ABSTRACT AND REFERENCES

APPLIED MECHANICS

DOI: 10.15587/1729-4061.2019.160456

DETERMINING THE DYNAMIC LOADING ON A SEMI-WAGON WHEN FIXING IT WITH A VISCOUS COUPLING TO A FERRY DECK (p. 6–12)

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We have modeled the dynamic loading of a semi-wagon body when it is fixed by a viscous coupling relative to the deck of a railroad ferry. The relevance of this research relates to the fact that the movement of wagons by sea on railroad ferries is accompanied by the effect of significant magnitudes of loads on the load-bearing structures of their bodies. The numerical values of these loads are significantly higher than those that act on a wagon under operation along a railroad. In addition, the current scheme does not ensure the reliability of fastening the body and thus causes damage to its structural elements. This necessitates conducting unplanned repairs of wagons that are transported on railroad ferries. It is therefore proposed to improve the scheme of fixing a wagon relative to the deck of a railroad ferry. In order to mitigate the effect of loads exerted by chain couplers on a wagon body, it is suggested that they should be connected by a flexible link, rather than rigid, by installing a specialized device – a damper between a body and a deck.

To simulate the dynamic loading of a wagon body taking into consideration the proposed technical solutions, a mathematical model has been constructed and the magnitudes of accelerations acting on the body have been determined. The model accounts for the movement of a railroad ferry with wagons under side rocking motion as one of the main types of vessel fluctuations. It was established that it becomes possible, by taking into consideration the proposed scheme of fixing a wagon body relative to the deck, to reduce the magnitude of its dynamic loading by 30 %.

We have also determined the dynamic loading on a wagon body by computer simulation in the programming environment CosmosWorks. Numerical values and the fields of deployment of semi-wagon body's accelerations have been determined. The constructed models were verified based on an *F*-criterion. The present research will contribute to maintaining the bearing structures of wagons' bodies when they are transported on railroad ferries, as well as improving the efficiency of their operation along international transport corridors.

Keywords: bearing structure, dynamic loading, rail and water transport, rail and ferry transportation, modeling of dynamics, metrological tests.

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DOI: 10.15587/1729-4061.2019.162153

ANALYSIS OF AXISYMMETRIC PROBLEM FROM THE THEORY OF ELASTICITY FOR AN ISOTROPIC CYLINDER OF SMALL THICKNESS WITH ALTERNATING ELASTICITY MODULES (p. 13–19)

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Asymptotic methods play an important role in solving three-dimensional elasticity problems. The method of asymptotic integration of three-dimensional equations of elasticity theory takes an important place in solving the problems of the limited transition from three-dimensional problems to two-dimensional for elastic membranes. Based on the method of asymptotic integration of equations of the elasticity theory, the axisymmetric problem of elasticity theory for radially non-homogeneous cylinder of small thickness is explored. The case when elasticity modules change by the radius according to the linear law is considered. It is expected that the lateral part of the cylinder is free from stresses and boundary conditions, leaving a cylinder in equilibrium, are assigned at the ends of a cylinder. The stated boundary-value problem is reduced to the spectral problem. The behavior of solutions to the spectral problem both in the inner part of a cylinder, and near the ends of a cylinder if the parameter of thinness of cylinder's walls tends to zero, is studied. Three groups of solutions were obtained and the nature of the constructed homogeneous solutions was explained. The solution corresponding to the first iterative process determines the penetrating stressed-strained state of a cylinder. The solution corresponding to the second iterative process represents edge effects in the applied theory of shells. The third iterative process determines the solution which has the character of a boundary layer. The solution corresponding to the first and second iterative processes determines the internal stressed-strained state of the cylinder. In the first term of asymptotics, they can be regarded as a solution on the applied theory of shells. It was shown that the stressed-strained state, similar to the case of a homogeneous cylinder of small thickness, consists of three types: penetrating stressed state, simple edge effect and a boundary layer. The problem of meeting the boundary conditions on the ends of a radially non-homogeneous cylinder using the Lagrangian variation principle was considered.

Keywords: radially non-homogeneous cylinder, asymptotic method, boundary layer, edge effect, variation principle, main vector, eigenvalue.

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DOI: 10.15587/1729-4061.2019.164091

INVESTIGATION OF THE INFLUENCE OF HARDNESS CHARACTERISTICS OF THE COLLET-PART LATHE SYSTEM (p. 20–25)

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The results of the study of the hardness characteristics of the collet-part lathe system, which are essentially nonlinear and influence the damping parameters of the spindle assembly unit, are presented.

The aim of the work is to study the characteristics of the nonlinear hardness of the elements of the collet-part technological system. In order to realize this aim, in the course of experimental research, static and dynamic characteristics of the spindle core hardness are defined, which are looped hysteresis curves that are characteristic of mechanical systems with a large number of bonds.

Measurements of nonlinear parameters of the hardness of the collet-part system are carried out. Measurements are made according to the original method. The basis of the technique is the multi-cycle static load of the spindle in the processing zone in the direction of the vector of the dynamic component of the cutting force by the developed equipment. The equipment includes a screw loader, a two-way ring dynamometer and a mandrel fitted in the spindle of the machine.

As a result of the research, the features of the nonlinear characteristics of the hardness of the collet-part lathe system are determined. For the collet-part system, the width of the hysteresis loop in the cold state can reach 20...70 microns. The hysteresis characteristics of the collet-part system in the heated state have the width of the hysteresis loop of 50...200 microns with clamping the part with a diameter of 80...115 mm and a radius of 100...120 mm.

Recommendations on the assessment of the hardness change limit depending on the design of the collet are developed. The proposed technique allows one cartridge position to be measured by pressing according to the scheme of loading «on a cam» and «between cams», which reduces twofold the amount of experimental research.

Keywords: metal cutting machine, collet, part, clamping hardness, elastic system, equipment design

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DOI: 10.15587/1729-4061.2019.161769

SYNTHESIS AND CLASSIFICATION OF PERIODIC MOTION TRAJECTORIES OF THE SWINGING SPRING LOAD (p. 26–37)

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The study of possibilities of geometric modeling of non-chaotic periodic paths of motion of a load of a swinging spring and its variants has been continued. In literature, a swinging spring is considered as a kind of mathematical pendulum which consists of a point load attached to a massless spring. The second end of the spring is fixed motionless. Pendular oscillations of the spring in a vertical plane are considered in conditions of maintaining straightness of its axis. The searched path of the spring load was modeled using Lagrange second-degree equations.

Urgency of the topic is determined by the need to study conditions of dissociation from chaotic oscillations of elements of mechanical structures including springs, namely definition of rational parameter values to provide periodic paths of their oscillations. Swinging springs can be used as mechanical illustrations in the study of complex technological processes of dynamic systems when nonlinearly coupled oscillatory components of the system exchange energy with each other.

The obtained results make it possible to add periodic curves as «parameters» in a graphic form to the list of numerical parameters of the swinging spring. That is, to determine numerical values of the parameters that would ensure existence of a predetermined form of the periodic path of motion of the spring load. An example of calculation of the load mass was considered based on the known stiffness of the spring, its length without load, initial conditions of initialization of oscillations as well as (attention!) the form of periodic path of this load. Periodic paths of the load motion for the swinging spring modifications (such as suspension to the movable carriage whose axis coincides with the mathematical pendulum) and two swinging springs with a common moving load and with different mounting points were obtained.

The obtained results are illustrated by computer animation of oscillations of corresponding swinging springs and their varieties.

The results can be used as a paradigm for studying nonlinear coupled systems as well as for calculation of variants of mechanical devices where springs influence oscillation of their elements and in cases when it is necessary to separate from chaotic motions of loads and provide periodic paths of their motion in technologies using mechanical devices.

Keywords: pendular oscillations, path of motion, swinging spring, Lagrange second-degree equation.

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DOI: 10.15587/1729-4061.2019.160487

CONSTRUCTION OF A FORCE METHOD FOR ESTIMATING THE LONGITUDINAL STABILITY OF THE PROCESS OF THIN SHEET ROLLING (p. 38–48)

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We have analyzed theoretical features of rolls gripping capacity at simple rolling process under a steady mode. It is shown that depending on the conditions for deformation the ratio of the maximum gripping angle to a friction coefficient can be equal to, be less or more than 2.

An experimental study has been performed involving the rolling of lead stepped samples measuring the forward creep at each step. Results of the experiment demonstrate that in the extreme case of deformation the forward creep is greater than zero, that is, there is a sufficient reserve of frictional forces so that reduction can be further increased, however, it is impossible.

We have analyzed the balance of all horizontal forces at deformation site. It is shown that at each cross section the stretching horizontal contact forces are used not only to overcome the ejecting ones, but also to compensate for the longitudinal internal forces that occur as a result of plastic deformation of a metal.

A force method for estimating the longitudinal stability of the sheet rolling process has been developed. An indicator of stability is a criterion that is determined from the diagrams of distribution of a normal contact stress and the stress of friction. It is shown that at a positive value of the criterion the rolling process proceeds under a steady mode; at a negative value, the stable process is impossible; and in the case it equals zero, the limit deformation occurs.

A theoretical study has been conducted into determining the maximum gripping angle under different conditions of sheet rolling. It is shown that the ratio of the maximum gripping angle to a friction coefficient almost does not depend on a strip thickness, the diameter of rolls, as well as friction coefficient, and equals 1.43–1.44. A decrease in the gripping capacity of rolls is explained by the effect, at a deformation site, not only of contact forces, but the internal forces as well.

Keywords: balance of forces, sheet rolling, deformation site, gripping capacity, stability criterion.

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DOI: 10.15587/1729-4061.2019.160585

DERIVATION OF ENGINEERING FORMULAS IN ORDER TO CALCULATE ENERGY-POWER PARAMETERS AND A SHAPE CHANGE IN A SEMI-FINISHED PRODUCT IN THE PROCESS OF COMBINED EXTRUSION (p. 49–57)

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The possibilities of using and embedding kinematic trapezoid modules with curvilinear boundaries of different shapes were explored. Based on the energy method, the generalized formulas for calculating the power of deformation forces inside the axial trapezoidal kinematic module were derived. Different types of selecting the functions that describe a curvilinear boundary of the axial trapezoidal module were identified. We have analyzed the possibilities of using known techniques for the linearization of integrand dependences in order to calculate the power of deformation forces when it is impossible to obtain a given magnitude in the form of an analytical function. The ways to derive engineering formulas for the computation of components of reduced pressure inside an axial trapezoidal kinematic module were proposed. Based on the energy method, we obtained formulas for the calculation of a step-by-step change in the shape of a semi-finished product under assumption $\dot{\gamma}_{rz} = 0$ within the axial trapezoidal kinematic module.

We modeled the process of combined extrusion of hollow parts with a flange and established regularities in shape formation depending on geometrical parameters. The data about a step-by-step change in the shape of a semi-finished product during deformation were obtained. A comparative analysis of calculation schemes for the rectilinear trapezoidal kinematic module and with a curvilinear boundary under assumption $\dot{\gamma}_{rz} = 0$ within the studied module was performed.

It was confirmed that the reported ways for obtaining engineering formulas, as well as the algorithm for the calculation of processes of combined extrusion that is based on them, simplify the development of technological recommendations. This applies both to determining the force mode of extrusion and preliminary assessment of a change in the shape of a semi-finished product with the possibility to control a metal outflow in the process of deformation.

Keywords: combined extrusion, kinematic module, energy method, linearization of functions, process of deformation.

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DOI: 10.15587/1729-4061.2019.162330

DISTRIBUTION OF LOCAL VELOCITIES IN A CIRCULAR PIPE WITH ACCELERATING FLUID FLOW (p. 58–63)

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The results of experimental studies of accelerating fluid flow in a cylindrical pipe from rest are presented. With accelerated fluid flow, a delay of laminar-turbulent transition with instantaneous Re numbers, which are several orders of magnitude higher than critical Re in stationary conditions is observed. To determine the local characteristics of the unsteady flow, hot-wire equipment was used. For measuring the local velocity in the pipe, a hot-wire cone sensor was used, and for measuring shear stresses – a sensor mounted flush with the inner pipe wall. To process the experimental data, in addition to ensemble averaging, smoothing by time averaging over five adjacent points was also carried out. It turned out that in order to obtain smoother functions for the desired characteristic, it is necessary to have much more experiments the ensemble, especially in the wall area. It is found that with accelerated fluid flow from rest to the onset of turbulence, a uniform velocity distribution remains in the pipe section and velocity gradients are observed only in a thin surface layer. A sharp transition in the shear stress characteristic on the pipe wall τ_0 with the laminar-turbulent transition is also observed in the characteristics of local velocities. At the moment of transition to the turbulent regime, a turning point appears on the average velocity graph, and velocity distribution and turbulence intensity undergo significant changes compared with steady turbulent flows. Turbulence is generated in the wall area and distributed to the pipeline section center at an almost constant velocity. The front of laminar-turbulent transition with unsteady fluid flow in the pipe is distributed towards the section center at an almost constant velocity.

Keywords: cylindrical pipe, fluid flow, flow structure, turbulence generation, hot-wire equipment.

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