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JUSTIFICATION OF THE METHODOLOGY FOR INSTALLING A DEFORMATION RECORDER IN A MAIN PIPELINE SECTION THROUGH ANALYSIS OF ITS STRESS-STRAIN STATE

pages 6–11

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Object of the research is a deformation recorder designed for monitoring the stress-strain state of main pipelines. This study investigates the hypothesis regarding the feasibility of installing a deformation recorder on a pipeline section that has been preloaded with the maximum allowable operating pressure, in order to ensure the recorder's reliable performance under various pipeline operating conditions. Structurally, the examined deformation recorder consists of two clamps, with four longitudinal strain multipliers mounted at diametrically opposite locations between them. By comparing their relative strain values, it is possible to determine the spatial curvature of the pipeline axis. A 3D model of a pipeline section with a diameter of 270 mm and wall thickness of 5 mm was developed, incorporating a deformation recorder with a measurement base of 300 mm. Based on this model, a multi-step finite element model was created to calculate the stress-strain state and the contact interaction of a 4.6-meter-long pipeline section. One end of the pipeline was modeled as axially compliant, and the stress recorder was installed on it. Series of numerical experiments were conducted to analyze the stress-strain behavior of the assembly under varying preload forces of the clamp bolts. The results confirmed the initial hypothesis and allowed the determination of an acceptable preload range. Specifically, the preload force must be no less than 15 kN to ensure secure attachment of the clamps on a non-operational pipeline, and must not exceed 30 kN to comply with the pipeline's strength requirements. Based on the analysis, recommendations were made regarding the development of a redesigned clamp lock. Additionally, the study proposes that changing the material of the deformation recorder may reduce the required bolt preload force.

Keywords: main oil and gas pipeline, stress-strain state, express analysis, deformation recorder.

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MECHANICAL ENGINEERING TECHNOLOGY

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IMPROVING THE DESIGN OF THE EXTRUDER TO IMPROVE THE QUALITY OF POLYMER PRODUCTS

pages 12–17

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The object of research is an extruder for the manufacture of polymer products. The article considers the problem of improving the quality of polymer products on the basis of improving the design of the extruder. The selected design of the extruder with the execution of a three-section worm in the compression

zone with different heights of barrier gaps in each section. The ratio of the length of individual sections to the total length of the compression zone should be in the range of 0.1–0.5. In this case, the height of the barrier gap in the first section should exceed the height of the gaps in subsequent sections by 1.1 times between adjacent turns of the worm. In the first section with a larger gap, there is an intensive dissipation of the mechanical energy of the drive, which leads to the melting of the polymer and the release of heat. At the same time, a significant part of the unmolten material is retained before entering subsequent sections with a smaller gap. Thus, the worm does not experience a sharp increase in pressure in the compression zone and local overheating of the material along its length in the compression section. In subsequent sections, further separation of the melt and solid particles of the polymer occurs, and the clearance height decreases gradually, ensuring a controlled distribution of heat flows in the material. The proposed design of a worm in the compression zone with a closed barrier gap $h = 0.001$ m and open barrier gaps h at 0.0105 m and 0.0075 m is illustrated by the example of an extruder ($D = 0.63$ m; $\varphi = 17.1°$) in the processing of recycled high-pressure polyethylene. The use of open barrier gaps between the worm and the extruder body reduces heat dissipation on its working surfaces by almost three times than with closed barrier gaps, as demonstrated by the obtained dependence of the dissipation function on the worm rotation speed. This reduces the risk of material degradation, the thermal conditions of the polymer stay are mitigated, the homogeneity of the melt increases and will contribute to improving the quality of finished polymer products, in particular polymer pipes, films, etc.

Keywords: extruder, extrusion, worm, turns, three-section compression zone, barrier gap, reducing polymer degradation, melt uniformity, quality improvement.

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ELECTRICAL ENGINEERING AND INDUSTRIAL ELECTRONICS

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ANALYSIS OF METHODS AND ALGORITHMS FOR QUADROTOR POSITION CONTROL

pages 18–23

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The object of research is the system of position control of a quadrotor unmanned aerial vehicle (UAV) as a nonlinear multi-input multi-output (MIMO) system with strong cross-channel coupling and high sensitivity to parametric and structural uncertainty. The problem addressed is the lack of robust and computationally efficient control algorithms that can ensure stability under uncertainty and be implemented on embedded platforms with limited resources.

This study presents an analytical review of modern control methods for quadrotor position stabilization. The methods analyzed include classical proportional-integral-derivative (PID) controllers, linear optimal, robust, adaptive, and intelligent systems (neural networks, fuzzy logic). The analysis focuses on the structure, sensitivity to uncertainty, computational complexity, and feasibility of implementation on STM32-based flight controllers.

As a result of the review, it was established that classical PID controllers, while widely used, are highly sensitive to model variations and sensor noise. Intelligent systems show better adaptability but exceed the computational capacity of low-cost microcontrollers. The most promising direction is identified as energy-based control methods that minimize local functionals of instantaneous energy values. These methods allow generating closed-form control laws, avoid signal differentiation, and maintain robustness with minimal processor load.

The comparative evaluation shows that the proposed algorithm has the potential to improve control quality by more than 7% and reduce the impact of parametric disturbances by an average of 10% compared to traditional PID-based systems. The results are recommended for UAV control systems operating under limited computational capacity, absence of GPS, or in disturbed environments, such as tactical drones, FPV platforms, and autonomous navigation systems.

Keywords: quadrotor control, parametric and structural uncertainty, energy-based control, nonlinear MIMO systems.

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DEVELOPMENT OF A GRIP FORCE RECOGNITION SYSTEM BASED ON EMG SIGNALS AND NEURAL NETWORKS

pages 24–28

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The object of research is a bionic prosthesis control system that uses EMG signals read using the MYO bracelet, as well as feedback sensors to determine the grip force. In the context of the development of modern bioengineering and neurotechnology, this system is aimed at ensuring accurate and adaptive control of the prosthetic hand, taking into account the user's intentions.

The problem considered in the research is to recognize the grip force of a bionic hand based on EMG signals and transmit feedback to the user. Special attention is paid to the use of a deep neural network for classifying force levels and developing a real-time signal processing technique. The task is to create a stable and user-friendly grip control system.

The essence of the results obtained is to create an experimental system that classifies the grip force of objects with a bionic hand with high accuracy (95%). The system is based on a neural network with a two-layer autoencoder, trained on labeled and unlabeled data. To improve the accuracy of the model, the temporal characteristics of EMG signals were used: MAV, RMS, SD and WL.

The results are explained by effective biosignal processing and machine learning. The division of force into 8 levels and the use of a fuzzy controller ensured stable control of the grip and the transfer of information to the user via vibration feedback. The system was successfully tested in real time.

The innovation lies in the integration of the MYO bracelet, force sensor and FSR with deep learning. This provides accurate force classification and natural feedback, which increases controllability and ease of use.

The use of the system provides new opportunities in prosthetics: it more accurately conveys the user's intentions, reduces errors and increases comfort. The results have the potential for clinical implementation to improve modern prostheses.

Keywords: electromyography, prosthetics, training, neural network, sensor, vibration, feedback, capture, control, management.

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BLINK READING MONITORING SYSTEM USING MAGNETIC PROPERTIES OF FERROFLUID

pages 29–33

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The object of the study is an eye movement monitoring system based on a combination of a permanent magnet, ferrofluid and glasses with built-in inductive sensors. In the current conditions of development of wearable technologies and biomedical devices, such a system has the potential for application in medicine, in particular for monitoring eye movements in real time, which can be useful for diagnostics and rehabilitation.

The problem considered in the study is to create a compact, comfortable and accurate system for non-contact monitoring of the frequency and nature of blinking. The main attention is paid to optimizing the design of the eyeglass frame with built-in coils, as well as the development of algorithms for collecting and processing induced signals, which allows for effective detection of eye movements without discomfort for the user.

The essence of the results obtained is the development of a wearable system that uses ferrofluid applied to false eyelashes and magnetic coils built into a 3D-printed eyeglass frame. Experimental tests demonstrated the system's ability to clearly distinguish between slow and fast blinking based on induced signals obtained using an Arduino Uno board with a reading frequency of 200 Hz. It was found that the amplitude of the signals during fast blinking is significantly higher, which ensures reliable tracking of eye movements in different modes.

The results are explained by the innovative combination of a contactless magnetic sensor with a liquid form of ferrofluid, which ensures flexibility, comfort and invisibility of the system. Coils built into the frame allow for amplification of the induction signal, reducing the impact of noise and improving data quality. The use of a 3D model of the frame optimized for coil fixation ensures design reliability and repeatability of the results.

The innovation of the approach lies in the combination of advanced materials and 3D printing technologies with traditional electronic solutions to create a compact and convenient eye movement monitoring device. The proposed system is a promising tool for further application in medical, rehabilitation and interface technologies, where precise control of blinking is critically important.

Keywords: system, monitoring, reading, blinking, magnetic, properties, ferrofluid, sensors, signals, control.

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IMPROVING THE MEASUREMENT EFFICIENCY OF MARINE SHIP-BORNE RECEIVERS OF GLOBAL NAVIGATION SATELLITE SYSTEMS

pages 34–39

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Global navigation satellite systems (GNSS) play a decisive role in maritime navigation. The differential mode of operation of ship-based GNSS receivers using coordinate corrections allows to significantly increase the accuracy of positioning of a seagoing vessel compared to the autonomous mode. The object of the study was marine GNSS receivers capable of operating in differential mode.

This research examines the problems of reliably determining the actual operating mode of a shipboard GNSS receiver (autonomous or differential). It outlines the risks associated with the ambiguity and unreliability of standard differential mode indicators (flags posMode = D, Fix Quality = 2). This leads to misinterpretation of the accuracy status by related navigation systems, in particular, the Automatic Identification System (AIS), and poses a threat to maritime safety.

It has been experimentally proven that outdated receiver models can falsely indicate operation in differential mode, relying solely on user settings rather than the actual receipt and application of corrections. It has been established that modern receivers solve this problem but create a new level of complexity by separating the concepts of "accuracy" and "integrity" of the navigation solution. They can produce a highly accurate position while simultaneously flagging it as unreliable (NavStatus flag = V) if a faulty satellite is detected. A systemic conflict between the requirements of the International Telecommunication Union (ITU) and International Electrotechnical Commission (IEC) standards regarding high-accuracy criteria for AIS has been identified.

It has been established that inaccurate mode indications in outdated equipment are related to the particularities of its software logic, which links the mode flag to the setting rather than to the availability of data. The behavior of modern receivers is explained by the implementation of advanced integrity control algorithms (RAIM) and the logic of new standards (in particular, IEC 61108-7), which require reporting the loss of confidence in data.

The research results can be used by developers of marine equipment (AIS, ECDIS) to create comprehensive GNSS data analysis algorithms that take into account a set of indicators. International organizations (IMO, ITU) can use them to harmonize standards. Ship operators and technical specialists can use these results to form a correct understanding of the limitations of standard indicators and the need for a comprehensive assessment of the status of the GNSS receiver.

Keywords: navigation safety, AIS, positioning accuracy, differential mode, NMEA.

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TECHNOLOGY AND SYSTEM OF POWER SUPPLY

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IDENTIFICATION OF HYDRAULIC FRACTURING IMPACT FACTORS ON THE SKIN EFFECT IN THE NEAR-WELLBORE ZONE OF THE RESERVOIR

pages 40–49

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The object of this research is the clogging of the near-wellbore zone of the productive reservoir, which leads to the formation of a positive skin factor and a decrease in well productivity. The subject of the study is the impact of hydraulic fracturing on the reservoir properties of the near-wellbore zone, as well as the assessment of the effectiveness of modern numerical modeling methods for predicting well productivity and optimizing technological parameters of production stimulation operations.

The study addressed the problem of gas well productivity decline due to the deterioration of the filtration and capacitive properties of the near-wellbore zone of the formation caused by clogging, fluid accumulation, retrograde condensation and other physical and chemical processes that impede the movement of fluids to the bottomhole. The work is aimed at finding an effective stimulation method to increase well production and reduce the skin factor, as well as refining methods for forecasting production rate taking into account reservoir properties.

In the course of identifying patterns, an injection test and regression analysis, software productivity modelling, and hydraulic fracturing of the X1 well. After fracturing, a significant increase in absolute free flow rate was recorded – from 1240 to 13250 m^3/d. The numerical modelling performed before and after hydraulic fracturing allowed to optimize engineering solutions, reduce uncertainty in work planning and achieve high accuracy of the flow rate forecast. In the course of identifying patterns, the dependencies between fracture geometry, skin factor and flow rate were determined, which made it possible to quantify the effectiveness of hydraulic fracturing. A practically oriented approach to the implementation of well modelling was developed.

The obtained results can be effectively used in the design and modelling of hydraulic fracturing in practice under conditions of clogging of the near-wellbore zone, positive skin factor, and low permeability of the formation, will significantly increase well production rates and the efficiency of reservoir development with complex filtration conditions.

Keywords: near-wellbore zone, reservoir permeability, clogging, skin, gas flow rate, stimulation, hydraulic fracturing.

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ASSESSMENT OF DEFORMATION PROCESSES IN BACKFILL MASSES USING CRUSHED ROCK MODELS

pages 50–57

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The object of the study was the deformation processes in backfill masses made of crushed rock, which are used for roof control in mining panels. The study addressed the issue of preventing sidewall collapses by ensuring the stability of the backfill masses. Deformation processes were investigated using experimental models made of crushed rock that simulated various backfill structures. The study considered uniaxial compression of crushed rock with lateral expansion capability, as well as compressive loading. Uniaxial compression was used to simulate partial backfilling of the gob area, while compressive loading represented complete backfilling. Under loading conditions, a hyperbolic relationship was established between the relative volume change of the backfill material per unit of side rock convergence, ΔV_K (m^{-1}), and the compaction coefficient of crushed rock. This relationship enables the prediction of the material's ultimate settlement. The determining factor in this relationship is the relative deformation of the backfill mass. Under loading of crushed rock and comparable compaction coefficient values, the difference in deformation properties reaches 2.5 to 3 times. This is recorded due to the transformation of shape or change in volume under different compression conditions. It is shown that with an increase in the parameter ΔV_K, the specific potential energy of deformation of the backfill material changes according to a logarithmic relationship. The specific potential energy of deformation is determined by the mechanical properties and compression conditions of the crushed rock.

Maximum stability of gob-side retained entries can be ensured through complete backfilling of the gob area, while the expected subsidence of the backfill mass depends on the initial backfill density and the deformation properties of the crushed rock used for filling.

Keywords: backfill mass, deformation, compaction, crushed rock, convergence, safe working conditions.

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REGULARITIES OF THE PROCESS OF CRACK FORMATION IN CLAY FILTER CAKE DURING WELL CEMENTING

pages 58–64

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The object of this research is the process of crack formation in the clay filter cake upon its contact with hardening cement slurry/stone.

During well cementing, it is impossible to completely remove the clay filter cake formed on the borehole walls. This creates prerequisites for poor wellbore sealing due to the formation of channels for fluid migration at the contact boundary and directly within the clay filter cake. Studying the processes that occur during cementing makes it possible to better understand their nature and to propose technological measures to ensure the tightness of the wellbore seal.

It has been established that the process of crack formation is characterized by three periods: induction, cracking, and stabilization. The duration of each period is determined by the state of the "clay filter cake – hardening cement slurry/stone" system. The process proceeds most intensively under conditions corresponding to the near-surface (wellhead) part of the well. This is explained

by the dehydration of the cement slurry during its pumping in the annular space and the loose structure of the clay filter cake. In this case, the area of the clay filter cake affected by cracks exceeds 80%, while in conditions of the bottom hole part of the borehole, it does not exceed 30%.

The effect of aqueous electrolyte solutions on the crack resistance of the clay filter cake has been investigated. It was found that with a decrease in the concentration of $CaCl_2$ and an increase in the concentration of NaCl, the area of the clay filter cake affected by cracks decreases. No crack formation was observed in the clay filter cake after its treatment with 2% and 5% solutions of Na_2CO_3.

It was established that with a decrease in the thickness of the cement sheath, the induction and cracking periods increase, while the overall area of the clay filter cake affected by cracks decreases.

The obtained results will serve as a basis for developing a comprehensive approach to ensuring high-quality wellbore sealing. This may include optimizing well design and improving the formulation of drilling fluids for specific geological and technical conditions.

Keywords: wellbore seal tightness, cement slurry/stone, clay filter cake cracking process.

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NUMERICAL MODELING AND COMPARATIVE ANALYSIS OF STRATEGIES FOR ENHANCING OIL RECOVERY AND GEOLOGICAL STORAGE OF CO_2 IN A DEPLETED OIL RESERVOIR

pages 65–71

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The object of the study is the processes of enhancing oil recovery and geological storage of CO_2 in a depleted, highly waterflooded oil reservoir, modeled using a three-dimensional compositional reservoir simulation model.

The key problem addressed in CCUS projects is the internal contradiction between maximizing oil production and optimizing the volume and safety of long-term CO_2 storage. The study examined the choice of an operational strategy that would balance these objectives under conditions of high geological heterogeneity and the risk of early gas breakthrough.

It was established that the "injection – depletion" strategy provides the highest cumulative oil production (about 1.8 million m^3) but is inefficient due to early gas breakthrough (after ~ 2 years). The pressure-maintenance strategy proved to be the most balanced: gas breakthrough was delayed by 1.5 years, ensuring high CO_2 storage efficiency, but cumulative oil production was lower (about 1.5 million m^3). The water-alternating-gas (WAG) technology, for the geological conditions of this reservoir, proved detrimental, causing abnormal pressure build-up (up to 824 bar) and blockage of oil reserves.

The obtained results are explained by the physics of the process. The early gas breakthrough in the first scenario is due to CO_2 gravitational segregation and the formation of a gravity override ("gravity tongue"). The efficiency of the second scenario is associated with the creation of a more stable displacement front through pressure maintenance. The complete inefficiency of WAG is explained by the presence of high-permeability channels in the geologically heterogeneous formation, through which water moved, bypassing the oil.

The results can be practically applied by operators of mature fields to justify the choice of a CCUS strategy. They provide a quantitative basis for assessing the trade-off between short-term economic benefits (production) and long-term environmental objectives (storage). The study confirms the critical importance of conducting detailed geological modeling before applying WAG, in order to avoid substantial financial losses.

Keywords: enhanced oil recovery, geological storage of CO_2, CCUS, numerical modeling, WAG, optimization, geological heterogeneity.

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IMPROVEMENT OF THE PROCESS OF CLEANING EXHAUST GASES OF MARINE DIESELS FROM SULFUR OXIDES

pages 72–79

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The object research is the process of cleaning exhaust gases of marine diesel engines from sulfur oxides, which is associated with the need to fulfill the requirements of Annex VI MARPOL. The research results on reducing emissions of sulfur oxides with exhaust gases of marine diesel engines by additional fuel treatment are presented. It is determined that during the operation of marine diesel engines, it is mandatory to ensure their environmental performance in terms of emissions of harmful substances, including sulfur oxides. Scrubber cleaning is considered as a method that ensures the cleaning of exhaust gases from sulfur-containing components. At the same time, additional fuel treatment using its ultrasonic irradiation is proposed. The results of research carried out on a Bulk Carrier class vessel with deadweight of 82,000 tons are presented. The ship's power plant included the main engine STX-MAN B&W 6S60ME-C and three auxiliary diesel generators Yanmar 6EY18ALW2, the exhaust gases of which were subjected to scrubber cleaning. At the same time, ultrasonic fuel treatment was additionally used in the diesel fuel preparation system. For various operating modes of the ship's power plant, it was found that the relative reduction in emissions of harmful substances when using additional ultrasonic fuel treatment is: for sulfur dioxide SO_2 emissions 12.24–24.12%; for the ratio of sulfur dioxide emissions to carbon dioxide emissions SO_2/CO_2 10.56–22.54%. It is noted that the use of additional ultrasonic treatment is more effective when ships are inside special ecological areas, i.e. in coastal waters. Ultrasonic fuel treatment is possible for any types of liquid marine fuel, regardless of its viscosity, density and component composition.

Keywords: environmental indicators, maritime transport, fuel treatment, exhaust gas cleaning, marine diesel.

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