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INVESTIGATION OF THE INFLUENCE OF VIBRATION OSCILLATIONS IN THE PROCESSES OF STRENGTHENING PROCESSING OF MACHINE PARTS

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The object of research is the technological process of improving the reliability of the recovery of ploughshare disks of grain seeders by vibration hardening. One of the most problematic places is the lack of knowledge of this process in the restoration of agricultural machinery. For the emergence of a deeper understanding of the process of vibration hardening of the material of parts, it is necessary to conduct experimental studies on the effect of processing parameters on the hardening degree.

In the course of research, the process of vibration hardening of the weld surface is carried out on a vibration installation made by the authors of this study. To select processing parameters and determine their optimal values, microstructural studies of the disk material are carried out. The main parameters of hardening are revealed and substantiated: amplitude and frequency of oscillations of the processing tool, hardening time, and their values are determined: $A=0.5$ mm; $n=1400$ min^{-1}; $t=20$ s.

As a result of the research, it is established that during vibration hardening, the structure of the material is more fine-grained. The increase in microhardness on the surface of the deposited layer can be explained by the greater fragmentation of grains and an increase in their number. This, in turn, causes the activation of dislocations in all grains adjacent to the surface. During vibration deformation, the length of the grain boundaries increases and thereby more dislocation slip zones are formed. This can explain the hardening mechanism.

The evaluation of the operational reliability of the disks on the following indicators: the performance per season and the coefficient of technical use. For seeders with discs restored by welding segments with sormite surfacing and vibration strengthening, the coefficient of technical use is 1.053 times higher than for seeders with new discs.

Thanks to the use of the developed restoration technology, it is possible to reduce the blade blunting speed by 1.49–1.70 times. This provides an increase in the operation time. Compared with similar known technologies, the developed technology of vibration hardening of blades provides the greatest wear resistance and an increase of 1.34 times the operating time compared to new discs.

Keywords: technological treatment process, vibration hardening, wear resistance of parts, coefficient of technical readiness.

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MECHANICS

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ESTIMATION OF THE DRILL PIPES RESIDUAL RESOURCE UNDER THE MULTIAXIAL STRESS STATE

page 10–14

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The object of research is the operation of drill pipes in a complex stress state. One of the most problematic places in this case is the process of fatigue, that is, the gradual accumulation of damage to the material of drill pipe under the influence of time-varying stresses. This leads to accidents, the elimination of which is accompanied by significant material and temporary losses.

Based on the conducted critical analysis of scientific developments on this issue, it is noted that the use of kinetic diagrams of fatigue failure allows us to experimentally establish empirical parameters of fatigue of the material of drill pipe by laboratory research of small samples. And also to take into account the influence of the front shape of semi-elliptic and annular fatigue cracks on the residual resource. In addition, it is concluded that methods requiring additional attention, taking into account the combined effect on the kinetics of fatigue damage of normal and shear stresses.

Therefore, in the course of the research, the positions of fracture mechanics were used. In particular, a feature of the proposed approach is the use in the formula for determining the stress intensity factor before the front of a semi-elliptical fatigue crack in the cross section of a tubular structure of equivalent stress, taking into account both the normal and shear component. This same stress, determined in accordance with the fourth theory of strength, is also used to calculate the critical crack depth.

In order to assess the obtained results, a comparative calculation is made of the number of cycles of load change required to increase the depth of the specified crack from the initial to the critical value, not taking into account the value of the shear stress. It is established that the latter, with other unchanged conditions, can reduce the life of the drill pipe by up to two times.

Thanks to the proposed method, it is possible to construct graphical dependencies of the fatigue life of drill pipes, taking into account the magnitude of the torque, other things being the same.

Keywords: drill pipe, shear stress, residual life, semi-elliptical crack.

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LABORATORY RESEARCH OF THE STRESS-STRAIN STATE OF THE DRILL STRING IN THE LOCAL BEND OF THE WELL

page 15–24

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The object of research is the operation of the drill string in the local bend of the well. One of the most problematic aspects in this case is the establishment of its stress-strain state. This is very important information, which, in particular, is used to make decisions on the duration and possibility of operating the drill string in a given geological and technical conditions.

Based on a critical literature review, physical modeling of the object of study was chosen to solve this problem. In particular, a special laboratory stand was designed, manufactured and tested, which provides:

– load model of the drill string axial tensile force and torque;

– modeling of curvilinear axes of wells with possible local excesses, based on the results of industrial inclinometry and profilometry;

– measurement of stresses and deformations of the model of the column and their interpretation to the values of the natural object.

As a model of a drill string, a copper tube with a weighting agent was used to provide criterial similarity with a full-scale object. To measure normal stresses on a drill string model, strain gauging was used. At the same time, analog voltage values on strain gauges are digitized and transferred to a personal computer for further processing and interpretation.

With the help of the proposed laboratory stand, experimental studies of the stress-strain state of a 127-mm drill string model in a local bend of well No. 10 of the Odesa deposit (Ukraine) were carried out. It has been established that the normal bending stresses that arise in this case can more than three times exceed the same values obtained without taking into account the presence of the specified curvature of the borehole axis.

Thanks to the proposed experimental method, it is possible to study the deformations and stresses that occur in the drill strings during their work in wells with local axial kinks. There is no need to apply complex analytical transformations and algorithms. In addition, the model has the same physical nature as the object of study. This is an extremely weighty argument, especially in the study of complex cases of interaction between the drill string and the borehole walls.

Keywords: stress-strain state, drill string, local bend, laboratory research.

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MATERIALS SCIENCE

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CONTINUAL DESCRIPTION OF POLYCRYSTALLINE SYSTEMS TAKING INTO ACCOUNT THEIR STRUCTURE

page 25–30

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The object of research is the behavior of grain boundaries, the conditions for the formation of intergranular damage and intercrystalline destruction of polycrystalline alloys under the influence of force loads. The problem of creating internal boundary zones with given thermodynamic, physical and mechanical characteristics in alloys, the solution of which is the most promising way to improve their properties, requires the use of mathematical modeling methods. It is allow one to quantify the influence of chemical composition, heat treatment and external loads on the formation of intergranular damage to polycrystalline systems.

In the course of research based on the energy approach of describing continual media taking into account physical effects occurring on a scale commensurate with the structural components and their boundaries, the mathematical relationships of the model of polycrystalline systems are constructed. This model is the basis for calculations and establishing the stress-strain state of the material at the meso level. It is shown that the mechanical behavior of materials is influenced not only by the absolute values of the parameters of the properties of individual microvolumes of bodies, but also by their gradient.

The relationship between the presence of grain boundaries in improved steels with an increased level of energy and the ability to form intergranular damage when exposed to an external load is obtained. A conceptual approach has been developed to control the properties of the internal surfaces of the alloy section by changing their structural-energy state. This is due to the fact that the proposed model and experimental dependencies are based on a physically reasonable parameter – the relative property gradient, which determines the segregation of impurities and the separation of phases by the density of dislocations in the boundary zones of the grains.

The limiting values of the characteristics of local volumes of grains, at which the ability to form intergranular damage and intercrystallite destruction of alloys, is established. This ensures the possibility of introducing innovative technologies of grain-boundary design of the structure of metal products. It is makes possible to significantly increase the reliability parameters of machine parts in comparison with the known technologies – durability, service life, reliability with minimal economic costs.

Keywords: mathematical relationships of the model of polycrystalline systems, state of the grain boundaries of polycrystals, intergranular damage.

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INVESTIGATION OF ELECTROPHYSICAL PROPERTIES OF NANOMODIFIED FIREPROOF EVA POLYMER COMPOSITIONS

page 31–38

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The object of research is the electrophysical properties of fireproof composite materials of ethylene with vinyl acetate, which include filler-flame retardants and modifiers. One of the biggest problems is the change in the electrophysical properties of fireproof composite materials, depending on the chemical properties and dispersion of fillers, fire retardants and modifiers. In order to solve this problem, the dependence of electric strength, specific volume electrical resistance, permittivity and tangent of dielectric loss angle on the number of modifiers and properties of ingredients of polymer compositions is investigated. A copolymer of ethylene with vinyl acetate is used as well as methods for determining the electrical strength, electrical bulk resistance, dielectric loss tangent, permittivity.

The results show that the dielectric strength significantly increases to 32–35 kV/mm in the case of use as fillers-flame retardants of aluminum oxide trihydrate with a smaller average particle diameter of the EVA-1-based polymer matrix and modifier 1. When using the EVA-2-based polymer matrix, high rates (41 kV/mm) obtained for compositions with hydromagnesite and modifier 2. The specific volume electrical resistance varies little for modified polymer compositions using magnesium oxide dihydrate with a smaller average particle size and modifier 2, as well as for the EVA-1 and EVA-2 polymer matrices. After exposure to moisture, the specific volume electrical resistance has a maximum value of $1.2 \cdot 10^{13}$ Ohm cm for the EVA-1-based polymer composition, a flame retardant – aluminum oxide trihydrate and modifier 1. The permittivity and dielectric loss tangent have the best performance for EVA-1-based polymer compositions, hydromagnesite and modifier 2 ($\varepsilon=3.3$; $tg=6 \cdot 10^{-3}$).

This makes it possible to increase the electrical properties of fireproof compositions for the manufacture of insulation and cable sheaths compared with similar known materials, this reduces material consumption by reducing thickness and makes it possible to increase the economic efficiency of production of fire-resistant cables.

Keywords: modified polymer compositions, ethylene-vinyl acetate copolymer, filler-flame retardants, electrophysical characteristics.

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THE DEVELOPMENT OF THE MATHEMATICAL MODEL OF A NONLINEAR ELECTRICAL CIRCUIT WITH AN INDEPENDENT CONTROLLABLE ELECTROMECHANICAL ENERGY CONVERTER

page 39–43

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The nonlinear electric circuit with an independent controllable electromechanical energy converter is the object of this research. Such circuit nowadays has large practical use in many vehicles. The developers of these vehicles conduct frequent research and calculations of these circuits during the design stage.

The one of the problems of such circuits is the complexity of its calculations. The circuit has a few nonlinear elements: an electric motor, a battery, and a supercapacitor. Numerical calculations of such circuit would be extremely complex and require huge computational power. As a result, a lot of existing models created for conducting research of such circuits are oversimplified, which leads to inaccuracy of energy calculations.

During this research the mathematical model of the circuit under consideration was created to be as simple as possible with the accuracy being acceptable for energy calculations. In order to achieve this, the existed models were examined: parameters, which have weak impact on electromagnetic processes, were neglected while momentary effect, such as the impulse form of energy transformation, and additional energy losses were taken under consideration. Thereafter the computer model of the nonlinear electric circuit with an independent controllable electromechanical energy converter was created to meet the accuracy requirements for energy calculations and to be reasonably complex at the same time.

The obtained model is more accurate for energy calculations than most of existing models due to the accounting of the impulse working modes of the electrical converter and electromagnetic losses of the electromechanical converter. Also due to the neglecting of some poser supply parameters that have slight effect on the energy losses this model is less complex then other accurate models of the circuit under consideration. Thus, the obtained model is optimal for the energy calculations of the nonlinear electric circuit with an independent controllable electromechanical converter.

Keywords: nonlinear electric circuit, Li-Ion battery, supercapacitor, induction motor.

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NUMERICAL INVESTIGATION OF THE PROBLEM OF NONLINEAR THREE-PHASE FILTRATION

page 44–50

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The object of research is the numerical simulation of the filtration process of oil, gas and water on adaptive grids taking into account some properties of liquids during their joint flow. To obtain an adequate description of the processes, it is necessary simultaneously take into account the effect of most of these factors on filtration. Mathematically, this leads to solving the systems of nonlinear partial differential equations, the complexity of which does not allow them to be studied deeply enough by analytical methods. Experimental studies of these processes are associated with lengthy and expensive laboratory and field experiments.

One of the most problematic places in the theory of multiphase filtration is that the spatial variable steps should be reduced in areas of abrupt changes not only in the water saturation gradient, but also in the gas saturation gradient. This is because due to the very low viscosity, the free gas under the action of the gradient pressure overtakes the rest of the components. This is because due to the very low viscosity, the free gas under the action of the gradient pressure overtakes the rest of the components of the mixture, such as water and oil.

An algorithm for constructing adaptive grids used, which can be adapted to the properties of the solution. The methods of computational mathematics, including the difference-iterative method in moving grid are used.

The numerical experiments are conducted to assess the impact of the proposed method on the displacement and the size of the oils shaft. The comparative analysis of the results is obtained.

Due to this, it is shown that when the oil shaft approaches to the production well, only gas escapes from the reservoir, and as the oil viscosity decreases, the time that the oil shaft approaches to the production well decreases. It is also shown that with an increase in oil viscosity, the length and growth of the oil shaft decrease, and the decrease in comparison with that occurs at a higher rate. It is also shown that with an increase of oil viscosity, the length l_v and growth of the oil shaft h_v decrease, and the decrease of l_v in comparison with h_v occurs at a higher rate. And with an increase of the filtration rate and difference of pressure, the geometric dimensions and the «increment» of the oil shaft increase abruptly.

Keywords: capillary forces, three-phase filtration, adaptive grid, Thomas algorithm, viscoplastic fluid.

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DIAGNOSTICS OF THE PRE-FAULT SITUATION OF THE BOLTED CURRENT-CARRYING JOINT IN THE CONDITIONS OF CHANGING REGIME PARAMETERS

page 50–57

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The object of research is the methods of non-destructive monitoring of the state of a bolted current-carrying joint under conditions

of dynamically changing current load conditions and ambient temperature. One of the most problematic places in the modern conditions of economic development of enterprises is the reduction in the accident rate of production due to the weakening of the bolted current-carrying joint. Studies of the causes of stopping electrical equipment at a number of ferrous metallurgy enterprises, mining and processing complexes, in medical institutions have shown that in 1.5–2 % of cases the cause of an emergency shutdown of electrical equipment is the weakening of the bolted current-carrying joint. The main problem of the bolted current-carrying joint is the mechanical weakening of the contact density. The appearance of a temperature gradient in the place of a bolted joint is influenced by climatic parameters and dynamically changing modes of operating current loads and network voltage.

The study of operating parameters of the network and load currents is based on the use of a technique for monitoring the quality of electricity indicators using self-recording spectrum analyzers. In this study, the spectrum analyzer Fluk 435 (Ukraine) is used, the characteristics of which correspond to the ISO 9001 measurement system certificate. Statistical processing methods are used as the basis for processing the experimentally obtained data.

In the course of the study, the inequality between the measured temperature of the bolted current-carrying joint and the calculated temperature of the serviceable joint is determined. The inequality is fulfilled in the sections, the stationarity of which is determined for deterministic and random modes of change of the controlled parameters. The functions of Boolean variables are compiled, the disjunctive functions that determine the normal and pre-crash modes of the bolted joint are minimized. The obtained theoretical results allow developing algorithms and devices for diagnosing and protecting equipment.

This provides the opportunity to reduce the accident rate of the equipment. Compared with similar well-known protection equipment, taking into account the modes of load currents, mains voltage and ambient temperature provides a high sensitivity and accuracy of detecting the initial moment of loosening of a bolted current-carrying joint.

Keywords: weakening of bolted current-carrying joint, state diagnostics, random and deterministic mode of load current.

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