MECHANICS

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DEVELOPMENT OF A MATHEMATICAL MODEL OF ACOUSTIC PROCESSES IN THE OPERA STUDIO OF THE KYIV CONSERVATORY

pages 6–10

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The object of this study is the acoustic characteristics of a concert hall, with a particular focus on the reverberation time, which significantly affects both the perception of sound by listeners and the performance of musicians.

The study emphasises the importance of mathematical modelling of acoustic processes in concert halls, especially in optimising reverberation time. In the context of modern materials and advanced acoustic design technologies, precise calculations and analyses are required to evaluate the impact of various elements on a room's overall acoustics. Poor design or material selection can result in listener discomfort and reduced sound quality, highlighting the critical role of scientific methods in analysing and modelling acoustic processes under specific conditions.

The research utilised mathematical models developed in MATLAB® software to calculate reverberation time based on different materials and their surface areas.

The key findings demonstrate that mathematical models can accurately simulate acoustic processes in a room, enabling predictions of acoustic characteristics based on defined parameters. The correlation between theoretical calculations and experimental data confirms that mathematical modelling is an effective tool for improving the acoustic quality of concert halls, considering the use of different materials.

The practical significance of the results lies in the ability to implement recommendations for optimising acoustic conditions in concert halls. The identified parameters can guide the design of spaces for musical events and enhance methods of acoustic design. Applying these findings in practice can improve sound quality, thereby increasing listener comfort and enhancing the overall perception of music.

Keywords: mathematical modelling, MATLAB®, acoustic design, acoustic concert hall characteristics, reverberation time, sound absorption.

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OPTIMIZATION OF THE CONCRETE PRODUCTION PROCESS IN TERMS OF ENERGY CONSUMPTION

pages 11–15

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The object of study is the power supply system of a concrete mixing plant. The research made it possible to identify and eliminate the shortcomings of the existing power supply system in order to increase its energy efficiency and productivity. A new concept has been proposed, which provides for an individual arrangement of bins with isolated conveyors for each of them.

The study revealed a number of significant advantages of the proposed system, namely:

– separate conveyors for each hopper allow to optimize the routes of material movement, avoid unnecessary movements and reduce the load on the drives;

– the use of modern electric motors with high efficiency and other energy-saving components can further reduce energy consumption;

– due to the independent operation of each hopper, it is possible to load different materials in parallel, which reduces the time required to prepare a new portion of the concrete mixture;

– the absence of a common hopper reduces the risk of congestion and obstacles that can lead to equipment downtime;

– due to the independence of each hopper, different types of concrete mixtures can be prepared simultaneously.

However, there are some potential disadvantages and risks to consider before implementing a new system, including:

– the implementation of a new system may require significant investment in new equipment and installation;

– the number of system components increases, which may complicate its maintenance and repair;

– the efficient operation of the new system requires the development of special software and automation systems.

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Despite some drawbacks, the introduction of a power supply system for a concrete mixing plant is a promising direction for the development of the machine-building and construction industry. The results of the study indicate the high efficiency of this technology and its economic feasibility in the long term.

Keywords: power supply systems, concrete mixing plant, hopper, conveyor, concrete mixture, automation system.

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MODELING THE LOADING PROCESS OF PNEUMATIC SEPARATION CHANNELS

pages 16–24

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The object of research is the problem of uniform distribution of bulk materials across the width of the working elements of the separation equipment. Such a problem limits the productivity and quality of the process of separation of bulk materials by aerodynamic and dimensional characteristics. To ensure uniformity of the layer of bulk material across the width, an integrated design of the loading device is proposed, which consists of a gable surface with a variable angle of inclination from the center of the feed to the extreme limits of the device. The working part of the device is made in the form of surfaces of variable width, and the width of each slope of the surface increases proportionally to the distance to the walls of the housing. This allows for controlled distribution of the material across the width. The studies were conducted using analytical and experimental methods. To determine the parameters of the movement of the bulk grain medium along the integrated inclined surface, analytical expressions were obtained that take into account the parameters of the proposed loading device and the properties of the bulk grain material. The patterns of change in the rate of descent of particles of bulk grain material from the inclined surface, as well as the dependence of the velocity of their fall to the hopper bottom, were obtained. Experimental studies were based on high-velocity video recording of the process with identification of dynamic parameters of bulk material and comparison with modeling data. The adequacy of the model was confirmed by experiments with a difference of up to 3.6 %. The influence of the following significant factors on the final velocity of particles of bulk grain material (BGM) was established: the length of the sloping surface at the level of 47.5–116.5 %, then the distance from the surface to the hopper bottom at the level of 76.7–85.6 % and the angle of inclination of the sloping surface at the level of 24.4–41.1 %. The ranges of variation of the BGM particle velocities were established: the initial velocity of particles on the sloping surface 0.82–1.27 m/s, the velocity of particles descending from the sloping surface 0.85–1.43 m/s, the velocity of falling particles 0.68–1.47 m/s. The research results were rational parameters of the integrated loading device, which provides excellent particle movement velocities and leads to uniform distribution of bulk grain material across the width of the separation equipment with an inlet to outlet ratio of (1:5). The results obtained prove the existence and method of scientific and technical solution to the problem, create conditions for further research and design of separation equipment with high technological indicators.

Keywords: dynamics of bulk material, grain mixture, distribution uniformity, analytical expressions, rational parameters, separation equipment.

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DEVELOPMENT AND IMPROVEMENT OF ROLL CASTING TECHNOLOGIES FOR UNIVERSAL BEAM MILLS

pages 25–35

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The object of this research is the casting technology of double-layer rolls for universal beam mills (UBM). They are critically important components of the metallurgical industry, ensuring the production of beams, profiles, and other structural elements, widely used in construction, mechanical engineering, transport, energy, and other industries. Developing innovative approaches to manufacturing rolls is strategically important for strengthening Ukraine's production potential. Since one of the most problematic areas is the dependence on imported rolls, which leads to significant economic losses, logistical risks and restrictions on the country's technological independence. Existing domestic technologies do not always lead to achieving the necessary operational characteristics, such as wear and heat resistance, and durability, complicating the competitiveness of products on the international market.

The work proposes an innovative technology for manufacturing two-layer rolls, using stationary casting molds, a bainite-martensitic outer layer structure, and optimization of temperature conditions. This provides high hardness, heat resistance, and wear resistance of the outer layer. The inner layer, made of high-plasticity materials, compensates for residual stresses and improves structural stability. The use of alloying elements (nickel, molybdenum, copper) in combination with mathematical modelling of temperature fields made it possible to reduce the number of structural defects, such as porosity and delamination while ensuring uniform connection of the layers. This is because the proposed technology combines modern approaches to alloying, heat treatment optimization, and high-tech modelling of temperature conditions during casting. A notable characteristic is the optimization of materials to withstand elevated mechanical and thermal stresses, complemented by an advanced casting mold design that enhances interlayer adhesion and minimizes the likelihood of defects. This facilitates the reliable performance of rolls under challenging operational conditions, characterized by elevated mechanical and thermal stresses. Compared with similar known solutions, the proposed technology increases the service life of rolls by 20–25 %, reduces repair and maintenance costs by 15–20 %, and increases the efficiency of production processes by reducing the frequency of equipment shutdowns.

Keywords: universal beam mills, double-layer rolls, casting technology, heat treatment, bainite-martensitic matrix.

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TECHNOLOGY AND SYSTEM OF POWER SUPPLY

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IMPROVEMENT OF THE PROCESS OF PREPARING CARGO TANKS OF CRUDE OIL TANKERS FOR CARGO OPERATIONS

pages 36–40

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The object of research is the process of inerting the cargo tank of an oil tanker. Issues related to improving the process of preparing cargo tanks of oil tankers for cargo operations are considered. It is noted that the efficiency of oil tanker operation, in addition to transport operations, is determined by the technologies used during the preparation of the vessel for receiving new cargo. One of such technologies is the inerting cargo tanks, which precedes any cargo operations. The study was aimed at improving the inert flue gas system by using a new technology for supplying jets of inert gas to the cargo tanks of an oil tanker. The main task of the research is to establish the degree of influence of the gas flow parameters (formed by the inert flue gas generator) at the entrance to the cargo tank on the nature of the change in air concentration in the entire volume of the tank. The final result of solving this scientific and applied problem is determined to be a reduction in the inerting time of cargo spaces of oil tankers. During the experiments, the supply of inert gas to the cargo hold was provided according to three technological schemes. The first contained only one jet source with an opening angle of 60°, which was located at the central point of the cargo tank bottom. The second contained four sources of inert gas jets, which were located crosswise on the tank bottom. The nozzles were installed diagonally in the centers of four identical rectangular zones of the tank bottom. Their opening angle to create a conical jet torch was 30°. The number of sources of inert gas jets of the third scheme was five. At the beginning of the inert gas supply process, four sources were used, which were located at the corners of the tank with an opening angle of 30°. When the initial value of the oxygen concentration in the air was reduced by thirty percent, the inert gas was supplied only from the fifth – the central jet source. It used a nozzle that creates 90° cone opening angle of the jet torch. With the start of operation of the central nozzle, all angular sources of inert gas jets were turned off. It has been proven that this scheme ensures an improvement in the inerting process of an oil tanker, which is reflected in a reduction in the time required for its implementation.

Keywords: cargo operations, inert flue gases, oxygen concentration, jet opening angle, oil tanker, inert gas system.

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IMPLEMENTATION OF BLOCK ARTIFICIAL COOLING UNITS FOR GAS PREPARATION

pages 41–45

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The object of research is the process of implementation and use of block artificial cooling units in the technology of natural gas preparation.

The research has confirmed the high efficiency of using artificial cooling units. Due to deep gas cooling, it is possible to achieve a significant increase in condensate production and improve gas quality. In addition, modern units are characterized by high energy efficiency and compactness.

A comprehensive analysis of existing gas preparation technologies and a comparative assessment using block artificial cooling units revealed a number of significant advantages of the proposed system, namely:

– block units provide deeper removal of heavy hydrocarbons, water and other impurities, which improves the quality of the final product;

– due to lower gas temperature, more intensive condensation of heavy hydrocarbons is achieved, which leads to additional extraction of valuable components;

– modern block units are equipped with energy-efficient equipment, which reduces energy costs;

– the units have a modular design, which facilitates their transportation, unit and maintenance;

– the use of block units allows to reduce emissions of harmful substances into the atmosphere;

– the ability to adapt to different operating conditions and product quality requirements.

The study found that existing natural gas preparation technologies have a number of disadvantages, such as:

– low efficiency of gas purification;

– high energy consumption;

– complexity of maintenance;

– large dimensions of the equipment.

Despite some drawbacks, the introduction of block artificial cooling units is a promising direction for the development of the gas industry. The results of the study indicate the high efficiency of this technology and its economic feasibility in the long term.

Keywords: block artificial cooling units, low-temperature separation, unit performance, gas recovery.

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RESEARCH OF METHANOL CONTENT IN TECHNOLOGICAL FLOWS OF FACILITIES THAT PROCESS GAS BY LOW-TEMPERATURE SEPARATION METHOD

pages 46–53

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The object of research is methanol as an inhibitor, which is used in the process of collecting and preparing products from gas, gas condensate, and oil fields to protect against hydrate formations. It is important to ensure the rational consumption of this inhibitor, taking into account its solubility in gas, water, and liquid hydrocarbons. This work is aimed at analyzing the use of the methanol hydrate formation inhibitor in the process of low-temperature gas preparation and determining ways to use it more effectively.

The work presents the results of modeling the distribution of the hydrate formation inhibitor along the technological flows of low-temperature gas separation units according to the following schemes:

– low-temperature separation with gas cooling due to the Joule-Thompson effect;

– compression of gas from wells using PCS (pressure compressor station) + low-temperature separation with gas cooling due to the Joule-Thompson effect;

– compression of gas from wells using PCS + low-temperature separation with gas cooling due to the operation of a turboexpander unit;

– compression of gas from wells using PCS + low-temperature separation with gas cooling due to the operation of an artificial refrigeration unit (propane refrigeration unit).

The use of a computer simulator allowed to track in detail the distribution of methanol during the gas preparation process. The iteration method determined the minimum values of methanol consumption at which the hydrate-free operation mode of the equipment is maintained. Based on the modeling results, an analysis of methanol content in technological flows was performed. And the patterns of inhibitor separation in the separation equipment were also determined, namely, the dependence of methanol distribution on gas pressure in separators, and the methanol content in the output lines of gas preparation units.

It was established that the results of the study can be applied in the development of technologies for the collection, regeneration and reuse of methanol in technological processes of low-temperature gas preparation. The practical value of the results lies in the possibility of improving typical methods of protecting equipment from hydrate formations by developing an automated inhibitor supply system that, by monitoring the parameters of the technological process, changes the inhibitor dosage and ensures its economical use.

Keywords: natural gas, associated formation water, inhibitor, gas hydrates, computer modeling.

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DEVELOPMENT AND RESEARCH OF ENERGY-EFFICIENT HELIO-AIR COLLECTORS FOR DRYING AGRICULTURAL PRODUCTS

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The object of study is the drying of agricultural plant products. Artificial heat drying of agricultural plant products (seeds, fruits, nuts, grain, etc.), as a traditional method of canning and preparation for storage and further processing, usually takes place in dryers of seasonal use. To reduce the consumption of traditional types of organic fuel, it is proposed to use a lightweight portable film solar collector to heat the drying agent in seasonal dryers. A mathematical description of thermal processes in a solar collector is given. To increase the efficiency (degree of air heating), devices are proposed – heat exchange intensifiers. Effective methods of increasing the thermal power of the solar collector based on the use of ring and spiral turbolyzers of the coolant flow and sectional multi-pipe (multi-element) absorber have been theoretically substantiated, experimentally confirmed. The use of these structural elements of the solar collector will increase the thermal performance per unit area of the solar radiation absorber, which will increase the heating of the blunt carrier with 26 °C before 32 °C for tube absorbers and up to 36 °C for sectional absorbers. Maximum specific power of the solar collector with an area 240 m^2 – 0.2 kW/m^2 with a specific flow rate of the coolant of 23 $m^3/h{\cdot}m^2$. For systems of active ventilation of seed material with specific air flow rates up to 100 $m^3/h{\cdot}m^2$, it is possible to heat the atmospheric air up to 10 °C, which ensures round-the-clock drying of the product. A simplified mathematical model is formulated to intensify parameters according to the data of experiments. The heat transfer coefficients from the film absorber of solar energy to the heated air are determined. The results of the experimental determination of the thermal characteristics of the solar collector and its energy efficiency are presented. As the calculations showed, a further increase in the performance of the tubular solar collector is possible with an increase in the flow rate in the film absorber, which can be realized by reducing the diameter of the pipeline.

Keywords: solar radiation, heliocollector, drying agent – air, heat transfer, film sleeves, solar absorber.

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