MECHANICS

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ENVIRONMENT EFFECT ON MECHANICAL PARAMETERS OF SOIL-MIXING

pages 6–11

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Soil improvement is originally an economical solution to make soil buildable, particularly compared to deep foundation methods using piles. The object of this research is the understanding of the behavior of soil-mixing material, in particular, what concerns the effect of environmental parameters, whether: temperature, water table level, chemical attacks, the phenomenon of aging etc. on the mechanical and physical characteristics (resistance to simple compression, resistance to simple bending, modulus of elasticity, porosity, density, etc.), of a soil-mixing column, in the short term and long term. The big problem is how to carry out experiments in the laboratory, which will be representative of the different phenomena that take place on a real scale (on site). To do this, our approach consists of studying different soil-mixing mixtures composed of «artificial» soils (clay and sand) and a CEM III/C cement, and with a variable W/C ratio. After making the test pieces, with the different dosages of cements and a ratio between clay and fixed sand, they were kept under normal temperature conditions, in order to reach a maturation age (180 days), to be able to begin the series of experiments. Once the specimens were subjected to the aging test, let's begin to crush them with simple compression and simple bending. The parametric study highlights a percentage of clay beyond of which the resistance decreases and the rigidity of the material can pose a problem for certain structural uses. The different results obtained show that for a low cement dosage, the humidification-drying cycle influences both the resistance to simple compression and to bending simple, as well as the number of cycles affects the resistance values in a significant way. On the other hand, for a greater or lesser dosage of cement, the resistance values are not affected. Based on the results obtained, it is possible to conclude that the choice of cement dosage depending on the nature of the soil influences the soil-mixing column and plays an important role on the lifespan of the column; therefore, it is necessary to give primary importance to the choice of cement dosage depending on the nature of the soil treated.

Keywords: soil-mixing, formulation, mechanical properties, durability, damage, aging cycle, compressive resistance, bending resistance.

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RESEARCH AND ANALYSIS OF TOWER CRANE LOAD BEHAVIOR WHEN THE ROPE BREAKS

pages 12–15

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The object of research is the behavior of the load of the tower crane during the break of the sling. One of the most problematic areas is the safety of work and the prevention of emergency situations. Despite the presence of mandatory safety measures, during cargo transportation, one of the sling branches may be destroyed due to the presence of a dynamic component during the operation of the crane, or errors of the slinger when securing the cargo. Also, the presence

of hidden internal or unnoticed defects in the sling construction itself cannot be ruled out. Also, one of the most problematic places is the chaotic fluctuations of the load, which negatively affect the stability of the crane and safety. The paper describes the case of the destruction of one of the branches of a two-rope sling during the transportation of a long product by a tower crane.

The proposed method of cargo behavior analysis is based on the use of a dynamic description of cable system failure modes within the framework of setting and solving differential-algebraic equations. This makes it possible to more accurately describe the behavior of the cargo when the sling breaks.

The obtained results show that the application of the proposed method makes it possible to bring the mathematical model of the two-link mathematical pendulum significantly closer to the actual mutual oscillations of the load during the sling break. This is due to the fact that the proposed method has a number of features, in particular, high sensitivity to changes in the behavior of the cargo and a quick reaction to a rope break.

These results can be used in practice in the design and operation of tower cranes. Thanks to the application of the proposed method, it is possible to obtain accurate values of cargo behavior indicators and timely detection of a rope break. Compared to similar known methods, this method has such advantages as high efficiency, reliability and safety of operation.

Keywords: tower crane, sling break, two-link pendulum, load swinging, Lagrange equation, nonlinear differential equations.

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MECHANICAL ENGINEERING TECHNOLOGY

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IMPROVING THE DESIGN OF A JAW SHUTTER TO INCREASE THE EFFICIENCY OF MATERIAL CRUSHING

pages 16–21

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The object of research is the design of a jaw crusher for crushing limestone for the production of silicate bricks. The article is devoted to the study of the problem of reducing the efficiency of material crushing in a jaw crusher. The efficiency of crushing materials in jaw crushers ensures the quality of manufacturing bricks, etc. Therefore, this work is aimed at choosing a way to improve the design of the jaw crusher to increase the efficiency of material crushing.

The article defines the classification of jaw crushers, their advantages and disadvantages, describes the principle of operation of the most widely used jaw crushers in the construction industry with simple and complex rocking of the cheek. A literature and patent search and analysis of existing methods of increasing the efficiency of material crushing in jaw crushers was carried out. As a result of the literature and patent search, one of the methods of improving the design of the jaw crusher to increase the efficiency of material crushing based on the use of longitudinal protrusions on the movable jaw was selected and proposed. The protrusions on the flat sections of the working surface of the plate are made with the same pitch of their location within each section with a decrease in the pitch of the protrusions in the direction of distance from the upper part of the plate. The considered design of the movable jaw with longitudinal protrusions in the jaw crusher will ensure reliable pulling of the material into the gap between the movable and stationary jaws, which ensures high contact stresses acting on the crushed material from the side of the working surface of the plate.

Compared to known designs of jaw crushers, the improved design of the movable jaw in the jaw crusher with longitudinal protrusions of different sizes with a decrease in their size in the direction from the upper part of the plate on three sections of the working surface of the plate will contribute to ensuring high contact stresses acting on the crushed material from the side of the working surface cheeks, during its advancement between the moving and stationary cheeks and increases the efficiency of destruction of various materials.

Compared to known designs of jaw crushers, the improved design of the jaw crusher has a movable jaw with longitudinal protrusions of various sizes. At the same time, these protrusions are located on three sections of the working surface of the plate with a decrease

in their size in the direction from the upper part of the plate. This will help ensure high contact stresses acting on the crushed material from the side of the working surface of the cheek, during its advancement between the moving and stationary cheeks. Also, this design of the working jaw of the jaw crusher with longitudinal protrusions helps to increase the efficiency of destruction of various materials.

Keywords: jaw crusher, moving jaw, fixed jaw, longitudinal protrusions, material crushing efficiency, contact stresses.

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THE CHOICE OF RATIONAL ADJUSTMENT OF THE CHEMICAL COMPOSITION OF IRON MELTED IN AN ELECTRIC ARC FURNACE ON THE BASIS OF TECHNOLOGICAL AUDIT OF SERIAL FILMS

pages 22–26

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The object of research in the work is cast iron of the SCh20 grade according to GOST 1412-85 (DSTU EN 1561, EN-GJL-200), which is melted in an electric arc furnace. In this work, the parameters of serial smeltings of cast iron used for machine-building castings were determined, which were used to select the content of elements of the chemical composition.

The existing problem is that the impossibility of taking into account many factors influencing the formation of the chemical composition of cast iron during smelting leads to deviations of the chemical composition from the requirements regulated by the technical conditions. The main reason for this is the uncontrollability of the chemical composition of the charge materials and the difficulty of accurately determining the soot of the elements during the smelting process. This can lead to the formation of a shortage of cast iron, or to excessive costs for smelting, associated with the need for additional technological operations and the use of additional materials to eliminate detected deviations of the composition from the requirements.

The procedure of technological audit of serial smeltings is proposed, the feature of which is a comprehensive assessment of the actual indicators of smelting. They include: mathematical expectations of the content of the elements of the chemical composition, estimates of their dispersions, root mean square deviations, systematic errors, scattering fields and deviations of the lower and upper limits of the content of each element from the lower and upper limits required by the technical conditions. The results of such an audit are the possibility of calculating corrective combinations of charge materials and ferroalloys, which eliminate inaccuracies in the calculation of the charge and the determination of the heat of the elements during the smelting process.

As a result of the audit of a sample of 31 serial smelters, it was established that the average content of the elements C, Mn, Si, Cr exceeds the average required by technical conditions. These deviations are: +0.04 % C, +0.06 % Mn, +0.038 % Si, +0.06 % Cr. To compensate for these deviations, the following combination of charge materials and ferroalloys, which are introduced into the melt before delivering the cast iron to the casting area, is proposed: 44 kg of steel scrap +88 kg of recycled iron.

The presented study will be useful for machine-building enterprises that have foundries in their structure, where iron is melted for the production of castings.

Keywords: electric arc smelting, chemical composition of cast iron, technological audit, serial smelting, charge materials, ferroalloys.

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IMPROVING THE TECHNOLOGY OF MANUFACTURING CAST BRAKE DRUMS IN PINK SAND MOLDS

pages 27–30

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The object of research in the paper is the production technology of casting «brake drum» from cast iron of the basic grade SCh20 according to GOST 1412-85 (DSTU EN 1561, EN-GJL-200). The existing problem is that due to the imperfection of the technological processes of manufacturing castings, final internal defects of a shrinking nature are possible. This can lead to a decrease in the strength and operational reliability of the drums, regardless of the chemical composition, which may meet the technical conditions and should provide the specified strength indicators according to the grade of cast iron.

Based on the results of 3D modeling, it has been found that with the existing technology of manufacturing brake drum castings in one-time sand molds, final shrinkage defects are formed in the upper part of the casting. To eliminate this problem, a decision is proposed to increase the allowance for mechanical processing on the upper surface of the casting. The possible excess of the mass of the casting and excess consumption of the alloy that will occur when implementing this solution can be compensated by reducing the allowance on other surfaces based on their optimization by the method of dimensional chains and reducing the thickness of the casting wall. For this, a reduction in the carbon content in the alloy is proposed as a factor in increasing the tensile strength of cast iron. On the basis of 90 serial meltings in industrial conditions, the possibility of increasing the strength limit of cast iron by approximately 11 % by reducing the average carbon content in cast iron from 3.45 % to 3.4 % has been proven.

The proposed solutions are the essence of improving the production technology of cast brake drums, which are produced by casting in one-time sand molds.

The presented study will be useful for machine-building enterprises that have foundries in their structure, where iron is melted for the production of castings.

Keywords: brake drum, chemical composition of cast iron, allowances for mechanical processing, serial melting of cast iron, charge materials, strength limit of cast iron.

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MATERIALS SCIENCE

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CONSIDERATION OF ELECTRONIC MEAN HEAT TRANSPORT VIA A LOW DIMENSION SYSTEM

pages 31–41

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The object of research is the complex realm of energy localization and coherent ballistic electronic transport within low-dimensional silicon quantum wires, specifically those doped with germanium atoms. Unlike their three-dimensional counterparts, low-dimensional systems exhibit unique electronic transport behaviors, necessitating novel analytical approaches for a comprehensive understanding. The core of this investigation leverages the Phase Field Matching Theory (PMFT) and the tight-binding (TB) approximation, sophisticated methodologies that enable a deep dive into the quantum mechanical nuances of these systems. Through this lens, we examine the intricate dynamics of dispersion relationships, phase factors, group velocities, and notably, the impact of defects introduced by the germanium doping.

This research meticulously analyzes how these defects affect electronic and thermal conductivities, along with densities of states, offering new insights into the role of Fano resonances in the fluctuation of transmission and reflection spectra. These resonances, we find, are crucially dependent on the nature of the defects, their configuration, and the electronic parameters in their vicinity, underscoring the nuanced interplay between material composition and electronic properties in low-dimensional systems.

The implications of our findings extend far beyond the theoretical. They pave the way for significant advancements in nanotechnology and the design of electronic devices, highlighting the potential for creating more efficient, high-performance components. Furthermore, this work proposes a framework for developing non-destructive testing methodologies that could revolutionize material science by enabling the precise analysis of defects in low-dimensional systems without causing damage. This is particularly critical for the ongoing development of materials with optimized properties for various applications, from electronics to energy storage.

In essence, this research not only enriches our understanding of the physics governing low-dimensional systems but also offers practical insights into leveraging these properties for technological innovation. By bridging the gap between theoretical physics and material science, our study sets the stage for the next generation of electronic components and non-destructive evaluation techniques, marking a significant step forward in the application of quantum mechanics to real-world challenges.

Keywords: Phase Field Matching Theory (PMFT), tight-binding (TB), Landauer Büttiker formalism, Green's functions.

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TECHNOLOGY AND SYSTEM OF POWER SUPPLY

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DESIGN OF THE INTENSIFICATION METHOD WITH THE HELP OF FRACCADE SOFTWARE

pages 42–50

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The object of research in the work is the FracCADE software, with which it is possible to simulate the process of hydraulic fracturing and well field, on which the intensification method is designed. This hydraulic fracturing simulator was developed by Schlumberger Ltd. based on proven physical principles of hydraulic fracturing to optimize the treatment process and proven in practice. The system includes a range of hydraulic fracturing models, from 2D models to extensive 3D simulations with lateral communication. It includes a number of complementary modules for fracturing fluid and proppant optimization, injection scheduling, real-time monitoring, pressure equalization, production forecasting and economic evaluation. Some models allow simulating the geometry of the fracture, solving proppant concentration problems, and simulating possible shielding due to proppant covering the fracture or the dehydration process.

Hydraulic fracturing remains one of the main engineering tools for increasing the productivity of wells. The effect is achieved due to:

– creation of a conductive channel (fracture) through the damaged (contaminated) zone around the well, in order to penetrate beyond its boundaries;

– spreading of the channel (fracture) in the formation to a considerable depth in order to further increase the productivity of the well;

– creation of a channel (fracture), which would allow changing, influencing the fluid flow in the formation.

In the latter case, fracturing really becomes an effective tool that allows to manage the operation of the reservoir (in particular, change its filtering characteristics) and implement long-term strategic development programs. The concept of hydraulic fracturing is quite simple. In general, for relatively simple geology, the physical foundations of fracturing theory are fairly well developed and tested. For the most part, the difficulties boil down to two problems: the real geological conditions and the complex multidisciplinary nature of the fracturing process itself.

The process of designing fracturing in order to achieve a certain result is closely related to rock mechanics (which affects the geometric parameters of the fracture), fluid hydromechanics (in which the tasks of controlling the flow of the working fluid and placing the proppant in the fracture are solved) and chemistry, which determines the behavior of materials, which are used during hydraulic fracturing. Moreover, the hydraulic fracturing project must take into account the physical limitations imposed by the specifics of the real deposit and well. In addition, to achieve the desired results, the fracturing operation must be carried out in strict accordance with the calculations (that is, a complete cycle in which each operation plays its role).

Keywords: FracCADE, hydraulic fracturing, fracture, permeability, proppant, viscosity, well, productive horizon.

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ANALYSIS OF THE ENERGY EFFICIENCY OF A SYSTEM WITH A HYBRID SOLAR COLLECTOR AND THERMAL ENERGY STORAGE

pages 51–56

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The object of research is heat transfer in a hybrid thermal photovoltaic solar collector.

International agreements and strategies aimed at combating climate change and reducing greenhouse gas emissions strongly call for the

active implementation of renewable energy sources on a global scale. A special emphasis is placed on the development of solar energy, which has significant growth potential due to the constant improvement of technologies and cost reduction of production. With this in mind, the authors focused on the development and analysis of a computer model of an innovative hybrid system that effectively combines a solar collector for the simultaneous production of both thermal and electrical energy.

The research included a detailed study of the temperature changes of the heat carrier in the hybrid photovoltaic solar collector and thermal accumulator during the period of solar irradiation. Thanks to careful monitoring, the main patterns of gradual temperature increase in both key components of the hybrid system were established. In addition, an assessment of the dynamics of changes in the instantaneous thermal power of the solar collector under the influence of various factors, such as the intensity of solar radiation, the angle of inclination of the collector, wind speed, etc., was carried out.

The results of computer modeling showed the average indicator of the efficiency of the entire hybrid system, as well as its variations during a certain time of operation. In addition, the change in the instantaneous specific heat capacity and the overall efficiency of heat energy generation by the hybrid photovoltaic solar collector were analyzed. Special attention was paid to the study of the dynamics of changes in the thermal efficiency of the entire system, as well as its ability to efficiently store thermal energy in a specialized battery.

The comprehensive analysis made it possible to obtain the key thermophysical parameters of the developed hybrid system with a photovoltaic solar collector. This data is extremely important, as it will allow engineers and scientists to accurately calculate the potential performance and efficiency of such a system when it is put into practical use in the future. In general, the results of the study emphasize the promising development of hybrid solar collectors as one of the leading technologies in the field of renewable energy in the context of global challenges of climate change.

Keywords: energy efficiency, solar collector, thermal battery, energy supply system, alternative energy sources.

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CONSIDERATION OF THE ISSUE OF REGULATING LOW-FREQUENCY VIBRATIONS OF THE DRILL STRING WHEN DRILLING WITH A DOWNHOLE MOTOR

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The object of research is the dynamic processes that occur in the drill string during the deepening of the hole in deep wells. The work is aimed at solving the problem for an idealized system in the form of rod systems while preserving its main oscillatory properties.

The nature of oscillatory processes that occur in the drill string during drilling with downhole motors is considered, in some cases it turns out to be very complicated. In the general case, the dynamic process changes according to an aperiodic law, which is superimposed by processes of an oscillating nature with an increasing (damping) nature of the amplitudes of different frequencies.

The influence of the torque characteristics of the downhole motor and bit on the development of oscillatory processes in the drill string during well drilling has been theoretically determined.

The results of theoretical and experimental studies of oscillatory processes and their interaction with the use of proposed models of hole deepening in the future make it possible to create a simulation model. This model would include taking into account the mode parameters of drilling, the mechanical properties of the rocks to be drilled and the layout of the drill string bottom (DSB).

The obtained research results can be applied in practice in the process of designing the structure of the drill string bottom (DSB) with the use of downhole motors, in particular, screw motors, the use of which leads to energy stress, the complication of work processes and structural schemes. As a result, the nature of vibrations changes and the vibration loads on parts of the downhole motor, bits and elements of the drill string are reduced.

In the future, it is necessary to take into account the hydrodynamics and the type, as well as the design and parameters of the applied downhole elements for the development of their dynamic models.

Keywords: drill string, downhole motor, bit, low-frequency oscillations, oscillatory processes, hole deepening.

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