Analysis of practical experience in the construction and operation of the main fairings of launch vehicles has revealed the currently widely used sandwich structures with composite load-bearing sheathing combined with a cellular filler. The considered structures are characterized by a rather large number of parameters whose variation significantly changes the mass of an article.

An approach to optimizing such structures as the main fairing of a launch vehicle in terms of mass has been further developed. The approach includes the essentially improved components of fragments of known analogs, previously developed by a team of authors, as well as the new fragments, which were not taken into consideration before. In contrast to known works, the approach has made it possible to solve the complex multi-parametric task on the optimal design of the considered class of equipment, almost without loss of accuracy. To this end, the optimization process was divided into several stages based on the reasonable levels of parameters' significance that are included in the objective function – a minimal mass. An analysis of effectiveness of the reinforcement structure for bearing sheaths has been performed, as well as the preliminary optimization of a cellular filler’s properties, which significantly simplified the selection of their optimal parameters. It has been shown that at a minimum gain in mass due to the optimal reinforcement scheme, which is approximately 5% compared to a quasi-homogeneous sheath, there is an actual risk of a two-fold increase in the mass of a sheath when choosing a substantially non-optimal structure of the sheath.

The result of this study is the established rational parameters for a scheme of reinforcement of bearing sheaths and a cellular filler, as well as their geometric parameters, which ensured a reduction in the mass of the main fairing in comparison with the basic variant, by 51% or 118.2 kg. The results obtained allow further development and improvement, with almost no changes in its concept and structure in the direction of integration of auxiliary structural elements of the head fairing into optimization.

Keywords: optimization for mass, head fairing, sandwich structures, bearing sheaths, cellular filler.

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DETERMINING THE INFLUENCE OF PHYSICAL NONLINEARITY OF SOIL STRENGTH PROPERTIES ON THE ESTIMATED BASE RESISTANCE (p. 19–27)

Oleksandr Shashenko
Dnipro University of Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-7012-6157

Vladimir Shapoval
Dnipro University of Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0003-2993-1311

Oleksandr Kovrov
Dnipro University of Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0003-3364-119X

Alexandr Skobenko
Dnipro University of Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-8122-6383

Oleksii Tiutkin
Dnipro National University of Railway Transport named after Academician V. Lazaryan, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0003-4921-4758

Kateryna Babii
M. S. Polyakov Institute of Geotechnical Mechanics NAS of Ukraine, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-0733-2732

Oleksandr Samorodov
Kharkiv National University of Civil Engineering and Architecture, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-4395-9417

Sergey Slobodyanyuk
Prydniprovskaya Academy of Civil Engineering and Architecture, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0003-4874-7296
The paper has examined the potential of using nonlinear models of strength in determining the initial critical load on soil, as well as the standardized and estimated base resistance, which makes it possible to reduce labor intensity in the process of determining the strength properties of soils.

Based on the analysis and generalization of results from theoretical studies into geomechanical processes using analytical mathematical methods, the formula modifications have been derived that are intended for determining the initial critical load on soil, as well as the standardized and estimated base resistances.

We have established interrelation between strength, in particular specific cohesion, and the angle of internal friction, which are included in the strength conditions by Mohr-Coulomb and A. Shashenko, thereby making it possible to improve the procedure for calculating external loads on soil.

The dependences of critical loads on base on the mean pressure under the sole of the foundation haven been analyzed in the range of pressure $P = 100...500$ kPa using the strength conditions by Mohr-Coulomb and A. Shashenko.

It has been established that when using generally accepted estimation formulae to determine the critical loads on base, it is required that the pressure range should be taken into consideration at which the properties of soil strength were determined. In this case, using the Shashenko failure criterion to determine critical loads on base makes it possible to properly consider the impact exerted by the mean pressure on them under the sole of the foundation.

In contrast to dependences used currently in the Ukrainian, Belarusian, Russian regulatory documents, as well as in other countries’ standards, the resulting formulae make it possible to take into consideration the dependences of soil strength properties on the mean pressure on soil under the sole of the foundation. The results obtained make it possible to improve the reliability of determining the initial critical load on soil, as well as the standardized and estimated base resistances. This is achieved by taking into consideration the nonlinearity of the Mohr limiting circles’ envelope using the strength condition by A. Shashenko.

**Keywords:** failure criteria by Mohr-Coulomb and A. Shashenko; load on soil, cohesion, angle of internal friction.

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**ESTIMATION OF THE AERODYNAMIC CHARACTERISTICS OF A STEPPED NACELLE FOR THE AIRCRAFT POWERPLANT** (p. 27–31)

Yuriy Yu. Tereshchenko
National Aviation University, Kyiv, Ukraine
**ORCID:** http://orcid.org/0000-0002-1908-0923

Yuriy M. Tereshchenko
National Aviation University, Kyiv, Ukraine
**ORCID:** http://orcid.org/0000-0003-4367-3232

Alexander Sliyarov
State Aviation Research Institute, Kyiv, Ukraine
**ORCID:** http://orcid.org/0000-0002-3836-1886
The purpose of this work is to estimate the aerodynamic characteristics of the stepped nacelle of a gas turbine engine with a turbofan unit. The research was based on the method of model physical experiment. The wind tunnel applied for the study was provided with the necessary equipment, which includes various nozzles of static and dynamic pressure with coordinate devices, etc. For the experimental study, we built the models of nacelles for an aviation power plant with front location of the fan module and with the rear arrangement of a turbofan unit. We have experimentally investigated the aerodynamic characteristics of the stepped nacelle for a gas turbine engine with a turbofan unit.

The results of this study demonstrated a possibility to decrease the aerodynamic drag of the stepped nacelle for an engine with a turbofan unit compared to the nacelle of a turbojet double-pass engine with the front arrangement of the fan. In the range of angles of attack $\alpha = 0...20^\circ$ the value of aerodynamic drag of the stepped nacelle for a gas turbine engine with a turbofan unit decreases by 49...55%.

The obtained results showed that the coefficient of lifting power of the stepped nacelle for a gas turbine engine with a turbofan unit increases by 24...64%. The coefficient of aerodynamic drag is lower by 18...28% compared with the aerodynamic drag coefficient of a cylindrical nacelle for a double-pass turbojet engine in the range of angles of attack $\alpha = 2...20^\circ$. Our findings indicate the prospects of using engines with a turbofan unit. The structural feature of the stepped nacelle would reduce the loss of efficient engine thrust by decreasing aerodynamic drag almost by two times and could increase fuel efficiency of the engine.

**Keywords:** stepped nacelle, aerodynamic drag, lift force, gas turbine engine, turbofan unit.

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**STUDYING THE EXCITATION OF RESONANCE OSCILLATIONS IN A ROTOR ON ISOTROPIC SUPPORTS BY A PENDULUM, A BALL, A ROLLER (p. 32–43)**

**Volodymyr Yatsun**
Central Ukrainian National Technical University, Kropyvnytskyi, Ukraine
ORCID: http://orcid.org/0000-0002-4973-3080

**Gennadiy Filimonikhin**
Central Ukrainian National Technical University, Kropyvnytskyi, Ukraine
ORCID: http://orcid.org/0000-0002-2819-0369

**Natallia Podoprygora**
Volodymyr Vynnychenko Central Ukrainian State Pedagogical University, Kropyvnytskyi, Ukraine
ORCID: http://orcid.org/0000-0002-5843-4552

**Vladimir Pirogov**
Central Ukrainian National Technical University, Kropyvnytskyi, Ukraine
ORCID: http://orcid.org/0000-0002-4973-3080

We have analytically examined the steady motion modes of the system, composed of a balanced rotor on the isotropic elastic-viscous supports, and a load (a ball, a roller, a pendulum), mounted inside the rotor, thus enabling its relative motion. In this case, the pendulum is freely mounted onto the rotor shaft, while the ball or roller rolling without slipping along a ring track centered on the longitudinal axis of the rotor.

The physical-mathematical model of the system has been described. We have recorded differential equations of the system’s motion with respect to a coordinate system rotating at a constant speed of rotation in the dimensionless form.
All steady motion modes of the system have been defined under which a load rotates at a constant angular velocity. In the coordinate system that rotates synchronously to a load, these motions are stationary.

Our theoretical study has shown that under motion steady modes:

– in the absence of resistance forces in the system, a load rotates synchronously with the rotor;
– in the presence of resistance forces in the system, a load is lagging behind the rotor.

The load jamming regimes are the one-parameter families of steady motions. Each jamming mode is characterized by the corresponding jam frequency.

Depending on the system parameters, one, two, or three possible load jam velocities may exist. If, at any rotor speed, there is only a single angular velocity of a load jam, then the corresponding motion mode (a one-parameter family) is globally asymptotically steady. If the number of jam velocities varies depending on the angular rotor speed, the asymptotically steady are:

– the only existent mode of jamming (globally asymptotically steady when there are no others);
– jamming modes with the smallest and greatest velocities.

A load jam mode with the lowest angular velocity (close to resonance) can be used in order to excite resonance oscillations in vibration machines. The highest frequency of a load jam is close to the rotor speed. This mode can be used to excite the non-resonance oscillations in vibration machines.

Keywords: passive auto-balancer, Sommerfeld effect, inertial vibration exciter, resonance vibration machine, bifurcation of motions.

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ESTABLISHING THE EFFECT OF A DECREASE IN POWER INTENSITY OF SELF-OscILLATING GRINDING IN A TUMBLING MILL WITH A REDUCTION IN AN INTRACHAMBER FILL (p. 43–52)

Kateryna Deineka
National University of Water and Environmental Engineering, Rivne, Ukraine
ORCID: http://orcid.org/0000-0001-7376-6734

Yuriy Naumenko
National University of Water and Environmental Engineering, Rivne, Ukraine
ORCID: http://orcid.org/0000-0003-3658-3087

Effect of the degree of chamber filling with the charge on efficiency of the self-oscillating grinding process in a tumbling mill has been assessed.

By using the approximate analytical and experimental method, dynamic effect of increasing the self-oscillating impact action of grinding fill on the crushed material was compared with the conventional steady-state motion mode. A significant increase in average sums of vertical components of the self-oscillating collision momenta and the average sums of power of such components with a decrease in the chamber filling degree was found. Manifestation of this effect is due to the increase in the self-oscillations swing with
decreasing filling. An increase in the maximum momentum values was found to be approximately 2.4 times at the degree of filling $\kappa = 0.45$, 3.1 times at $\kappa = 0.35$ and 5.8 times at $\kappa = 0.25$. An increase by 5.7 times in maximum values of momentum power was found at $\kappa = 0.45$, by 9.6 times at $\kappa = 0.35$ and by 45.5 times at $\kappa = 0.25$.

Technological effect of significant decrease in the specific power intensity and productivity growth of the innovative self-oscillating grinding process as compared to the characteristics of the conventional steady-state process with a reduction in the chamber filling degree have been experimentally established.

The process of grinding cement clinker with a complete filling of gaps between spherical grinding bodies with a relative size of 0.026 with particles of the crushed material was considered. It was found that during excitation of self-oscillations, power intensity of grinding decreased and productivity increased. A decrease in relative specific power intensity was observed: 27 % at $\kappa = 0.45$, 42 % at $\kappa = 0.35$ and 55 % at $\kappa = 0.25$. A 7 % increase in relative productivity was found at $\kappa = 0.45$, 30 % at $\kappa = 0.35$, and 46 % at $\kappa = 0.25$.

The effects established in operation have allowed us to predict rational parameters of the self-oscillating grinding process carried out in a tumbling mill with variation in the chamber filling degree.

**Keywords:** tumbling mill, chamber filling degree, fill self-oscillation, specific power intensity in grinding.

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CONSTRUCTION OF MATHEMATICAL MODELS OF THE STATICS OF GRAIN MEDIA CONSIDERING THE REYNOLDS EFFECT (p. 53–62)

Alexander Nanka
Kharkiv Petro Vasylenko National Technical University of Agriculture, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-4079-8822

Ivan Ivlev
Kharkiv Petro Vasylenko National Technical University of Agriculture, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-4041-9434

Vitaliy Sementsov
Kharkiv Petro Vasylenko National Technical University of Agriculture, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-4423-352X

Denis Boiko
Kharkiv Petro Vasylenko National Technical University of Agriculture, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-2231-4516

Viktor Duhanets
State Agrarian and Engineering University in Podilya, Kamianets-Podilskyi, Ukraine
ORCID: http://orcid.org/0000-0003-0262-0943

This study addresses the construction of a mathematical model, the statement of boundary-value problems on the statics of a grainy material related to the technological processes of agricultural production. A working apparatus employed to construct the model of a grainy material is the methods of equilibrium thermodynamics. We have stated the main thermodynamic equality, which makes it possible to derive a rheological ratio that establishes the connection between stresses and deformations of the granular material. The chosen grainy material is a granular medium that manifests a Reynolds effect. This effect occurs in the case of small deformations and indicates the presence of a dependence of dilation on the stress tensor deviator. In contrast to the classical methods that consider a model of continuous medium with the non-deformed and smooth grain's particles, the present work takes into consideration both a Reynolds effect and the presence of elastic deformations. The resulting rheological ratio produces the dependence for a stress tensor on the deformation tensor corresponding to ratios from the linear theory of elasticity.

For the case of an isothermal process of deformation, a boundary-value problem on the grain material's statics in the field of gravity has been stated. This paper shows the statement and solution to two particular tasks on the balance of a granular layer along the horizontal plane: in the absence of surface forces and under the action of tangent surface forces on a free surface.

The boundary problems on the equilibrium of a granular material are nonlinear in character, and the resulting solution represents a complex mathematical apparatus involving numerical methods.

The obtained models for the statics of a continuous environment precede the consideration of dynamic problems, in particular, the study of equilibrium stability.

Keywords: granular materials, equilibrium thermodynamics, Reynolds effect, horizontal grain layer, boundary-value problem, boundary conditions.

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DETERMINING MECHANICAL PROPERTIES OF A PRESSURE FIRE HOSE THE TYPE OF «T» (p. 63–70)

Oleksiy Larin
National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0002-5721-4400

Oleksandr Morozov
National Academy of the National Guard of Ukraine, Kharkiv, Ukraine

ORCID: https://orcid.org/0000-0002-1352-1783

Sergii Nazarenko
National University of Civil Defence of Ukraine, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0003-0891-0335
Experimental research into determining the mechanical properties (elastic and dissipative) of the pressure fire hose of type «T» with an inner diameter of 66 mm under conditions of static load were presented. The experiment was conducted on the experimental setup, which makes it possible to measure force and deformation. In the course of research, a series of field experiments in stretching with the sample under conditions of static loading-unloading cycles was carried out. The tests consisted of 5 cycles (modes) of loading-unloading, which were performed with a two-minute interval. Taking into consideration the experimental data, the elasticity module at stretching the material of the hose in the longitudinal (along the base) direction was determined. It was established that numerical results of mechanical properties depend on the hose loading «history», that is, in the first two load modes, elasticity modules increased and were stabilized only in the subsequent modes. The above, along with a significant reduction in residual deformations, increases the elastic properties of the fire hose material.

The results of the conducted studies showed that in the first two cycles, the material demonstrates short-term creep, which gets stabilized in modes 4–5. To generalize the experimental research, the results were approximated by corresponding trend lines. The curves of the sample deformation, which under conditions of cyclic loading-unloading formed the hysteresis loops, were determined. The hysteresis loops obtained during the study showed that in the first two modes, the loop is subjected to quantitative and qualitative changes, specifically, the slope of the hysteresis loop and its area decreases.

It was determined that a change of the properties of the material of the fire hose at consecutive loading-unloading deformation cycles is reversed, the gaps between the deformation cycles result in partial restoration of the mechanical characteristics, approximating them to the initial values. Relaxation time is from several hours to several days and even weeks, which depends heavily on the magnitude of the previous relative deformation.

**Keywords:** pressure fire hose, elasticity module, hysteresis, dissipative properties.

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CONSTRUCTION OF A THEORETICAL METHOD FOR EVALUATING THE KINEMATIC AND GEOMETRIC PARAMETERS OF LOOSENING ROLLERS IN THE CLEANERS OF RAW COTTON FROM LARGE IMPURITIES (p. 71–79)

Fazil Veliev
Azerbaijan State University
of Economics (UNEC), Baku, Azerbaijan
ORCID: http://orcid.org/0000-0002-2607-2091

The scheme of a feeder has been constructed, in which, along with conventional lobed rollers, the pinned or pinned-planked loosening rollers are used. The feeder of such a design achieves both a smooth and uniform feed of cotton to the machine and a change in the technological characteristics of raw cotton. Additional rollers lead to a change in the technological characteristics of raw cotton, thereby forming a process of intensive removal of weed impurities. The mechanics of the interaction between the working elements of feeding devices and the layer of a transported material has been investigated; in addition, the feed systems with a directed change in the technological properties of raw cotton have been selected.

It has been proven that a high cleaning effect could be achieved not only by intensifying the cleaning process, but also by a directed change in the technological properties of raw cotton while maintaining or improving the quality of the resulting product. It is obvious that the deformation that a particle undergoes in the examined scheme would be maximally possible, limiting, because the structure excludes the slippage of a product in the zones between the lobed and loosening rollers, which is not excluded in an actual design.

The technological properties of raw cotton as a cleaning material have been studied, the structural characteristics of cotton have been investigated, as well as the relation between their kinetics and cleaning processes. Relations between a structure coefficient and the magnitude of open surfaces of the raw cotton structural units have been established. The spatial characteristics of raw cotton clogging and the conditions of interaction between fiber and weeds in the
volume of clogged cotton mass have been studied. Variants of combinations of feed rollers with various structures of pinned rollers have been given, which make it possible to formulate the main ways to intensify the existing, and create new, technological processes of raw cotton cleaning.

Based on the established functional links, it becomes possible to construct new, or improve existing, structures of pinned sections in the cleaning machines ChKh-3M1. Experience shows that the application of the developed scheme of the feeder in the cleaners from large impurities produces a significant increase in the cleaning effect of the machine.

**Keywords:** fibrous material, large impurities, pinned rollers, cotton element, loosening rollers.

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