ABSTRACT AND REFERENCES

APPLIED MECHANICS

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ENERGY ABSORBERS ON THE STEEL PLATE – RUBBER LAMINATE AFTER DEFORMABLE PROJECTILE IMPACT (p. 6-12)

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The ability of energy absorption can be used to measure the strength of material against ballistic impact. This paper aims to analyze the rubber plated energy absorption plate that was shot with deformable projectiles. This study was conducted using numerical simulations based on the finite element that have been verified with experimental results. The simulation setting on a steel plate with different hardness with the addition of rubber thickness is prepared as a ballistic test panel. Manufacturing between layers made non fix with the back plate. Panel shot by using 5.56×45 mm deformable caliber bullet with a distance of 15 m of normal attack angle. The finite element code with Johnson-Cook and Mooney-Rivlin elasto-plastic material models was were employed to perform the simulation study. Simulation results show the energy due to ballistic impact received and absorbed by the panel rises significantly shortly after the collision until reaching a certain number on a single plate where energy will decrease because the projectile successfully penetrated the plate. While on a layered plate, after the projectile succeeded in penetrating the front side plate, the absorption energy reached the maximum number and then remained constant, which caused the projectile not to be able to penetrate the next layer. These findings indicate that the addition of rubber with a layered structure is able to absorb the energy of ballistic impact.

Keywords: energy absorber, hard plate, soft plate, ballistic laminate plate, rubber, ballistic impact, simulation.

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GEOMETRIC MODELING OF THE UNFOLDING OF A ROD STRUCTURE IN THE FORM OF A DOUBLE SPHERICAL PENDULUM IN WEIGHTLESSNESS (p. 13-24)

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We investigated the geometric model of the new technique for unfolding a rod structure, similar to the double spherical pendulum, in weightlessness. Displacements of elements occur due to the pulses from pyrotechnic jet engines acting on the endpoints of links. The motion of the obtained inertial unfolding of a rod structure was described using a Lagrange equation of the second kind. Given the conditions of weightlessness, it was built applying only the kinetic energy of the system.

The relevance of the chosen subject is emphasized by the need to choose and study the process of activation of the unfolding of a spatial rod structure. The proposed possible drivers are the pulse pyrotechnic jet engines installed at endpoints of the structure's links. They are lighter and cheaper compared, for example, to electric motors or spring devices. In addition, they are more efficient economically when the process of unfolding a structure in orbit is planned to be performed only once.

We propose a technique for determining the parameters and initial conditions for initiating the oscillations of a double rod structure in order to obtain a cyclic trajectory of the endpoint of the second link. That makes it possible to avoid, when calculating the process of transformation, the chaotic movements of the structure's elements. We built the time-dependent charts of change in the functions of generalized coordinates, as well as the first and second derivatives from these functions. Therefore, there is a possibility to estimate the force characteristics of the system at the moment of braking (locking) the process of unfolding.

The results are intended for the geometric modeling of one of the variants for unfolding the large-sized structures under conditions of weightlessness, for example, force frames for solar mirrors or space antennas, as well as other large-scale orbital infrastructures.

Keywords: rod structure, the process of unfolding in space, two-link rod structure, Lagrangian equation of the second kind.

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DEVELOPMENT OF THE METHOD WITH ENHANCED ACCURACY FOR SOLVING PROBLEMS FROM THE THEORY OF THERMO-PSEUDOELASTIC-PLASTICITY (p. 25-33)

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Complex behavior of bodies made from pseudoelastic and pseudoelastic-plastic materials requires the development of specialized algorithms for calculating the stressed-deformed state. This work reports the developed numerical method with enhanced accuracy for solving the multidimensional non-stationary problems from the theory of thermo-elastic-plasticity for bodies made from pseudoelastic and pseudoelastic-plastic materials. This method of component-wise splitting, which is based on the application of the new expression for two-dimensional spline-functions, made it possible to improve the accuracy of calculations by two orders of magnitude. Subject to the same accuracy when calculating by the classic finite-difference method, a given method allows us to obtain results faster, due to the choice of larger steps of integration based on coordinates. This leads to the two orders of magnitude reduction in the number of applied nodes in the spatial grid, which appears important and useful from a practical point of view.

We recorded basic equations. These include the equation of heat conductivity, the equation of motion, geometric correlations. When constructing the physical correlations, it was assumed that the deformation at a point is represented as the sum of the elastic component, a jump in deformation during phase transition, plastic deformation, and the deformation caused by temperature changes. The boundary and initial conditions are stated in a general form.

We have experimentally substantiated a variant of the phenomenological model for the behavior of a material possessing shape memory. This model implies a possibility to quantify complex interactions between stresses, temperature, deformation, and the speed of loading a material, which are suitable for modeling at the continuum level as well. Based on it, we have resolved a qualitatively new class of two-dimensional non-stationary problems for materials possessing shape memory when then unknown magnitudes are sought in the form of two-dimensional strained splines.

Keywords: pseudoelastic material, phase transitions, method with enhanced accuracy, two-dimensional splines.

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EXPERIMENTAL STUDY INTO ROTATIONAL-OSCILLATORY VIBRATIONS OF A VIBRATION MACHINE PLATFORM EXCITED BY THE BALL AUTO-BALANCER (p. 34-42)

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We have experimentally investigated the rotational-oscillatory vibrations of vibratory machine platform excited by the ball auto-balancer.

The law of change in the vibration accelerations at a platform was studied using the accelerometer sensors, a board of the analog-to-digital converter with an USB interface and a PC. The amplitude of rapid and slow vibratory displacements of the platform was investigated employing a laser beam.

It was established that the resonance frequency (frequency of natural oscillations) of the platform is: 62.006 rad/s for the platform with a mass of 2,000 gm; 58.644 rad/s – of 2,180 gm; 55.755 rad/s – of 2,360 gm. An error in determining the frequencies does not exceed 0.2 %.

The ball auto-balancer excites almost perfect dual-frequency vibrations of a vibratory machine platform. Slow frequency corresponds to the rotational speed of the center of balls around the longitudinal axis of the shaft, while the fast one – to the shaft rotation speed, with the unbalanced mass attached to it. A dual-frequency mode occurs in a wide range of change in the parameters and it is possible to alter its basic characteristics by changing the mass of balls and the unbalanced mass, the angular velocity of shaft rotation.

It has been established experimentally that the balls get stuck at a frequency that is approximately 1 % lower than the resonance frequency of platform oscillations.

Assuming the platform executes the dual frequency oscillations, we employed the software package for statistical analysis Statistica to select coefficients for the respective law. It was found that:

– the process for determining the magnitudes of coefficients is steady (robust); coefficients almost do no change when altering the time interval for measuring the law of a platform motion;

– the amplitude of accelerations due to the low oscillations is directly proportional to the total mass of the balls and the square of the frequency at which balls get stuck;

– the amplitude of rapid oscillations is directly proportional to the unbalanced mass at the auto-balancer's casing and to the square of angular velocity of shaft rotation.

The discrepancy between the law of motion, obtained experimentally, and the law, obtained using the methods of statistical analysis, is less than 3 %. The results obtained add relevance to both the analytical studies into dynamics of the examined vibratory machine and to the creation of the prototype a vibratory machine.

Keywords:inertial vibration exciter, dual-frequency vibrations, resonance vibratory machine, auto-balancer, inertial vibratory machine.

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INVESTIGATING A PROBLEM FROM THE THEORY OF ELASTICITY FOR A HALF-SPACE WITH CYLINDRICAL CAVITIES FOR WHICH BOUNDARY CONDITIONS OF CONTACT TYPE ARE ASSIGNED (p. 43-50)

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When designing spatial structures, it is necessary to know the stressed-strained state of a body. These problems include the calculation schemes, in which there is a half-space with cylindrical cavities, at the boundaries of which the contact type conditions are assigned. The segment of such problems is not enough researched and requires further attention.

The analytical and numerical algorithm for solving a special problem of the theory of elasticity for a half-space with cylindrical cavities was proposed in this paper. Radial displacements and tangential stresses are assigned at the boundaries of cavities, and one of the two types of the boundary conditions – displacement or stress – is assigned at the half-space boundary. Calculations revealed the stressed-strained state of the half-space.

Under the fixed geometrical conditions, a numerical analysis of the three variants of the problem, when displacements are assigned at the half-space boundary, and of the tree variants of the problem, when stresses are assigned at the half-space boundary, was conducted. A comparative analysis of the variants with different boundary conditions was carried out.

It was found that at the boundary conditions of the contact type, assigned at the boundaries of cylindrical cavities, if the assigned displacement function and the assigned function of stresses are the same, the boundary conditions at the half-space boundary in the form of stresses have more influence of the stressed state that boundary conditions in the form of displacements. It was also established that at different kinds of the assigned boundary conditions (stresses or displacements), stresses σ_ϕ and σ_z on the surface of applying such conditions change for the opposite, that is, from stretching to compressing and vice versa.

The presented analysis can be used during designing the structures, in the calculation schemes of which there is a half-space boundary with boundary conditions of the contact type, assigned on it, and cylindrical cavities, on the surfaces of which displacements and stresses are assigned.

Keywords: cylindrical cavities in half-space, Lame's equation, generalized Fourier method, infinite systems of linear algebraic equations.

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DEVELOPMENT OF THE UNIVERSAL MODEL OF MECHATRONIC SYSTEM WITH A HYDRAULIC DRIVE (p. 51-60)

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The growing demands to performance of mechatronic systems with a hydraulic drive of movable operating elements of self-propelled machines require application of new approaches to the process of their development and design. Functional parameters of the mechatronic systems depend on a rational choice of operating modes of the hydraulic system and the design implementation of the mechatronic modules of these systems. Quality of the mechanically driven mechatronic system is largely determined by its dynamic characteristics. In order to improve dynamic characteristics, a universal model describing dynamic and static processes occurring in the elements of the mechatronic system was proposed. The pump, the hydraulic motor, the safety valve and the working fluid are considered interrelated as a single whole. The universal model takes into account peculiarities of functioning and mutual influence of all elements of the mechatronic system as well as the features of the working fluid and can be used with any hydraulic machines of a volumetric action. The study of dynamics of the changes in functional parameters of the mechanically driven mechatronic system was carried out for four stages of its operation: acceleration of the hydraulic drive (triggering of the safety valve); valve closure; completion of acceleration and steady-state operation. The conducted studies have established that when activating the hydraulic drive of the mechatronic system from the moment of the safety valve activation and to its closure, operating conditions do not affect changes in the functional parameters. In the steady-state operation, there are fluctuations caused by unevenness of the pump feed and load fluctuations. It should also be noted that the mechatronic system with a hydraulic motor having larger working volume has better dynamic characteristics than that with smaller working volume.

Keywords: hydraulically driven mechatronic system, universal model, functional parameters, dynamic characteristics.

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RESEARCH INTO CAVITATION PROCESSES IN THE TRAPPED VOLUME OF THE GEAR PUMP (p. 61-66)

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We investigated processes in the trapped volume of the gear pump, formed due to the peculiarities in the geometry of the involute gearing characteristic of the pumps of a given type. In the fluid confined to a trapped volume, at gear rotation, there occur a series of complex hydrodynamic processes. A change in the magnitude of the trapped volume leads to the occurrence of fluid compression, as well as its rarefaction. Reducing the pressure in a fluid below the level of a saturated vapour pressure results in the emergence of cavitation in it. In addition, the result of gear rotation is the vortex motion of fluid that leads to eddies, in the centre of which there is a reduction in pressure; in other words, vortices are the potential embryos of cavitation. High-speed video registration makes it possible to consider in detail the process of emergence and growth of cavitation phenomena in a trapped volume, to explore the dynamics of deformation of a cavitation bubble and a cavity, formed in the trapped volume.

Based on the results of processing the sequences of frames acquired in the course of this study, we derived dependences that show the character of change in the size of a cavitation bubble and a cavity. The constructed dependences are non-linear and have points of an extremum. The extremum in the time-dependent chart is observed after opening the trapped volume, meaning that it would take some time (approximately 1 ms) for the pressure in a intertooth cavity to grow. In this case, the extremum is observed almost simultaneously both for the deformation of the cavity and the deformation of a single bubble. The radius of a bubble in a liquid depends on individual factors, namely, properties of the fluid and the pressure magnitude, which can be calculated by applying the dependences, given in this work, depending on the conditions for the occurrence of cavitation.

Keywords: gear pump, trapped volume, vortex, video registration, cavitation, cavitation bubble.

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DEVELOPMENT OF THE METHOD FOR ESTIMATING SERVICEABILITY OF EQUIPMENT FOR THE TRANSPORTATION OF COMPRESSED NATURAL GAS (p. 67-73)

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To ensure safe transportation of compressed natural gas, we proposed, based on the results of studies conducted, the algorithm for a method for the evaluation of combined type tanks. The method implies determining parameters of the state of gas in the process of filling a tank, taking into consideration heat exchange processes and evaluation of the stressed-strained state of the tank, considering the operating conditions and the results of technical inspection. To implement the method, the tools for detecting and determining the shape and dimensions of probable corrosive damages of the metal liner surface under the composite shell were used. It was proposed to assess the stressed-strained state of tanks, taking into consideration the operating conditions, through the development and analysis of relevant models. The possibility of obtaining reliable results in the presence of available mechanisms was proved by our own research into the patterns of loading and unloading processes. To verify correctness of construction of the simulation model at the stage of studying the stressed-strained state of the tank with consideration of the actual operating conditions, we proposed the mathematical model that takes into consideration conditions for the interaction between elements of the structure, the effect of internal gas pressure and temperature. The use of the model decreases the costs of experimental research and contributes to ensuring the reliability of simulation results. The advantage of this method is determining the estimated destruction pressure of the combined type tanks at the current state of the dangerous areas and the influence of operating conditions. The practical significance of the obtained results is determined by the possibility of their application to ensure serviceability at the design stage and when tanks are in operation.

Keywords: combined type tanks, operating conditions, corrosive damage, simulation, serviceability.

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