DEVISING AN ENGINEERING PROCEDURE FOR CALCULATING THE DUCTILITY OF A ROLLER BEARING UNDER A NO-CENTRAL RADIAL LOAD (p. 6–10)

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Known theoretical approaches to calculating the ductility of rolling bearings include rather complicated analytical dependences and require cumbersome computation. That makes it a relevant task to undertake a research aimed at the development of an engineering approach to the calculation of radial ductility of bearings.

The current study proposes an engineering method for determining radial ductility using cylindrical roller bearings as an example. It accounts for the radial gap, contact deformation of parts, the deformations of bending and misalignment of rings for cases when a bearing is exposed to the action of a central radial load and a radial load with eccentricity. The adopted simplified linear calculation model for determining the angle of rings misalignment is valid for small angles when contact is maintained over the entire length of the roller. Computation of radial ductility of roller bearings under a no-central radial load is based on determining the sum of variable elastic deformations in a contact between rings and the most loaded roller. The values for elastic deformations are determined from known formulae for solving the contact problem in elasticity theory taking into consideration a mismatch between the geometric centers of outer and inner rings.

Adequacy of the proposed engineering procedure has been confirmed by results from calculating the specific ductility of the cylindrical roller bearing 2211 with a central radial load. By using the proposed methodology, we have derived values for specific ductility that are 3.4 % lower compared to similar results obtained from a known procedure. By using the cylindrical roller bearing 42726 as an example, we have investigated structural parameters considering a no-central radial load. A decrease in the bearing 42726 ductility with an increase in the number of rollers and rigidity of the outer ring has been shown, as well as with a decrease in the eccentricity of a radial load.

The ductility of rolling bearings must be known when constructing dynamic models of certain machines: machine tool spindles, shaft-gears at large-size reducers, crane structures. Therefore, the proposed engineering procedure for determining the ductility of roller bearings at small angles of rings misalignment could be applied in the practice of designing machines and mechanisms for which the elastic characteristics of all their components are important.

Keywords: engineering calculation procedure, roller bearings ductility, contact deformations, no-central radial load, misalignment of rings.

References
A variational numerical-analytical method (called the RVR method) is suggested for calculating the strength and stiffness of statically loaded non-thin orthotropic shell structures weakened by holes (stress concentrators) of arbitrary shapes and sizes. The theoretically substantiated new method is based on the Reissner variational principle and the method of I. N. Vekua (the method of decomposing the desired functions into the Fourier series of the orthogonal Legendre polynomials with respect to the coordinate along the constant shell thickness). In this case, the use in the proposed RVR method of the general equations of three-dimensional problems of the linear theory of elasticity makes it possible to determine the total stress-strained state of an elastic shell (in particular, a plate) with holes. At the same time, using the R-functions, at the analytical level, the geometric information of boundary-value problems for multiply connected domains is taken into account and solutions structures are constructed that exactly satisfy different variants of boundary conditions. The use of a software-implemented algorithm for the two-sided integral assessment of the accuracy of approximate solutions in the study of mixed variational problems helps automate the search for such a number of approximations in which the process of convergence of solutions becomes stable.

For orthotropic and isotropic materials, the possibilities of the RVR method are shown in numerical examples of solving the corresponding boundary value problems of calculating the stress concentration in a cylindrical shell with an elliptical or rectangular hole under axial load. The results of the performed tests are discussed, and the features characteristic of the new method prove that it can be effectively used in the design of critical lamellar and shell elements of structures in various fields of modern technology.

**Keywords:** orthotropic shell with holes, stress concentration, Reissner principle, R-functions theory.

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abstract and references. Applied mechanics


To ensure the structural strength of open-top wagons, it has been proposed to introduce the concept of a traction device that could be implemented in open-top wagons with bearing elements made of round pipes. Feature of the concept is that the console parts of the girder beam are filled with a viscous substance with damping and anticorrosive properties. To convert the shock kinetic energy into the dissipation energy, the concept design includes a piston with two throttle valves (inlet and outlet).

In order to determine the dynamic load on the bearing structure of an open-top wagon equipped with a concept design of the traction device, mathematical modeling was performed. A mathematical model of the open-top wagon dynamic load during shunting collision has been constructed. It was considered that the frame of an open-top wagon is exposed to a longitudinal load of 3.5 MN. Differential equations were solved in line with a Runge-Kutta method in the programing environment Mathcad. It was established that the maximum magnitude of acceleration that acts on an open-top wagon, taking the improvement into consideration, is about 30 m/s². The proposed technical solutions make it possible to reduce the magnitude of dynamic load on an open-top wagon’s bearing structure at shunting collision by 25 %.

The software CosmosWorks was used to perform computer simulation of the dynamic load on an open-top wagon. The finite element method was applied as a calculation technique. In this case, maximum accelerations amounted to about 37 m/s² and were concentrated at the console parts of a girder beam.


DOI: 10.15587/1729-4061.2019.166329 DETERMINING THE DYNAMIC LOADING ON AN OPEN-TOP WAGON WITH A TWO-PIPE GIRDER BEAM (p. 18–25)

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Adequacy of the developed models of dynamic loading on an open-top wagon’s bearing structure was tested against the Fisher criterion (F-criterion). The optimal number of measurements was defined based on the Student-Gorset criterion. The results from calculation have demonstrated that the hypothesis of adequacy is not rejected.

This study will contribute to a decrease in the dynamic load on the bearing structures of open-top wagons in operation, as well as bring down the cost of unscheduled repairs. The current research enables the compilation of guidelines on designing innovative rolling stock with improved technical and economic indicators.

**Keywords:** open-top wagon, bearing structure, accelerations, dynamic loading, traction device, shunting collision.

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**A STUDY OF THE EFFECTS OF CLIMATIC TEMPERATURE CHANGES ON THE CORRUGATED STRUCTURE (p. 26–35)**

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The study provides the results of experimental tests on temperature distribution throughout the surface of a corrugated metal sheet.

Mathematical models are proposed for calculating the thermal conductivity and the thermal stress state of a fragment of the corrugated metal frame of a transportation facility whose lateral surfaces are heated to different temperatures. It is assumed that the temperature depends on two spatial variables. As a possible criterion for choosing the desired function of temperature distribution throughout the construction, it is assumed that the functional defined by a set of admissible functions is minimized in the form of an
integral throughout the region of the body from the expression
given by the production of entropy.

In the study of the temperature field, the differential
equation of thermal conductivity is used, and the stress-
strain state is measured by the equation of the theory of
thermal elasticity. To solve the differential heat equation,
the method of finite differences is used, and for the solution
of the equations of the theory of thermal elasticity, the finite
element method is applied.

It has been established that the temperature is distribu-
ted unevenly throughout the corrugated metal sheet. There
is a temperature difference between the lower and upper
surfaces of the corrugated metal sheet. The temperature
difference between the bottom and top sides of the sheet is
+7.1 °C at the highest atmospheric temperatures and –5.5 °C
at the lowest atmospheric temperatures.

It has been determined that the magnitude of the stresses
that appear on corrugated metal sheets due to the atmo-
spheric temperature difference is up to 25 % of the permis-
sible stress. Therefore, when designing corrugated metal
structures, it is necessary to calculate the effect of climatic
temperature changes.

The obtained data of the thermal stress state of corru-
gated metal structures are important for design enterprises. It
is because taking into account the action of the temperature
field on the stress state of the structure as a whole at the
design stage helps select materials to reduce the temperature
stresses that have a direct influence on the development of
corrosion damage to the metal of the pipe.

Keywords: corrugated metal frame, temperature distri-
bution, temperature field, thermal stress state.

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ic models and investigation methods of hetero-phase
Operating conditions of asphalt-concrete layers on cement-concrete slabs differ significantly from other structural solutions. Practical road construction applies the insufficiently developed methods for calculating the strength of asphalt-concrete coating for rigid road beds since only separate strength criteria of the asphalt-concrete layer are standardized. Current calculation methods do not take into consideration the patterns in the stressed-strained state of an asphalt-concrete layer on cement-concrete slabs under various conditions for the application of load, such as the middle part of a slab, the edge of a slab, and the corner of a slab. The mismatch between the conditions for calculation and the actual stressed-deformed state of a structure determines the premature failure of an asphalt-concrete layer and, consequently, shortens the inter-maintenance period and leads to additional costs for unplanned repair.

We have simulated the stressed-strained state of a road bed structure by using a finite-element method in the programming environment ANSYS for three variants of arrangement of transport loading, specifically, in the center of a slab, at the edge of a slab, and in the corner of a slab.

The paper provides, for the accepted variants of the transport loading, the derived values for the von Mises stresses, principal stresses, horizontal and maximal horizontal shear stresses. The stresses’ values were determined at the surface of an asphalt-concrete layer, at a point of contact between an asphalt-concrete layer and a cement-concrete slab, and at a contact point between a cement-concrete slab and a base.

We have compared the defined stresses in the layers of a road bed for different variants of the application of a transport loading, as well as compared the results obtained with known solutions.

That has made it possible to establish that for the asphalt-concrete layer the arrangement of load in the corner of a slab is the most dangerous, both in terms of shear stresses and the von Mises stresses. The stresses that occur when the load is applied at the corner of a slab are approximately 10% higher than the stresses that occur when the load is applied at the edge of a slab, and are approximately 20% higher than the stresses arising when the slope is applied in the center of a slab.

Keywords: asphalt-concrete layer, modulus of elasticity, stressed-strained state, load application point, cement-concrete slab.

References

The energy method of studying rotor dynamics has been modernized. The method is applicable to the rotors mounted on isotropic elastic-viscous supports when bodies are attached to the rotors and relative motion of these bodies is prevented by elastic and viscous forces. The method is designed to search for steady motions and determine conditions of their existence as well as assess stability of the rotor system. Relative motions of the attached bodies cease at steady motions and the system rotates as a single whole around the axis of rotation formed by supports.

Effectiveness of the method was illustrated by an example of a flat model of a rotor and an auto-balancer with many loads in the form of balls, rollers or pendulums.

It has been established that the system has family of main motions (the rotor is balanced at them) both with and without damping in supports at a sufficient balancing capacity of the auto-balancer.

In the absence of damping in supports, the system has:

- isolated secondary motions at which the center of mass of the loads is deflected to the side of imbalance or in the opposite direction if there is unbalance of the rotor;
- one-parameter families of secondary motions at which the centers of mass of the loads lie on one straight line in the absence of unbalance of the rotor.

In the presence of damping in supports:
- there are no secondary motions in the absence of rotor imbalance.

The secondary motions and domains of their existence do not depend on the angular velocity of the rotor in the absence of damping in supports but they depend on the angular velocity of the rotor in the presence of the rotor imbalance.

Both in the presence and in the absence of damping in supports:
– only the secondary motion at which total imbalance of the rotor and loads is greatest can be stable at sub-resonant rotor speeds;
– only a family of main motions can be stable at super-resonant rotor speeds.

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

**References**


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MODELING THE RESONANCE OF A SWINGING SPRING BASED ON THE SYNTHESIS OF A MOTION TRAJECTORY OF ITS LOAD (p. 53–64)

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The paper reports a technique for building the resonance trajectories of the motion of a swinging spring load. A swin-
ging spring is the kind of a mathematical pendulum consisting of a point load attached to a weightless spring. The other end of the spring is fixed immovably. We have considered the pendulum-like spring oscillations in a vertical plane provided its axis straightness is maintained. Calculations have been performed based on the solutions to a system of differential equations with components that include values for the frequency values of vertical and horizontal displacements of a point on a spring.

The relevance of the subject is predetermined by the necessity to study the technological processes of dynamic systems when the nonlinearly connected oscillatory components of the system exchange energy. Using a swinging spring phenomenon illustrates the exchange of energies between the transverse (pendulum) and longitudinal (spring) oscillations. In this case, we also take into consideration the influence of the initial conditions for initiating oscillations. Of particular importance is to study the resonance state of a swinging spring when the frequency of longitudinal oscillations differs by a multiple number of times from the frequency of transverse oscillations. In addition to a common «classic» case (resonance 2:1), there is a need to consider cases with different values for the frequency ratio. The result is the derived geometric shapes of the motion trajectory of a swinging spring load that correspond to the patterns in the state of its resonance.

The results obtained in the current paper make it possible, by using a computer, to synthesize the motion trajectory of a swinging spring load that would match the assigned frequency ratio of longitudinal and transverse oscillations. For this purpose, in addition to basic parameters (a load’s mass, rigidity of the spring, its length in a no-load state), we added the initial values for the parameters during oscillation initiation. Specifically, the «starting» coordinates for a load, mass, rigidity of the spring, its length in a no-load state, we performed based on the solutions to a system of differential equations with components that include values for the frequency values of vertical and horizontal displacements of a point on a spring.

The results could be used as a paradigm in order to study the nonlinear connected systems, as well as in the calculation of variants for mechanical devices where springs affect the oscillation of their elements. Additionally, for cases when the technology of using mechanical devices necessitates abandoning the chaotic movements of loads in order to ensure the periodic trajectories of their displacements.

**Keywords:** swinging spring, a swinging spring resonance, pendulum oscillations, a load motion’s trajectories.

**References**


Drum mixers ensure a high level of uniformity when mixing the components of feed additives. However, the issues on theoretical and experimental substantiation of the structural and kinematic parameters of drum mixers have not been scientifically explored in detail. The aim of this study is to improve the efficiency of producing feed mixtures by ensuring the optimal angular rotation velocity of a drum mixer.

To determine the radial speed of a particle’s motion along a drum blade, we solved a homogeneous differential equation. The numerical value for angular velocity was determined by a computer simulation method. We experimentally studied the uniformity of redistribution of feed components in a mixture of fodder using the designed experimental drum mixer. The mixer included a chamber, a rectangular frame, a supporting frame, and a drive. The mixing chamber included a loading/unloading window with a closed lid. Radial blades were installed inside the chamber along its entire length and evenly along the perimeter.

Experiments were conducted using a drum mixer with a drum radius of 0.17 m, which included radial blades with a width of 25 mm, with a chamber’s fill factor of 0.5. It was established that the drum mixer ensures the maximum scattering of a material’s particles on the surface of the working segment at the drum’s angular rotation velocity of 9.69 rad/s.

The results of experimental research have established that at rotation frequency of the laboratory plant’s drum of 9.42 rad/s the uniformity of mixture is 92.5–93%, which meets acting zootechnical requirements for all types of mixed fodder. In this case, a maximum deviation of the theoretical results from experimental data was about 9%. The results obtained suggest the possibility of determining a numerical value for the angular velocity of drum mixers by using the proposed method of computer simulation.

**Keywords:** blade, radial velocity, fill factor, mixing time, feed additives, control component, mixture, drum radius.

**References**


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DETERMINING THE PARAMETERS FOR CONNECTIONS AMONG THE ELEMENTS OF DESIGN OF VEHICLES IN TERMS OF ERGONOMICS AND CREW SAFETY (p. 72–80)

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This paper reports a study into the working processes of the system «operator – machine – external environment» in land vehicles using the constructed mathematical model.

A significant effect has been determined that the structure and parameters of relations between elements of the design exerts on meeting the requirements for ergonomics and safety for crews.

The results from numerical experiment have proven the need for an integrated approach at the design phase (modernization) when defining the parameters for the examined object (an example of such an object has been considered with parameters close to the parameters for BTR-60...BTR-80).

Feature of the integrated approach is that the requirements regarding ergonomics and the safety requirements have been met simultaneously. From the standpoint of ergonomics, the parameters for ride smoothness, accommodation of an operator (for example, a driver) relative to machine’s controls, were regulated and, in general, within a control cabin, taking into consideration its arrangement. From the standpoint of safety, the parameters were regulated for the case of a landmine explosion.

It has been shown that the framework of the applied procedure for optimal design of complex technical systems allows the implementation of the examined object (upgrade) that would comply with the requirements for both ergonomics and safety of crews.

The accomplishment of the goal has been confirmed by the calculation results in the form of oscillograms (displacements, velocities, accelerations, forces) for working processes aimed at transforming the force action from a disturbing factor along the way from a wheeled vehicle to operator.

The mathematical model makes it possible to quantify and to qualitatively estimate the role of the main parameters for the entire object, and, specifically, the elastic damping relations at two levels (the first level is cushioning a machine’s body, the second level is cushioning the seat of an operator).

The numerical experiment was conducted using a Runge-Kutta method with a variable step employing an original software.

Keywords: operator, vehicle, disturbing factor, explosion, ergonomics, safety.

References


