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ENERGY AND ELECTRICAL ENGINEERING

ELECTRONICS, PHOTONICS, INSTRUMENT ENGINEERING AND COMMUNICATION

SUMMARY. KEYWORDS

MECHANICAL

A. Yu. Popov, V. A. Prokofev
Improving the accuracy of processing deep holes by Electrical Discharge Machining with a rotating tubular electrode

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The article considers the factors affecting the accuracy of Electrical Discharge Machining. The process of formation of conglomerates resulting from processing is mainly investigated. Based on the literature analysis, the theoretical and real scheme of Electrical Discharge Machining is compared. As a result of the experiments carried out, it is revealed that in the process of deep holes, the electrode deviates from its axis due to the destabilization of the tool due to the non−rigidity of the electrode and the sticking of debris formed in the processing zone. The deviation of the electrode from the axis of rotation leads to uneven pressure from the liquid washing out the debris, which leads to uneven wear on the side of the electrode. During the study, samples of electroerosive debris are collected and studied. A direct relationship between the processing depth and the deviation value is revealed: the greater the processing depth, the greater the deviation value, which leads to distortion of the shape of the hole section and the formation of a cone instead of a cylinder. To improve the accuracy of processing deep holes, it is necessary to minimize the deviation of the electrode from the axis of rotation and protect the side surface of the electrode from the effects of current.

Keywords: EDM, precision hole processing, debris, super drill, deep hole processing, tubular electrode-tool, debris conglomerates.

E. V. Vasily'ev, Yu. A. Blokhina, M. M. Lakman
The scheme of shaping back surface of five-sided carbide inserts on CNC machines

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The methods of grinding the rear surfaces of multifaceted carbide inserts, as well as various schemes for shaping the back surfaces, are considered. The process of shaping the rear surface of a five-sided carbide insert is modeled. An algorithm for the implementation of the kinematic scheme for shaping the rear surface of pentahedral carbide plates using CAD tools has been developed. The processing of a multifaceted carbide inserts on a CNC grinding and grinding machine was carried out using the obtained mathematical dependence.

Keywords: cutting tool restoration, sharpening, carbide inserts, modeling, grinding method, shaping schemes.

A. V. Zhdanov
Theoretical studies of the steering hydraulic system of construction and road machines with flow amplifiers

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The article presents the results of theoretical studies of the functioning of flow amplifiers, the purpose of which is to increase the useful power of the hydraulic steering systems of heavy construction and road machines, which is especially important when upgrading existing equipment and designing a new one. Flow amplifiers allow to increase the supply of working fluid to the hydraulic cylinders for turning a multiple of the dosed volume by the dosing pump. A distinctive feature of the study is the consideration of two flow amplifiers of throttling and volumetric types, working in pairs. The design, the principle of operation are described, the main calculated dependencies are presented, on the basis of which mathematical modeling was carried out. To evaluate the qualitative and quantitative characteristics of the amplifiers, graphs of transient processes in the steering hydraulic system, as well as the static characteristics of the flow amplifiers, were obtained. The analysis of the obtained dependencies showed acceptable accuracy and quality of the hydraulic system. The results obtained can be used in the synthesis of such systems.

Keywords: steering hydraulic system, construction and road machines, flow amplifier, gain factor, theoretical studies, transients, static characteristics.

A.G. Kisel[1,3], D. S. Makashin[1,2],
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The analysis of the effect of cutting mode and coolant on formation of burrs when drilling aluminum alloy

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Drilling is an extremely important process widely used in the manufacture of fuel control equipment. The sustainable drilling process of aluminum alloy is promising for today's industry, which reduces energy and coolant consumption without compromising the quality of workmanship. This article examines the effect of feed and spindle speed on maximum power input, the height of the burrs generated during drilling, and the resulting deviation in the diameter of the drilled hole.

Keywords: drilling, alloys, aluminum, accuracy, cylindricity, hole, processing.

E. V. Lyubchinov,
K. L. Panchuk, T. M. Myasoedova
Solution of the inverse problem of modified cyclographic model

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In cyclographic modeling of a line of three-dimensional space, direct and inverse problems are known. A sufficient number of publications are devoted to the solution of these problems in the scientific literature. The authors of the work, on the basis of studies of the well-known classical cyclographic model, obtained its modification, called the modified cyclographic model. The need for this model caused by the solution of a number of practical problems of geometric modeling, in particular in the field of developing surface forms of roads, where traditionally only the direct problem of geometric modeling is considered, in which it is required to determine the surface shape of the latter along the spatial axis of the road. The authors proposed a

solution to the inverse problem of modeling for a modified cyclographic projection, which makes it possible to restore a curved line of space from its cyclographic image. The paper gives a justification and a solution to the inverse problem of cyclographic modeling, implemented on a numerical example. The results of the work can be used in computer-aided design systems that specialize in the design of general and special roads.

Keywords: geometric modeling, cyclography, modified cyclographic projection, inverse task, road surface form design.

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E. A. Rogachev[1], A. A. Krutko[1]
Modification of metal-cutting plates from tungsten-free hard alloy grade KNT16 by continuous ion beams

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This work is devoted to the problem of developing technological operations aimed at improving the structure and properties and, as a result expanding the scope of metal-cutting inserts from tungsten-free hard alloys. The search for alternative analogues of traditional tungsten-cobalt hard alloys is an urgent task of modern materials science, due to the high cost and shortage of their components. In this paper, we study the effect of a continius ion beam on the change in the morphology, mechanical properties, and performance characteristics of metal-cutting inserts made of tungsten-free hard alloy grade KNT16 (TiCN-Ni-Mo). It has been found that the effect of continuous ion beams leads to a significant change in the wear resistance of cutting plates during turning operations on medium-carbon steel 40KhN. A rational composition of the ion beam has been established, in which the cutting plate is subjected to the least wear after completion of the test cycle. Using the methods of scanning electron microscopy and scanning probe microscopy, a study of the microrelief and morphology of the surface of the samples is carried out.

Keywords: tungsten-free hard alloys, continuous ion beam, surface morphology, turning, scanning and atomic force microscopy.

L. R. Safarova,
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Methodology for finding parameters of cutting transitions in APQP process of preproduction of new automotive components

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The article discusses the content of the methodology for assessing the technological state of the machine tool system based on the method of planning experiments for cutting pre-designed and manufactured for special precision characteristics of automotive components of product samples. Using the example of an internal landing hole, the finding of diagnostic components of a special characteristic that are the result of the action of pre-known technological factors is considered. Their finding is designed for the use of both shop and coordinate measuring instruments. The obtained regression models of diagnostic components make it possible at various stages of the APQP process to determine the intervals of the cutting process parameters that provide a predetermined margin of accuracy of a special characteristic, or to conclude that the accuracy of the machine system is inadequate. The application of the methodology together with statistical methods of quality management allows to ensure the maximum achievable level of stability of special characteristics in cutting operations, starting with the release of the first serial samples of products. The methodology can be used when selecting and evaluating the technological accuracy of newly purchased equipment in the APQP process of preparing the production of a new automotive component, acceptance of existing equipment after modernization or repair, as well as the audit of the technological process by the auditors of the supplier.

Keywords: APQP preproduction process, experiment planning, diagnostics, technical condition, machine system, cutting modes.

I. A. Loskutov[1],
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Dynamic rationing using agent-based modeling of the assembly process of equipment for nuclear power plants

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The work is raised as an agent-based model designed to calculate the time spent on the assembly stage of the manufacturing process for manufacturing equipment for nuclear power plants. The article focuses on the need for development, states the justification for research and development of the field of nuclear energy, with repeated facts. The paper uses various approaches to accounting for labor productivity. The concept of a gradual increase in employee fatigue for the development of the technical process is taken as the base. The agents of the model contain the workers and the technological process. The components of programs implemented in the C# language are shown, descriptions of classes are described, their actions to simulate the behavior of agents of a production system. The class diagram shows the selected classes and the relationships between them in terms of inheritance. There is a study of the use of models of a typical assembly process — the assembly of a cabinet frame, consisting of seven main operations. The paper presents structured, empirically analyzed values of fatigue categories and process time for 85 employees in graphical form by operations. It shows an example of an increase in fatigue for one of the employees and a Gantt chart, which can be used to evaluate how the operations went over time. As the output of the agent-based model, the calculated value of the time spent for the entire stage of the technological process of assembling equipment for nuclear power plants is provided. The accuracy of calculations of data convergence, income on the environment in Matlab Mathworks and Microsoft Excel during manual modeling is argued. The agreements state a slight deviation from the data model of the developed agent-based model of a practical experiment carried out as part of the implementation of the contract for the creation of equipment for a new power unit, a causal analysis is carried out. Also, in the applications, exceptional values of some performance indicators are analyzed and attention is focused on the unjustification of classical average approaches in the analysis of overall performance, using several examples. Information is given on the application of the agent model in possible options.

Keywords: nuclear power plant, dynamic rationing, installation, agent-based modeling, assembly, technical process.

I. A. Loskutov[1],
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Ecosystem controlling as a solution to complex task of optimizing the technological process of industrial production

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The article is devoted to the study of ecosystem controlling and divided into three structural sections. The study is of an overview nature, aimed at popularizing ecosystem approaches in the domestic industry. The main methods of scientific research are systematization and analysis. The introduction provides evidence of the need to search for new solutions to optimize and improve modern domestic industry. The first section analyzes definitions related to the ecosystem. It is considered from the classical (biological) point of view and from the point of view of application in industry. The evidence base of the justification of this approach is given. The second section is devoted to the problems present in industrial ecosystems. The list of the most significant features caused by staff misunderstanding of new approaches is made and the unjustifiability of outdated methods of production organization used everywhere is argued. At the same time, the section focuses on the importance of the manager who is responsible for the functioning of departments and specifies the characteristics required for him. The third section shows the importance of ecosystem controlling as a way to solve the described problems. As evidence, it is divided into two obvious components — technical and human. The direction of the Internet of Things as an integral part of the industrial ecosystem is noted. As a solution to the human component, an example of implementation for little-changing systems is given and recommendations are given for systems of a different nature. In conclusion, the supporting facts of the correctness of the conclusions are given.

Keywords: ecosystem, enterprise, industry, controlling, problems, organization of production.

ENERGY AND ELECTRICAL ENGINEERING

A. A. Belsky, A. I. Zamyatin

The analysis of power curves of wind power plants

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The use of wind power plants is growing rapidly, despite the continued growth in the extraction of traditional fossil resources. In this paper, the analysis of the power curves of real wind turbine models and the polynomials common among the scientific community describing the dependence of the wind turbine output power on wind is carried out. The article discusses 82 models of wind power plants with a horizontal axis of rotation, rated power up to 100 kW and with a method of limiting the speed of rotation in the operating mode pitch control. The calculation of the potential generation of each wind turbine at an oil and gas field for a period of twenty years with an interval of one hour is carried out, the Installed Capacity Utilization Factor is calculated, after which the values are compared with the results of calculations based on polynomials of other authors. The results obtained can be widely applied in modeling the operating modes of wind power plants

and will improve the accuracy of feasibility studies for the implementation of autonomous power supply systems.

Keywords: power curve, wind power plant, autonomous electrical complex, wind turbine.

V. Yu. Karandey, O. B. Popova,
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Research of changes in electromagnetic parameters in controlled asynchronous special electric drives

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The article researches the changes in the electromagnetic parameters of controlled asynchronous special electric drives. Special asynchronous electric drives are controlled cascade electric drives of cylindrical and axial designs. The study of the dynamics of parameter changes is carried out on the basis of the method of electromagnetic energy conversion and the theory of electromagnetic circuits. As a result, for new mathematical models of the electromagnetic system of the studied asynchronous electric drives, the parameters of the electromagnetic field of a closed coil of one coil of an electric winding with electric current in a homogeneous medium are determined. The solved problem is spatial, since the distribution of electromagnetic induction in a coil of a given shape of an electromagnetic coil is determined. The obtained conclusions for determining the electromagnetic parameters of cylindrical and axial motors of special electric drives allow us to correctly solve the problems of modeling, designing and improving the efficiency of the studied electric drives and electromechanical energy converters of cylindrical and axial designs. The results of the study are applicable to create a computer-aided design system for the research asynchronous electric drives and solve modeling and design problems. The conducted research allows creating electric drives with optimal weight, size and energy indicators.

Keywords: special electric drive, controlled asynchronous cascade electric drive, energy conversion, mathematical modeling, electromagnetic field, electromagnetic system.

E. Yu. Salita,
T. V. Kovaleva

Twelve-pulse rectifiers in power supply system of urban electric transport aleva

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The introduction of twelve-pulse rectifiers instead of six-pulse ones at traction substations of urban electric transport leads to an increase in technical and economic indicators, energy savings, a decrease in leakage current. These result in electrical safety of passengers, a trolleybus driver and depot maintenance personnel. Twelve-pulse rectifiers can have a serial or parallel connection of six-pulse bridges. With a parallel circuit, it is necessary to have an equalizing reactor. The implementation of a twelve-pulse serial type rectification scheme can be carried out by industrial development by manufacturers of new dry converter transformers with different typical power and new rectifiers (blocks). As part of the new rectifiers, it is necessary to have tablet avalanche valves with coolers based on heat pipes due to their advantages over non-avalanche valves.

Keywords: urban electric transport, traction substation, twelve-pulse rectifier, tablet avalanche valves, leakage current, technical and economic indicators.

A. E. Savenko, P. S. Savenko
Operation stability of sea vessels onboard electrical power system when changing settings of diesel generator governor

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The article deals with the issue of ensuring the sustainable operation of ship electrical power systems. Experimental oscillograms of power exchange and in-phase oscillations during parallel operation of diesel generator units are presented. The results of mathematical modeling allow us to conclude that it is necessary to limit the change in the values and ratios of the transmission coefficients of the governor. It is proposed to limit the change in the transmission coefficients of the governor when eliminating power exchange oscillations.

Keywords: power exchange oscillations, parallel operation, autonomous electric power complex, stability, generating set, governor settings.

**G. Yu. Kiselyov, V. M. Trotsenko,
E. V. Petrova, V. A. Krivolapov,
S. S. Girshin, A. A. Bubenchikov
V. N. Goryunov
Losses of electrical energy in electrical networks**

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This article discusses the relevance of reducing electrical energy losses. The actual values and plans for reducing electric energy losses in PJSC «Rosseti» and the main branches of PJSC «Rosseti Siberia» are given. The existing standards of losses in electrical networks of different voltage levels are presented. Possible ways of reducing electricity losses to achieve the targets set by the «Energy Strategy of the Russian Federation for the period up to 2035» are considered.

Keywords: electricity consumption, electricity losses, development strategy, loss standards, development program, loss reduction.

**N. A. Tereshchenko[1], K. I. Nikitin[1],
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Calculation of additional shunt for current sensor of insulators**

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The purpose of the study is to review the existing devices and methods for diagnosing and monitoring the state of high-voltage insulation, which plays an important role in the criteria for the reliability of the power system. One of the main methods for diagnosing insulators is a visual inspection. At the moment, online methods have become widespread, allowing to fix the process of destruction of insulation under voltage. Despite the existence of various methods and devices, the problem of timely detection of insulation deterioration in the operating mode has not been solved at the moment. This problem is solved by using an additional shunt design. When the task is achieved, the method of calculating the strength analysis of the additional shunt is used, and the simulation of this process is performed in the ANSYS program. Mechanical strength sufficient for operation under voltage. Experimental tests are carried out with the developed sample of the shunt. As a result of the study, a number of experiments are carried out with this design of the shunt, which have confirmed its performance. Due to the presence of the shunt, it is possible to fix leakage currents of the order of several tens of microamperes. Thus, the authors have proposed the current sensor, which is made in the form of an additional resistive shunt.

Keywords: insulator, AC voltage, leakage current, resistive shunt.

**A. V. Simakov[1,2], V. V. Kharlamov[2], M. Yu. Chernev[3]
Development of the mathematical model for operation of digital substations relay protection complexes**

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The issues of introduction of electrical digital substations in the Russian Federation are considered. An existing criteria analysis for assessing the modern relay protection devices efficiency is carried out and an assessment of their sufficiency is made. A mathematical model development of the digital substations relay protection complexes operation has been developed using the queuing theory, the graphs theory and Markov chains. The failure-free operation probability calculated value of the relay protection complexes corresponds to the long-term analysis data. This indicates that the mathematical model is correct. The proposed mathematical model makes it possible to take into account the impact of the maintenance quality on the digital substation relay protection complexes efficiency.

Keywords: digital substation, IEC-61850, relay protection, condition-based maintenance, Markov chain, graph theory.

ELECTRONICS, PHOTONICS, INSTRUMENT ENGINEERING AND COMMUNICATION

**G. N. Anisimov[1], K. K. Kim[1],
A. A. Tkachuk[1], A. Yu. Kuzmenko[2]
The method of non-destructive measurement of power thyristor surge current**

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The article proposes a new method for the non-destructive measurement of one of the most important maximum permissible parameters of surge current power thyristors. The method is based on continuous control at each moment of time of the dynamic capacitance, the changing in the nature of the time dependence of which predicts the destruction of the semiconductor structure.

Keywords: power thyristor, dynamic capacitance, surge current, non-destructive measurement.

**A. A. Valke[1], V. A. Zakharenko[1],
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A. G. Shkaev[1], M. Yu. Nikolaev[1], S. V. Lukuta[2]
Infrared monitoring of the metal surface temperature of superheater pipes in transient modes**

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This work is devoted to the problem of infrared monitoring of the metal temperature of the surface of superheater pipes. Monitoring is implemented on the basis of a thermal imager cameras that performs contactless monitoring of the surface temperature of the pipes of the wall superheater.

The results of modeling the temperature distribution along the pipe of a wall-mounted superheater in the presence of contamination and without are presented. The calculation of the number of thermal imager cameras required for infrared monitoring is performed. The developed design solutions for the installation site of thermal imager cameras on a TP-82 type boiler have been confirmed experimentally.

Keywords: superheater, thermal imager camera, superheater pipe metal, boiler unit, temperature visualization, transient mode.

M. N. Lyutikova,
S. M. Korobeynikov, A. V. Ridel
Application of chromato-mass spectrometry to determine the acid composition of transformer oil

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This article presents the results of a study of the acid composition of transformer oil from high-voltage transformers that have been in operation for more than 30 years. The acid composition of oils is studied using a new technique based on a highly sensitive and highly selective analysis method — chromato-mass spectrometry. The technique makes it possible to determine the acid composition of the insulating oil in the context of low molecular weight acids (LMA), high molecular weight acids (HMA) and phenolic compounds (PC). The structure of some compounds identified in oil is given. It has been established that during oil aging, among the acid compounds, the following are predominantly formed: HMA $(60-95$ %$)$ > PC $(3-16$ %$)$ > LMA $(1-6$ %$)$. As part of the research, it is found that the share of the most dangerous low molecular weight acids in the total amount of acidic compounds is no more than 12 %. The rest of the acidity of the oil is due to the presence of macromolecular and phenolic compounds, which do not adversely affect the insulating properties of oil and paper in the detected concentrations, and some of them (compounds of a phenolic nature), on the contrary, even improve the stability against oxidation. These extended tests of oil samples from operating high-voltage equipment are of practical value in preventive diagnostics of the condition of its insulation.

Keywords: petroleum-based insulating oil, acid composition, gas chromatography-mass spectrometry, high-voltage transformer.

E. V. Leun
Fundamentals of design of jet-drop optical systems for three-coordinate measurements of electric, magnetic and gravitational field strengths by the pendant drop method. Part 1

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The article discusses the principle of operation and the main components of jet-drop optical measuring systems (JDOMS) based on the pendant drop method for monitoring electric field strength (EFS), magnetic field (MFS) and gravitational field (GFS).
To make a pendant drop sensitive to electric or magnetic fields, it is proposed to charge it electrostatically or to create it from a magnetic fluid, and its mass allows you to feel changes in the gravitational field. The use of magnetic fluids as the basis of a pendant drop is the most multifunctional for measurements of EFS, MFS and GFS.
The implementation of the zero measurement method using a pendant drop as a comparison device, a null organ that perceives the difference in the effects of the measured and reference field(s) at the level of quasi-zero three-coordinate displacements, is considered. They are measured by high-precision optical measurement methods. Different variants of modern optical measurement systems are analyzed.

Keywords: pendant drop, electric field strength, magnetic field strength, gravitational field strength, magnetic fluid, magnetometer, gravimeter, matrix video recorder.

A. I. Korniyenko, D. K. Avdeyeva, M. M. Yuzhakov,
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Increasing the resolution of ECG and EEG mapping equipment using nanosensors

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The problem of a large number of people with cardiovascular diseases and brain diseases is relevant all over the world. The problem of mortality and the consequences of these diseases is particularly acute. Therefore, an important way in medical instrumentation is to improve and increase the amount of information with the help of external methods of diagnosing these diseases. Nanosensors have been developed at Tomsk Polytechnic University to significantly improve the quality of electrophysiological measurements. It is proposed to apply the developed nanosensors for ECG and EEG mapping.

Keywords: nanosensor, EEG, ECG, mapping.