ABSTRACT AND REFERENCES

APPLIED MECHANICS

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AN INCREASE OF THE LOADING CAPACITY AND RELIABILITY OF GEARS BY METHODS OF OPTIMIZING INVOLUTE GEARING PARAMETERS (p. 6–15)

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A large volume of rocks containing valuable minerals is treated at mining and processing plants in Kazakhstan. Ball mills and rod mills are used for their grinding and further processing .

Ball mills with gear drive rings in the drums suffer from intense wear of the teeth due to the heavy mode of the mill operation. It thus necessitates their frequent replacement and long mill downtime. The gears of the ball mill drive experience an intense impact stress, which reduces the resource of their operation and the mill as a whole due to wear.

The article presents research on developing rational parameters of involute gearing, aimed at increasing the loading capacity of the gear as well as reducing the overall dimensions, noise, and vibration. In order to solve the set tasks, dynamic processes are simulated, modification of the teeth is proposed, and the task of designing the initial meshing contour is solved when the line of the tooth profile is slightly deviated from the involute curve of the tooth surface.

The kinematic and dynamic parameters of a tooth transmission influencing the wear resistance of teeth are found out, and also the influence of the loading capacity under conditions of stable lubrication is determined.

Because of the complexity of modifying a large diameter of the driven gear wheel, it is proposed to modify only the teeth of the driving wheel, both at their tops and legs.

Keywords: ball mill, tooth wear, involute gearing, tooth modification, tooth profile line.

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A SEMI-ANALYTICAL METHOD FOR ANALYS OF CONTACT INTERACTION BETWEEN STRUCTURAL ELEMENTS ALONG ALIGNED SURFACES (p. 16–25)

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A significant share of structures includes the components that are in contact with each other. These include, for example, stamps, molds, machine tools, technological equipment, engines, etc. They are characterized by a varied load mode. Therefore, an important aspect in studying the stressed-strained state of such structures is to determine the dependence of contact pressure on the external forces applied to them. A superposition principle for contact problems is not applicable in a general case. However, for this type of structures, the linear dependence of contact pressure on the load level has been established. In this case, the contact area does not depend on the load level. It has been demonstrated that this pattern holds not only for a one-component but also for the multi-component load. As a result, the possibility for rapid determining the stressed-strained state of such structures is ensured, while maintaining the accuracy of the results obtained.

The applicability of the constructed method has been demonstrated by using the machine tools' clamping accessories as an example. The established patterns are important when estimating the designs of structures. The derived direct proportional dependence of the solution on the applied loads makes it possible to shorten the design time of structures with the elements that interact when they are in contact at surfaces of the matching shape. In this case, we have considered different sets of loads, as well as the various varying variants of these loads. The examined cases have confirmed the direct proportionality of the components of the stressed-strained state of the magnitude of the applied forces for the case of their coordinated change. It has been also shown under an uneven change in the individual components of loads the dependence of contact pressure and components of the stressed-strained state of the examined objects on the applied forces demonstrates a complex character different from the directly proportional relation. The established dependences underlie the substantiation of the design and technological parameters of the structures that are designed, as well as their operational modes.

Keywords: contact pressure, stressed-strained state, theory of variational inequalities, machine tool, region of contact interaction

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CONSTRUCTION OF AN ALGORITHM TO ANALYTICALLY SOLVE A PROBLEM ON THE FREE VIBRATIONS OF A COMPOSITE PLATE OF VARIABLE THICKNESS (p. 26–33)

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The paper reports an algorithm to analytically solve one of the problems in the mechanics of elastic bodies, which is associated with studying the natural vibrations of a composite two-stage plate whose concave part is smoothly aligned with the part of a constant thickness. We have defined patterns for stating the boundary and transitional conditions, which should be taken into account when considering the natural vibrations of a two-stage plate.

The ratios have been obtained, which make it possible to study the distribution of deflections and determine the values of amplitudes of the curved vibrations of the plate. It was noted that the modes of vibrations are based on the symmetry and factorization methods that we had developed and refined earlier. Specifically, it has been found that the deflections can be explored through expressions that are derived through the sum of relevant solutions to two linear second-order differential equations with variable coefficients.

Based on the proposed approach, a system consisting of eight homogeneous algebraic equations has been defined, which allowed us to build a frequency equation for the plate rigidly fixed along the inner contour and free along the outer contour. We have determined the values for the plate's natural frequencies for the first three modes of natural vibrations. Moreover, in order to verify and expand a set of plates of different configurations, the plates with two types of concave in their variable part have been considered. The new approaches and the ratios based on them could be useful for the further advancement of methods for solving similar problems in mathematical physics on natural values. A practical implementation is the problems about the vibrations of plates with variable thickness and of different modes.

Keywords: natural frequencies, vibration modes, analytical solution, annular plate, free vibrations, symmetry method.

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THE STRESSED-DEFORMED STATE OF SLAB REINFORCED-CONCRETE HOLLOW STRUCTURES CONSIDERING THE BIAXIAL COMPRESSION OF CONCRETE (p. 34–42)

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In order to significantly reduce the weight of flat monolithic reinforced concrete floors, foundations, and other slab structures, construction operations have increasingly involved effective inserts as the separate articles made from relatively light and cheap materials that are placed in the midsection and left in the slabs after concreting.

The inserts made from relatively light and cheap materials, with respect to concrete, have the strength and rigidity that are orders of magnitude less and are essentially used to form hollows. The inserts considered in this paper are prismatic. When the inserts are arranged in two directions, which is typical for most slab structures, we obtain the I-sections, whose calculation involved the analysis of the impact exerted by the general and local strength factors. Under such conditions, slabs must be calculated taking into consideration the biaxial work of concrete. In this paper, we have examined the stressed-strained state of the slab reinforced concrete structures with a bidirectional location of inserts and have substantiated the estimation schemes and calculation dependences related to the procedure for calculating the floors and other slab reinforced concrete structures with a bidirectional location of inserts. The paper gives an example of the calculation of a monolithic flooring slab based on the proposed procedure, which demonstrated that accounting for the biaxial stressed-strained state of concrete significantly increases the strength of concrete and the rigidity of a flooring slab, by 19.3 %.

Thus, the consideration of biaxial compression of concrete is an important factor in the design of slab structures with a bidirectional arrangement of inserts.

Keywords: reinforced concrete hollow structures, stressed-strained state, biaxial compression of concrete, estimation schemes, strength, rigidity, example of calculation.

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DETERMINATION OF THE WORKFLOW OF ENERGY-SAVING VIBRATION UNIT WITH POLYPHASE SPECTRUM OF VIBRATIONS (p. 43–49)

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A new scheme for the excitation of vibrations of the working bodies of the blocks of a vibration unit based on a change in the phase angles of unbalances between themselves is developed. The implementation of such an idea allows for one revolution of imbalances to realize the number of vibration actions on the technological environment, how many vibration units the installation has. Thus, the frequency spectrum is implemented, which significantly increases the efficiency of the process. The proposed scheme is suitable for the implementation of various processes with a reduction in energy consumption compared to existing designs of vibration machines. A design diagram of a vibration unit with four vibration blocks is developed. A mathematical model is selected based on the representation of machine parameters as discrete, and the processing medium as continuous. The simulation of the working process of the vibration unit is based on the use of the finite element method. The finite element model is composed by approximating all the supporting elements, including the shaping surfaces, by two-dimensional finite elements.

Vibration isolating supports and elastic elements of the model are adopted three-dimensional, since the processes occurring in such structural elements are more complex in terms of energy dissipation. The workflow of an energy-saving vibration unit that implements polyphase vibrations is investigated. The equations of motion of such a system are compiled and the amplitudes and frequencies of vibrations that determine this movement are determined. The distribution of the amplitudes of the vibrations along the perimeter of the frame, mounted on the vibration blocks of the vibration unit, is estimated. The possibility of efficient use of the polyphase spectrum of vibrations when performing the processes of sorting and compaction of materials based on the implementation of shear and normal stresses is determined. The proposed scheme of an energy-saving vibration unit and certain parameters open up a real opportunity for creating a new class of machines for use in various industries. The obtained results are used in the design of an energy-saving design of a vibration unit with a rational choice of phase angles for compaction of process media.

Keywords: vibration unit, vibration blocks, unbalance, model, phase angles, amplitudes, frequencies and vibration modes.

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ESTABLISHING CONDITIONS FOR THE OCCURRENCE OF DYNAMIC AUTO-BALANCING IN A ROTOR ON TWO ELASTIC-VISCOUS SUPPORTS (p. 50–57)

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Were found the conditions for occurrence of dynamic auto-balancing for the case of a rotor mounted on two elastic-viscous supports, balanced by two or more passive auto-balancers of any type.

A modernized energy method has been applied under assumption that the mass of auto-balancers' loads is much smaller than the rotor mass. The method has been constructed for rotors on isotropic elastic-viscous supports, when such bodies are attached to the rotor, whose relative motion is hindered by elastic and viscous resistance forces. The method makes it possible to find stationary motions of the rotary system, assess their stability. At stationary motions the relative motions of the attached bodies stop, and the system rotates as a whole around the axis of rotation formed by the supports.

The mechanical and mathematical model of the system has been described. We have found the generalized potential under stationary motions, as well as a dissipative function corresponding to the supports. For the generalized rotor coordinates the equations of stationary motions of the system have been derived. The reduced potential has been investigated for a conditional extremum under an assumption that the equations of stationary motions hold, which correspond to the generalized coordinates of the rotor.

It has been established that dynamic balancing of the rotor is possible only for the case of a long rotor, two or more auto-balancers of any type, installed in different correction planes and only at the rotor rotation speeds exceeding resonance ones. It has been found that the resistance forces in the supports do not change the conditions for auto-balancing occurrence explicitly, but they can change these conditions implicitly – by changing the region of existence of stationary motions.

The result obtained coincides with the result that was derived from using a generalized empirical criterion for auto-balancing occurrence when damping in the supports is not taken into consideration. It has been shown that the modernized energy method (as well as the generalized empirical criterion for auto-balancing occurrence) makes it possible to find generalized conditions for auto-balancing occurrence, suitable for any type of auto-balancers. Therefore, both methods are applicable for building a general theory of passive auto-balancers, suitable for auto-balancers of any type.

Keywords: rotor, isotropic support, auto-balancer, stationary motion, motion stability, equation of steady motion.

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DEVELOPMENT OF DYNAMIC INTEGRAL EVALUATION METHOD OF TECHNICAL STATE OF ONE-SECTION ELECTRIC LOCOMOTIVE BODY (p. 57–64)

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At present, one of the main problems arising from the long-term operation of one-section electric locomotives is the need to maintain their good technical condition. In this case, the determining aspect is often rapid identification of existing defects and damage to the main bearing structural elements of machine bodies, as well as preventing their development into more serious structural deviations.

The aim of the study is to develop a specialized method that allows identifying defects of the main bearing structural elements of the bodies of one-section electric locomotives at the early stages of emergence and development. This method of dynamic integral evaluation is based on the analysis of partial dynamic spectrum of the electric locomotive. Based on the magnitude of the spectrum deviation relative to the theoretical one obtained from finite element modeling, it is possible to determine the approximate nature and location of damage, especially latent.

The frequency spectrum of the main bearing structural elements of the bodies of one-section electric locomotives obtained in the course of the studies is rather dense and lies in the frequency range up to 20 Hz. The presence of damage reduces its value, and for the most common types of defects, this reduction is 25–30 %.

The effectiveness of the practical application of the dynamic integral evaluation method is illustrated by the example of the DS3-008 machine. The method revealed hidden damage to one of the elements of the bearing frame of the front surface of the cab, which was not revealed during the standard maintenance procedure of the machine. The use of the method of dynamic integral evaluation of the technical condition of electric locomotives is quite versatile and can also be recommended for other units of railway rolling stock. In practice, the introduction of this approach will effectively prevent the development of emergencies.

Keywords: one-section electric locomotive, maintenance, dynamic integral evaluation method, technical condition.

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SUBSTANTIATING THE OPTIMIZATION OF THE LOAD-BEARING STRUCTURE OF A HOPPER CAR FOR TRANSPORTING PELLETS AND HOT AGGLOMERATE (p. 65–74)

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The strength parameters have been determined for the bearing structure of a hopper car used to transport pellets and hot agglomerate. The calculation was based on a finite element method, implemented in the software COSMOSWorks. Strength reserves of load-bearing elements in a carbody have been determined. In order to reduce material consumption for a carbody, it has been proposed to use pipes with a circular cross-section as the bearing elements. Mathematical modeling was applied to determine the accelerations that act on the optimized bearing structure of a wagon when it is struck at shunting. It has been established that the accelerations that act on the bearing structure of a wagon amount to 42.4 m/s^2 (4.3 g). The derived acceleration magnitude was accounted for when calculating the strength of a hopper car's bearing structure. The maximum equivalent stresses in this case reached about 270 MPa and were concentrated in the region where a girder beam interacts with a pivot beam while not exceeding the permissible ones for the grade of steel used in the metallic structure.

We have simulated the vertical dynamics of the optimized bearing structure of a hopper car used to transport pellets and hot agglomerate. During calculations, the parameters for a spring suspension of the 18-100 model's undercarriage were taken into consideration. The results of our calculations make it possible to conclude that the accelerations of a hopper car body, as well as undercarriages, are within the allowable limits. In this case, in terms of compliance with the requirements of normative documents, the car ride quality can be described as «excellent».

The proposed technical solutions justify the use of round pipes as the load-bearing elements of a hopper car body for transporting pellets and hot agglomerate. In this case, it becomes possible to reduce the hopper car tare by almost 5 % compared to a prototype car. In addition, the introduction of round pipes in the bearing structure of a hopper car could bring down manufacturing costs for railroad car building enterprises.

Our study would contribute to the construction of modern structures of hopper cars, as well as to the improved efficiency of railroad transportation.

Keywords: hopper car, specialized freight car, bearing structure, car body strength, dynamic loading, car body optimization.

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