper, we analyze linear communication channels with variable parameters. Linear distortions in communication channels with constant parameters were considered by the authors in the previous article. Radio circuits with nonlinear distortions are supposed to be analyzed in the next article.
Below we study the effect of the time variation of the signal amplitude and phase on the nature of its spectrum. In principle, this problem is considered in depth in various teaching aids in sections devoted to modulation. Nevertheless, given the task of demonstrating a universal mathematical apparatus known as the theory of paired echoes for analyzing linear and nonlinear phenomena in radio engineering circuits and communication channels, it is advisable to consider the effect of time variations in the amplitude and phase of the signal that occurs in channels of communication with variable parameters, on the structure of the spectrum of this signal. In contrast to conventional amplitude and angle modulation changes the amplitude and the phase of signal in channels of communication can take place simultaneously and under the influence of random factors. The specific examples considered in the article show that the time variation of the amplitude and phase of the signal transmitted through the communication channel with variable parameters leads to an additional expansion of its spectrum.

Keywords: transmission coefficient, transmission coefficient module, transmission coefficient phase, multiplicative interference, signal spectrum.

A. A. Kalachikov, N. S. Shelkunov
Measurement based modeling and validation of wireless MIMO channel models

This paper addresses measurement based wireless MIMO channel modeling and validation based MIMO channel on sounding data. Measurement is carried out in indoor laboratory environment at central frequency 2,3 GHz with measurement bandwidth 100 MHz, 4 transmit and 4 receive antennas

are used. Obtained impulse responses are presented and used for channel parameters estimation. Measured channel capacity CDF curves are presented. Full channel correlation matrix is calculated, showing spatial correlation. For statistical analysis estimation of distribution of channel coefficients and goodness of fit tests are numerically computed. Correlated channel capacity compared with uncorrelated channel is presented. Correlation-based models describe the (complex) correlation properties between all pairs of receive and transmit antennas. Two analytical MIMO channel models – Kronecker and Weichselberger models are evaluated.

Keywords: MIMO channel sounder, channel parameter estimation, full channel correlation matrices, MIMO channel capacity, analytical MIMO channel models.

E. V. Leun, V. I. Leun, A. E. Shahanov
Metrological analysis of laser active control devices of details dimensions using corundum tips

The article is devoted to calculation of measurement error of contact of active control devices (ACD) of product dimensions using artificially created corundum tips. It is shown that most of it is determined by the temperature error that occurs due to its thermal expansion of the tip when heated as a result of mechanical contact with the detail. The calculations are based on the formation in the tip of the route of the input and reflected optical flows at an angle to its front surface providing a complete internal reflection in the contact area with the detail.
The calculation of measurement error is made when creating a reference channel in the laser interferometer, fixing the displacement of the back side of the tip from its thermal expansion. A significant reduction of measurement error for this case is shown.

Keywords: active control device, corundum tip, thermal expansion of the tip, the tip wear, measurement error, laser interferometer.

G. M. Sidelnikov, D. V.Ognev
Noise stability of diversity system for signals PSK and DPSK in multipath channels

We consider noise stability of diversity system for signals PSK and DPSK in multipath channels with additive Gaussian noise. The analysis of noise stability is based in fluctuation of signal distance through multipath. Detailed analysis compares algorithms of diversity system of diversity. There are calculated curves of finite noise stability from PSK and DPSK for channels with different of diversity system. The obtained characteristics of signal distance determine the effectiveness of signals in different channels, as well as the analysis of noise immunity at various levels of additive noise determine the possibility of applying such channels as diversity reception, and the transmission.

Keywords: signal distance, the probability of error, loose multipath, additive Gaussian noise.

N. S. Chernysheva, B. P. Ionov, A. B. Ionov
Experimental setup for studying the effect of dustiness in case of non-contact temperature measurements

In this paper we present a laboratory installation for studying the effect of dustiness of the propagation medium in the case of non-contact temperature measurements. The presence of a non-stationary dust cloud in a real industrial environment between the object and the device of infrared thermal control is an important factor causing an additional error, which significantly distorts the measurement results. The article presents the results of experimental modeling of the base states of a dust cloud of clinker dust. The most informative signs of the estimation of these states are shown using the example of a

five-channel pyrometer with spectral separation of channels and an optical particle counter. It is shown that the proposed experimental setup allows to adequately simulate various situations of a dusty state of space between the contactless temperature control device and the object of measurement.

Keywords: non-contact temperature measurements, dust cloud, optical particle counter, transmission coefficient.

A. A. Fedotov, R. A. Ahmedzhanov
Noise immunity of active vibro-acoustic method of monitoring the state of the main pipeline

Improving noise immunity is one of the main tasks in developing methods and systems of vibro-acoustic control. The simulation of the functioning of the active vibro-acoustic method of monitoring the state of the main pipeline is implemented using the analytical model of transverse vibrations of the rod with the addition of interference received on the operating pipeline. The results give grounds for drawing conclusions about the prospects of using coherent signal accumulation in active pipelines monitoring systems.

Keywords: signal accumulation, pipeline, rod oscillation model, transverse oscillations, signal-to-noise ratio.

INFORMATION TECHNOLOGY

V. I. Potapov
The calculation of the average time of «life» of a class of redundant recoverable after system failures at any time failure rate and recovery

For redundant rebuilding after system failures consisting of *n* identical primary units and one standby at any time failure rate and the recovery there is found a class of functions of the intensities of recovery providing on average, under given function of the failure rate of blocks, healthy state of the system within a specified time. There are shown conditions for the existence of the system recovery rate functions after failures providing for the considered system an infinite time of «life» at a given function of the failure rate of blocks.

Keywords: redundant system, the failure rate, the recovery rate, the "lifetime" of the system, Markov process.

V. P. Pivovarov, A. V. Zubar
Additional limitations when searching for images on stereopairs along epipolar lines

The article regards the problem solution of finding additional restrictions on the area of the image searches according to the stereoscopic pairs set by the epipolar line. The feature of the given approach is a possibility of finding the restrictions based on mathematical dependences, which do not require the finding of the fundamental matrix and preliminary processing of images.

Keywords: epipolar line, an image search, a digital video camera, a vision system, a stereoscopic pair.

D. A. Pankov, L. A. Denisova

Control and diagnostics of faults in hardware-software complex

The paper proposes a set of parameters for control general faults in microcontroller systems. Questions of test simulation of malfunctions describe automation testing of products at the stage of development. Program and algorithmic modules of control and diagnostics is used for the approach to fault detection of hardware-software complex. The effectiveness of diagnosing failures and failures in hardware components is confirmed with monitoring and in simulation of malfunctions experimentally.

Keywords: control and diagnostics, fault simulation, test automation, hardware and software complex, hardware failure.