ABSTRACT AND REFERENCES

APPLIED MECHANICS

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INVESTIGATION OF MULTIPLE CONTACT INTERACTION OF ELEMENTS OF SHEARING DIES (p. 6–15)

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When justifying the design parameters, it is necessary to carry out the analysis of the strain-strain state of individual elements of technological systems, which are sets of parts under contact interaction conditions. These problems are nonlinear, and the principle of superposition does not apply to them. For this reason, the amount of calculations increases dramatically. To overcome this drawback, methods and models for the rapid and precise study of the strain-strain state of complex objects, taking into account contact interaction are developed. The feature of the problem statement is that the solution of contact problems under certain conditions linearly depends on the load. The patterns of contact pressure distribution are determined. It is concentrated in the areas of constant shape and size. Only the scale of contact pressure distribution varies.

This gives an opportunity to significantly accelerate design studies of die tooling while preserving the accuracy of numerical modeling of the stress-strain state.

The developed approach involves a combination of advantages of numerical and analytical models and methods for analyzing the stress-strain state of elements of shearing dies, taking into account contact interaction. This concerns the possibility to solve problems for a system of complex-shaped contacting bodies, which is impossible with the use of analytical models. On the other hand, the possibility of scaling the solutions of these problems with the stamping force is substantiated, which is generally not performed for nonlinear contact problems. So, it is sufficient to solve the problem of determining the strain-strain state of elements of such a shearing die. For the other value of stamping force, the proportionality rule is applied. Thus, the efficiency of research sharply increases and high accuracy of the obtained results is ensured.

Keywords: contact interaction, shearing die, stress-strain state, contact pressure.

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STUDYING THE QUALITY OF DRILL PIPES CLAMPED IN A WEDGE CLAMP (p. 16–21)

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Much attention has been recently paid to institutional measures aimed at improving quality of products related to petroleum machine building, in particular, the implementation of quality management systems based on the ISO standards of series 9000 [1]. However, technological methods of quality assurance have not been less important.

The paper considers the factors influencing the quality of a cylindrical thin-walled component during operation. The

most significant factors are the efforts to which the component us exposed when it is captured by a clamping mechanism.

We have performed experiments into the effects of loads on a clamped component. The aim of these experiments was to establish the impact of various factors on stresses and deformations of cylindrical thin-walled components. The main factors, in addition to the applied forces, are the capturing angle of the clamping element, the length of its contact with a part, load distribution over the teeth of the clamping element.

Given the development of deep drilling and an increase in loads acting on the wedge clamps, the requirements to their gripping capacity become stricter. Insufficient gripping capacity of the wedge clamp could cause damage to a pipe at the place it is clamped by wedges.

In this case, clamping efforts act in the same region of a pipe, forming a thinned neck at long operation. The result of such damage is a premature failure of a drill pipe's operation and the risk of an emergency.

Significant impact on the gripping capacity of a wedge clamp is exerted by the elements of its design. Of importance is also the stressed state of a drill pipe clamped by a wedge clamp. We have calculated the optimal geometrical characteristics for clamping jaws. The best indicators were demonstrated by the grooved jaws with oblique intersecting notch. We have considered the load distribution over the teeth of clamping jaws. It has been shown that the optimal load distribution over the teeth is provided by jaws with oblique intersecting notch. In this case, tooth 1 accounts for 26 % of the load, tooth 2–22 %, tooth 3–19 %, tooth 4–17 %, tooth 5–16 %.

The results obtained in the course of our research would make it possible to introduce such modifications to the design of clamping devices that could significantly improve their gripping capacity and reduce the risk of accidents.

Keywords: drill pipes, wedge clamp, load, stresses and deformations, gripping capacity.

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MODELING ANALYSIS OF THE EFFECT OF THE MAIN ROLL-HOOP LENGTH ON THE STRENGTH OF FORMULA STUDENT CHASSIS (p. 22–29)

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Chassis is a very important part of the vehicle, where the whole body of the vehicle is built. All vehicle external loads include their own weight supported by the chassis. Chassis design and analysis play an important role in making a vehicle. To find out the phenomenon of Formula Student Car, Autodesk Inventor simulation was made with variations in roll hoop length and static loading of 9, 6 and 5 kN. The chassis material is carbon steel which has a value of mechanical properties that meet regulatory standards. The results obtained in this study are the relationship between the main roll hoop length and normal stress and deflection is the same, the greater the value of the main roll hoop length, the greater the value of normal stress and deflection. The relationship between the main roll hoop length and normal stress is the greater the value of the main roll hoop length, the greater the normal stress value. While the relationship between the main roll hoop length and shear stress is the greater the value of the main roll hoop length, the lower the *T-x* shear stress value. The relationship between the main roll hoop length and normal stress and *T-y* shear stress is the same, namely the greater the value of the main roll hoop length, the higher the value of normal stress and shear stress *T-y*. The relationship between the main roll hoop length and normal stress is the greater the value of the main roll hoop length, the higher the normal stress and torsional value. Test results of normal stress, shear and torsional stress show that the chassis type B with a roll hoop height of 504 mm and the main roll hoop length of 125 mm meets the requirements.

Keywords: chassis, chassis design and analysis, Autodesk Inventor simulation, variation of roll hoop length, mechanical properties.

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ANALYZING AN ERROR IN THE SYNCHRONIZATION OF HYDRAULIC MOTOR SPEED UNDER TRANSIENT OPERATING CONDITIONS (p. 30–37)

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A hydraulic drive with two hydraulic cylinders was considered in which the rod movement speeds are synchronized by a divider of the working fluid flow. Based on the developed mathematical model, operation of synchronized hydraulic cylinders in transient operating conditions with a sudden change of load on one of the hydraulic cylinders was calculated. Speeds of movement of the hydraulic cylinder rods and pressures in the inter-throttle chambers of the flow divider were determined. It was established that there were variations of pressure in the inter-chamber chambers of the flow divider in the transient conditions of operation of the drive caused by a sudden change of load on the hydraulic cylinders and, as a result, an error of synchronization of speed of movement of the cylinders rods appeared at the initial stage. Relative pressure differential in the inter-throttle chambers reached 1 and the relative difference of speeds of movement reached 0.43. To improve accuracy of synchronization of hydraulic motor movement, a flow divider was proposed with an additional feedback in the pressure differential in the inter-throttle chambers of the divider. The additional feedback was realized through the use of a double-slotted throttling distributor of the spool-valve type. Proceeding from the conditions of a minimum synchronization error, the necessary dependence of change of area of the working slot of the controlled throttles was determined and recommendations on profiling the working slots of the spool throttle were given.

It was established by calculation and confirmed experimentally that the use of controlled throttles reduces the error of synchronization of speed of movement of the cylinder rods to 0.27 and the pressure differential in the inter-throttle chambers of the flow divider to 0.53.

Harmonics of higher order occurred in a transient process for speed and pressure. They were caused by movement of the spool valve of the double-slot distributor.

Presence of harmonics of higher order in variations of pressure and velocity did not significantly affect operation of hydraulic motors since amplitude of these variations was negligible.

Reduction of the speed synchronization error is due to simultaneous change of area of the throttle which stabilizes pressure differential and the area of the controlled throttle.

Keywords: flow divider, hydraulic motor, spool valve, throttling distributor, synchronization, transient process.

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ANALYSIS OF THE INFLUENCE OF THE INTER-WHEEL DIFFERENTIALS DESIGN ON THE RESISTANCE OF THE CAR CURVED MOTION (p. 38–45)

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The method and results of the analysis of the influence of the inter-wheel differentials design and the corresponding proportionality factors for the additional locking torque on

the curved motion resistance of the four-wheel drive vehicle on paved roads are given. This allows choosing the most suitable designs for the parametric synthesis of the internally automated inter-wheel differential taking into account the results of studying the efficiency of different types of inter-wheel differentials under off-road conditions. Parametric optimization will allow synthesizing the internally automated inter-wheel differential, which would satisfy the requirements both to the vehicle cross-country ability and dynamics while not preventing the curved motion.

In the process of modeling, the influence of the design and parameters of the inter-wheel differentials on power consumption in the motion with the given speed and trajectory, as well as on the actual turning radius of the vehicle, was estimated.

According to the modeling results, it is concluded that it is possible to create a permanent internally automated inter-wheel differential based on differentials, in which locking degree depends on the squared difference in angular velocities of the semiaxles. For this, it is necessary to carry out optimization with respect to the proportionality factor of the locking torque, taking into account the limitations set forth in the work and using the described method of analyzing the influence of the inter-wheel differentials design on turning resistance.

This will allow the effective operation of military and civil four-wheel drive vehicles both in difficult road conditions and on paved roads. In addition, the process of driving will not distract the driver to control the inter-wheel differentials, and the transmission will be performed without undue design complications.

Keywords: inter-wheel differential, limited-slip differential, locking torque, power efficiency, handling.

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CONSTRUCTION OF A THEORETICAL METHOD FOR ESTIMATING THE CALCULATION OF POWER USED BY FEED ROLLERS IN THE CLEANERS OF RAW COTTON FROM FINE DEBRIS (p. 46–54)

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The magnitudes for spreading efforts have been determined, which act on feed rollers and represent one of the most important factors in determining the power consumed by feed rollers, strength conditions of blade rollers and, most significantly, maintaining quality of the processed material. It is a relevant task to construct effective cleaners for raw cotton, aimed at enhancing the cleaning effect at minimal number of cleaning machines.

The stages in interaction between a pin and the surface of a fibrous material have been investigated – from the moment a pin touches the undeformed layer surface to deformation limit value $W(0)$ at the point prior to the pin penetrating the material.

In contrast to earlier proposed solutions that considered deforming the layer by conditional, round-shaped, rollers, and raw cotton as a one-dimensional deformed material, which is matched in the theory of elasticity with a material whose Poisson's coefficient is $\nu=0$, it has been proposed in the reported scheme to describe, under the same condition for a flow continuity, the deformation of raw cotton by blade rollers using the methods of contact problems from the theory of elasticity. The total capacity, used or received by a feed roller, can be determined from the matrix equation. The result of the study established that, provided cotton is an absolutely elastic medium, then the entire energy of layer compaction would be returned to the roller and the total consumption of energy by blades over a cycle of deformation would equal zero. If cotton is considered to be plastic, then, at $\varphi_i=\pi/2$, the blade would abandon the layer and the accumulated energy would not be returned to blades.

Results from calculating power used by the roller are given in the form of charts (at a mean angular velocity value of $\omega_{av}=1.047\ s^{-1}$). The results reported here imply the power consumed by the roller for the axial transportation of a cotton layer.

Addressing these issues would make it possible to find the optimal magnitudes for structural elements of feed rollers' blades at cleaners of raw cotton from fine debris.

Keywords: fibrous material, fine debris, feed rollers, pin rollers, layer deformation.

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DESIGN OF PARALLEL LINK MOBILE ROBOT MANIPULATOR MECHANISMS BASED ON FUNCTION-ORIENTED ELEMENT BASE (p. 54–64)

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To create effective mobile robot manipulators, a function-oriented element base is proposed. Element base selection is based on the analysis of schematics of mobile robot manipulators. It is substantiated that the effective schematics of manipulators are parallel link mechanisms. A rational structural scheme was adopted as a mechanism having six rods of variable length (hexapod). The schemes of mobile robot manipulators with different numbers and types of combined rod supports are considered. It is proved that the same type of element base in the form of spherical hinges can be used to implement a variety of schemes. Different embodiments of schematics of manipulators designed on the proposed function-oriented element base are considered. The basic requirements for the element base of mobile robot manipulators are defined. It is shown that the requirements are provided by the function-oriented element base on the basis of different hydrostatic or aerostatic hinges.

A series of variants of schematics and design solutions of regulated spherical hydrostatic and aerostatic hinges are proposed. The hydrostatic spherical hinge, which includes an accurate ceramic (boron carbide) ball has high precision characteristics. Technological approbation of this schematic is conducted by manufacturing a production prototype.

The regulated hydrostatic hinge is equipped with a mechatronic system for determining the spatial position of the sphere. This design solution allows you to adjust the position of the hinge sphere within the diametric clearance.

The combined aerostatic-hydrostatic support unit aggregated with manipulator drives is proposed. The unit has a jet system for adjusting the support reactions of the aerostatic-hydrostatic supports of the spherical hinge. Technological testing of the developed device is carried out.

In order to increase the efficiency of the proposed element base, special algorithms for controlling the position of the spherical manipulator hinges are developed. The algorithms are based on the mathematical modeling of dynamic processes in hinge devices. The algorithms include the implementation of spatial polyharmonic displacements of the sphere with the purposeful selection of the direction of the resulting displacements, which provides the necessary accuracy and speed of the process of adjusting the position of the manipulator.

Keywords: mobile robots, manipulator schemes, hydrostatic hinges, aerostatic supports, control algorithms.

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