ABSTRACT AND REFERENCES
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DEVELOPMENT OF THE MATHEMATICAL MODELING METHOD FOR DYNAMICS OF THE FLEXIBLE TETHER AS AN ELEMENT OF THE UNDERWATER COMPLEX (p. 4-14)

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Mathematical modeling of flexible tethers (FT) is an integral part of the study of remotely operated vehicles and underwater complexes in general. In this paper, for the mathematical modeling of the FT dynamics in the flow of liquid, the FT is represented as a set of series-connected elements – solid bodies. The governing equation of the FT element motion is given; it takes into account the external gravity, buoyancy and hydrodynamic drag forces, and internal constraint reaction forces between adjacent elements. The main problem in the inextensible FT modeling is to determine the constraint reaction forces.

There has been suggested the method of mathematical modeling of the flexible tether dynamics with automatic control of its elements axial motion (ACEAM). According to the ACEAM method, the flexible tether is represented as a multidimensional automatic control system. The controlled object is the set of the FT elements, the controlled parameters are the distances between adjacent elements, and the controlling parameters are the constraint reaction forces.

With the help of the inverse dynamics method, the regulator of the FT elements axial motion is synthesized as a part of the FT mathematical model. The developed regulator provides highly precise control of the distances between the FT elements and, therefore, accurate modeling of the inextensible flexible tether dynamics.

The method of the flexible tether simulation considering that its length varies during its operation is suggested. The basis of the method is the dynamic change of the number of the elements being involved in the calculation process, considering the current length of the released part of the FT. Changing the FT length causes additional loads on its inboard and running ends. Taking into account these loads allows accurate simulation of the dynamics of the FT impact on remotely operated vehicles and other components of underwater complexes.

The flexible tether motion dynamics is then modeled with the developed method. The modeling results are compared with the method of lumped masses springs. It is established that when the equal precision of the inextensible FT simulation is provided, the suggested method operates about 25 times faster than the method of lumped masses and springs.

Keywords: flexible tether simulation, umbilical cable, remotely operated vehicle, underwater complex.

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AN INCREASE OF THE BALANCING CAPACITY OF BALL OR ROLLER-TYPE AUTO-BALANCERS WITH REDUCTION OF TIME OF ACHIEVING AUTO-BALANCING (p. 15-24)

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The study has revealed an influence of the parameters of corrective weights (balls and cylindrical rollers) in auto-balancers on the balancing capacity and the duration of the transition processes of auto-balancing in fast-rotating rotors.

A compact analytical function has been obtained to determine the balancing capacity of an auto-balancer (for any quantity of corrective weights – balls or rollers), with a subsequent analysis thereof.

It is shown that the process of approach of the auto-balancing can be accelerated if the auto-balancer contains at least three corrective weights.

It has been proved that at a fixed radius of the corrective weights the highest balancing capacity of an auto-balancer is achieved when the corrective weights occupy nearly half of the racetrack.

The study has revealed that it is technically incorrect to formulate a problem of finding a radius of the corrective weights that would maximize the balancing capacity of the auto-balancer. The statement implies that if it is a ball auto-balancer, the racetrack is a sphere, but if it is a roller-type balancer, the racetrack is a cylinder. This leads to a practically useless result, suggesting that the highest balancing capacity is achieved by auto-balancers with one corrective weight. Besides, with $n \geq 5$ for balls and $n \geq 8$ for rollers, there happens a false optimization, which consists in several corrective weights being "excess". Their removal increases the balancing capacity of the auto-balancer.

It is correct (from the engineering point of view) that the mathematical task is to optimize the balancing capacity of an auto-balancer. Herewith, it is taken into account that the racetrack of the auto-balancer is torus-shaped, which restricts the radius of the corrective weights from the top. It is shown that the balancing capacity of an automatic balancer can be maximized if in a fixed volume the corrective weights have the largest possible radius and occupy almost a half of the racetrack.

The research on the duration of the transition processes for the smallest value has produced the following conclusions:

– to accelerate the achieving auto-balancing, the corrective weights should occupy nearly half of the racetrack;

– the shortest time of the auto-balancing is achieved with three balls or five cylindrical rollers.

Keywords: auto-balancer, auto-balancing, ball, cylindrical roller, balancing capacity, transition processes, optimization.

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IMPROVING THE ALUMINUM DRILL PIPES STABILITY BY OPTIMIZING THE SHAPE OF PROTECTOR THICKENING (p. 25-31)

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The methods of improving the durability of elements of the drill string were analyzed. A mathematical model of elastic deformation is developed and the loss of stability of aluminium drill pipe with inner and outer near-end protector thickenings in the middle section is investigated under the action of torque and axial compressive force. Based on the results of numerical analysis, we determined the magnitudes of critical loads: the torque and axial force, at which the loss of stability of pipe occurs depending on the different shapes of protector thickening. It was established that the shape of protector thickening does not exert significant influence on the magnitude of critical axial force, but to a larger extent affects the magnitude of critical torque at which the loss of stability of aluminium drill pipe occurs.

We proposed to improve the stability of aluminum drill pipe by optimizing the shape of protector thickening and received exponential dependence, which describes such a streamlined shape. Protector thickening of the optimal shape provides, compared to other characteristic shapes, better performance characteristics: higher stability of pipe and lower hydraulic resistance to the motion of washing fluid. We developed a new design of aluminum drill pipe with a protector thickening of streamlined shape that retains stability up to the critical values of axial force 36209 N and torque 152270 Nm.

Keywords: drill pipe, protector thickening, torque, axial force, stability, deformation.

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DEVELOPING A METHOD FOR THE ASSESSMENT OF AXIAL LOAD IN ARBITRARY CROSS-SECTIONS OF THE COLUMN OF PUMPING RODS (p. 32-37)

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For accurate and objective evaluation of the stressed-strained state of a column of pumping rods (PR), it is necessary to have reliable information about axial loads that act in its cross-sections at different depth. That is why the purpose of present research is to develop a method for the evaluation of loading in the arbitrary cross-sections of a PR column taking into account actual operating conditions. In the paper we present constructed simulation models of PR columns, which consider their design features, paprameters of operating modes of rod borehole pumping plants (RBPP), the peculiarities of interaction between columns of pump-compressor pipes (PCP) and PR, the laws of change in efforts in the point of their hanging.

Using a PR column as a mechanical communication channel between the wellhead and arbitrary cross-section, we established functions of change in the axial load along its length. This allows us to track the dynamics of its change and detect dangerous cross-sections in a PR column. Implementation of the models developed enables reproduction of the laws of change in the axial load during operation cycle for arbitrary cross-sections of PR column. Their existence is the basis for analysis of the stressed-strained state and for predicting the durability of elements in a PR column.

Keywords: column of pumping rods, axial load, deep dynamogram, model of a column of pumping rods.

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THE SYNTHESIS OF STRUCTURE AND PARAMETERS OF ENERGY EFFICIENT PNEUMATIC ACTUATOR (p. 38-44)

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It is known that compressed air is one of the most expensive energy carriers while a discrete pneumatic actuator with throttle braking of operating unit possesses a rather low degree of energy perfection. Present work posed and solved the problem on the isolation of all unproductive power consumption in the pneumatic actuator. Such power expenditures include losses due to the incompleteness of air expansion in the working cavity, losses in the dead space, losses for throttling, additional losses for the fixation of op-

erating unit, and the losses, related to the work to eject compressed air from the exhaust cavity.

Authors designed the circuits for actuators, as well as the principles of their operation, which make it possible to maximally decrease such unproductive power consumption.

One more essential shortcoming in the pneumatic actuators with traditional circuit of throttle braking is a rather limited level of inertia load, within which the actuator remains operational.

A cardinal solution for these problems in present work is achieved due to the transition from the circuits of throttle braking, which are quite formally transferred from hydraulic drive technique, to the circuits of braking through a change in the structure of commutation connections. Due to this, it was possible for each phase of the motion of operating unit to enable the most rational commutation relations, which allowed us to attain maximum realization of the working capacity of compressed air in pneumatic actuator and to achieve the most preferable form in the transient process. The latter made it possible to substantially increase inertia loads, at which the actuator remains operational.

Pneumatic circuits based on the commercially available pneumatic equipment are proposed, which realize these principles. A mathematical model in the dimensionless form with the isolation of criteria of dynamic similarity is developed. Based on this, a region of the rational utilization of the proposed actuators is determined in the plane of criteria of dynamic similarity; and one of the problems is solved on the parametric synthesis in the form of selecting a diameter of cylinder, which provides for the work of actuators in the zone of the most effective energy saving.

Authenticity of the obtained theoretical results is confirmed by the oscillograms of transient process in the experimental sample of energy-saving pneumatic actuator.

Keywords: discrete pneumatic actuators, structure of commutation relations, reduction in unproductive power consumption.

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INTRODUCING THE PRINCIPLE OF CONSTRUCTING AN AVIATION GRAVIMETRIC SYSTEM WITH ANY TYPE OF GRAVIMETER (p. 45-56)

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Measurements of parameters of the Earth's gravitational field from aircraft are the most important because they make it possible to carry out measurements in the zones of poles areas the Earth, the equator, mountain ranges and other hard to reach areas of the Earth. Studying these parameters is necessary for the exploration of mineral resources, forecasting earthquakes, tsunamis, etc.

We put forth general principles for constructing aviation gravimetric system (AGS) with any type of gravimeter. A list of basic components of AGS is compiled: gravimeter of any type, system for determining navigation parameters, altitude gauge, and onboard computing machine. We analyzed methodological errors of the system. Precision requirements to the components of AGS are formulated, provided the accuracy of AG measurements is 1–2 mGal. The choice of natural oscillation frequency of the AGS gravimeter is substantiated, which is 0.1 s^{-1}. The equation is derived that takes into account correction from the impact of angular velocity of the Earth rotation. We substantiated the application of a dual-channel method to construct an AGS gravimeter. Expedience of employing neural networks is demonstrated to eliminate instrumental errors of the AGS gravimeters.

Keywords: gravimeter, acceleration of gravity, gravitational field of the Earth, aviation gravimetric system.

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