ABSTRACT AND REFERENCES

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REVEALING THE EFFECT OF DECREASED ENERGY INTENSITY OF GRINDING IN A TUMBLING MILL DURING SELF-EXCITATION OF AUTO-OSCILLATIONS OF THE INTRACHAMBER FILL (p. 6–15)

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We have investigated a possibility to perform comparative evaluation of the effectiveness of grinding process in a tumbling mill under conventional steady and self-excited auto-oscillatory flow modes of the intrachamber fill.

A mathematical model for the parameters of impact influence of the milling fill on the ground material has been constructed. We applied an analytical-experimental method to visually analyze flow patterns in the cross-section of a rotating chamber.

Numerically, by using approximate procedures, we have established a dynamic effect of increasing mean sums of vertical components in impact pulses and mean sums of power of such components at self-excitation of auto-oscillations.

The technological effect has been experimentally established of a significant decrease in energy intensity and a certain increase in productivity of the identified self-oscillatory grinding process, compared with the characteristics of conventional steady-state process. This involved a sieve analysis of the ground product, as well as measuring the fill flow turnover and the power of a drum rotation drive.

The example considered was the process of grinding cement clinker at a degree of filling the chamber with a fill of 0.45, at a relative size of ball grinding elements of 0.026, while the gaps between grinding bodies were completely filled with the ground material. It was established that at auto-oscillation self-excitation the grinding energy intensity reduces by 27.2 %, while performance increases by 6.7 %.

The effects established in this work make it possible to predict the rational parameters for a-self-oscillatory process of grinding in a tumbling mill.

Keywords: tumbling mill, intrachamber fill, impact action, auto-oscillation self-excitation, energy intensity of grinding.

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DEVELOPMENT OF THE METHOD FOR GEOMETRIC MODELING OF *S*-SHAPED CAMBER LINE OF THE PROFILE OF AN AXIAL COMPRESSOR BLADE (p. 16–23)

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The method for geometric modeling of the S-shaped camber line of the profile of an axial compressor blade, which is a compound curve formed from three sections, was developed. Each of these sections is modeled in the natural parameterization using certain laws of curvature distribution along the arc of the modeled curve. The curvature of the input section obeys the linear law and that of the other two obeys the quadratic law of distribution from the length of the proper arc. Sections are connected with ensuring the second order of smoothness which implies the equality of the values of functions, derivatives, and the curvature at the conjugation point. In contrast to existing methods, it is proposed to plot the camber line of the compressor blade profile directly in the cascade of profiles, for which the axial length, stagger angle and its chord are known. In this case, the geometric angles of flow inlet and outlet are used as source data. Giving the S-shape to the camber line of the blade profile will facilitate multi-gradient motion of working medium at the outlet of the cascade of the profile, and therefore reduce energy losses in a compressor. Based on the proposed method, we developed a software code, which, in addition to digital information on the modeled camber line of the compressor blade profile, also displays the obtained results in a graphical form on the screen of a computer monitor. The performed calculation and experimental studies proved the efficiency of the proposed method for modeling camber lines of the profiles of axial compressor blades. This method can be useful to the organizations involved in designing axial compressors for gas turbine engines.

Keywords: axial compressor, blade profile, geometric modeling, camber line, natural parameterization.

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WEIGHT-BASED OPTIMIZATION OF SANDWICH SHELLED COMPOSITE STRUCTURES WITH A HONEYCOMB FILLER (p. 24–33)

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Sandwich multi-compartment shelled structures with load-bearing skins from polymer composite materials and honeycomb filler are widely used in products of different classes of equipment. This type of structures makes it possible to realize one of the highest indicators of specific strength and stiffness at minimal weight, which is one of the determining criteria of efficiency of different units. Given the fact that this structural-power configuration contains a very large number of parameters, at the change of which the weight of the product varies significantly, so far there are no generally accepted methodologies for their optimal design. The paper addresses development of the new procedure for optimization of the sandwich shelled composite structures with a honeycomb filler. Variable parameters in the procedure are thicknesses of load-bearing skin, honeycomb filler and bands of frames, geometric parameters of honeycombs; the technological mechanics of structures is also taken into consideration. The distinctive feature of the procedure is consideration in its implementation of the technological (mounting) and operational warpage of the considered shelled systems. This article analyzes the reciprocal impact of such warpages and shows the possibility to study their dependence on load parameters for the specified amplitudes of initial deflections of the technological origin. The obtained results make it possible to determine the optimal type of the reinforcement of load-bearing composite skin under the action of axial compression, transversal pressure and bending moment in the light of technological and operational deflections of the sandwich shelled system. The developed procedure and its software have implemented all major dependences of the mechanical properties of honeycombs on their geometrical parameters and the material. This made it possible to link the process of optimal designing the structures of the considered class to the technological processes of shaping the product and possibilities for a specific production according to structural materials and nomenclature of honeycombs. Implementation of the proposed procedure for optimization of the parameters of the multi-compartment sandwich shelled composite system of the type of nose fairing of a space launch vehicle revealed its efficiency expressed in reducing the weight of the optimal product. It was shown that the application of irregular hexagonal honeycombs is a fairly effective means for reducing the weight of the system.

Keywords: sandwich shelled structures, composite load-bearing skins, honeycomb filler, optimization of parameters.

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INFLUENCE OF ELASTIC CHARACTERISTICS OF RAW COTTON ON THE MECHANICS OF FEED ROLLERS IN THE CLEANERS FROM SMALL IMPURITIES (p. 33–40)

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The effect of the elastic characteristics of raw cotton on the mechanics of the feed rollers in fine impurity cleaners depends on maturity. In cleaners from small impurities, mechanisms are used with spike rollers having an asymmetrical arrangement of the blades. The location asymmetry of the feed rollers with straight blades can be characterized by the value of the angle θ of one roller blades' lagging behind or advancing ahead of the blades of another. The relative characteristic of the value of asymmetry can be the ratio of the modulus θ to its ultimate value $k_{as}=\theta/\pi$, the change interval of which is $0 \le k_{as} \le 1$. The analysis has shown that with an increase in k_{as} in cleaners of small impurities, the quality of raw cotton cleaning worsens. A matrix method is proposed for analyzing the mechanisms of cotton processing machines, including feed rollers in fine impurity cleaners, and an algorithm for its computer implementation has been developed. With an increase in the asymmetry of the spike rollers (k_{as}), the spacer forces arising between the rollers decrease by 20–25 %, which leads to a decrease in the cleaning effect of the machine.

A feeder circuit has been developed, where, along with traditional paddle rollers, spike or spike-slatted loosening rollers are used. In the feeder of this design, it is possible to detect both a uniform feeding of the machine with cotton and a change in the technological characteristics of raw cotton. Additional rollers lead to a change in the technological characteristics of raw cotton, thereby creating a process of intensive cleaning from impurities. Obviously, the deformation undergone by a particle in the process under consideration will be maximally possible, ultimate, since the new design eliminates product slippage in the areas between the paddle and loosening rollers, which is not excluded in the actual design.

The experience gained shows that the use of the developed feeder circuit in fine impurity cleaners gives a significant increase (18 %) of the cleaning effect of the machine.

Keywords: cleaner from small impurities, feed rollers, spike rollers, blade, layer deformation, spacer efforts, quality of raw cotton cleaning, structural particles.

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CONSTRUCTION OF ALGORITHMS TO AUTOMATICALLY DETERMINE INDIVIDUAL INDICATORS WHEN ASSESSING THE SHAPE QUALITY OF CROSS-WOUND PACKAGES (p. 41–49)

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The paper addresses issues related to the selection of individual indicators to estimate the shape quality of cross-wound packages, as well as the construction of algorithms to determine them automatically.

We have developed a method for evaluating the quality of shape of cross-wound packages based on the integrated indicator. To substantiate individual indicators, an expert poll was performed to rank defects in the shape of packages according to the degree of their influence on the suitability of packages for processing at subsequent technological transitions.

To quantify each of the specified defect in the shape of a bobbin, we defined individual indicators that make it possible to quantify their impact. We have developed decisive rules and algorithms to calculate them based on the earlier obtained array of data on the coordinates of points at the bobbin's surface. We have determined a score-based estimate of the influence of each indicator, which characterizes defects in winding, on the suitability of packages for processing at subsequent technological transitions.

A comprehensive assessment of the package shape could be obtained using a method of weighted index. The mean weighted index is constructed as a dependence whose arguments are the individual quality parameters and their weighted parameters.

Given this, we derived a dependence to calculate the integrated quality indicator of the bobbin's shape. The higher the value for this indicator, the higher the quality of the controlled package.

We have assessed the applicability of the constructed integrated quality indicator to analyzing the shape of packages. To this end, we analyzed a batch of packages, which confirmed the reproducibility of the process of analysis of the package shape using the proposed integrated indicator; as well as correspondence between estimates, derived using the proposed procedure, and visual assessments.

A method for the integrated quantification of package shape makes it possible to conduct optimization experiments and to assign, based on them, such adjustable parameters for winding mechanisms that would ensure that packages of the required quality are received. The process of designing new winding equipment could be based on the necessary means to regulate a winding process.

Keywords: development of algorithms, an individual indicator, bobbin's shape, defects in winding, integrated indicator, a weighted average.

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ESTIMATION MODEL OF THE DIESEL ENGINE FUEL SYSTEM WITH AN ELECTROMECHANICAL DEVICE TO INTENSIFY FUEL SUPPLY (p. 50–59)

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The key directions of the development and improvement of the fuel supply system for internal combustion engines with ignition from compression of the fuel/air mixture were pointed out. The need for the comprehensive implementation of electromechanical principles of fuel injection control in accordance with the various conditions of diesel engines operation was proved. The relevance of further development and modernization of the hydromechanical fuel systems on the background of ever-increasing interest in their electro-controllable analogues was highlighted. The unused potential possibilities of hydromechanical fuel equipment to improve the conditions of the fuel supply process were listed. To intensify fuel injection, it was proposed to use the electromechanical device that is mounted in the fuel discharge pipeline and modifies the phase-amplitude characteristic of the wave process of propagation of a single supplying pulse between the high-pressure fuel pump and the hydromechanical nozzle. We highlighted the important aspects of the procedure for constructing the calculation model of the switchgear-type fuel system of direct action with a new device for fuel supply intensification. It was proposed to consider the fuel injection process at some stages, taking into consideration the characteristics of functioning of a particular hydraulic node of the fuel system, including the proposed technical means of intensification. The systems of differential and analytical equations that make it possible to perform mathematical modeling of the process of propagation and mutual influence of the pressure waves in the pressure-pumping tract were presented. The resulting systems make it possible to obtain characteristics of a change in hydraulic pressure in different fuel volumes, the kinematics of motion of shut-off elements in a high-pressure pump and nozzle, etc.

In the course of a comparative study, carried out on the basis of the presented calculation model, the fuel injection process for the standard and improved fuel system for a turbo-diesel, a significant improvement of the injection quality by a large number of indicators was revealed. According to the results of calculations, the existence of high-rate character of increasing and decreasing of injection pressure at the initial and final phase of the process of fuel supplyi to the cylinders of a diesel engine is observed. It was noted that the rate of pressure change can reach 170 MPa/deg, maximum, and average injection pressure increases up to 75 MPa and 30...40 MPa, respectively. Calculation studies were carried out with the employment of the numerical method of integration – the Adams interpolation method, the choice of which is caused by the necessity of obtaining consistent solutions when solving the described systems of differential equations, which belong to the category of the rigid.

Keywords: estimation model, fuel supply intensification, fuel pump, electromechanical device, pressure waves.

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ANALYSIS AND SELECTION OF THE PARAMETRIC PROFILE OF A POWERPLANT ENGINE FOR A LIGHT TRAINER AIRCRAFT (p. 59–68)

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The relevance of this study is predetermined by the improvement to the fuel efficiency of an aircraft and, as a consequence, by the reduced cost of the life cycle of an aircraft engine, which is part of a power assembly at the training aircraft the type of DART-450. We have theoretically substantiated the flight-technical and economic characteristics of a modern light aircraft for training flying personnel. Underlying the research methods is a set of parameters, characteristics and indicators, which generally reflect the technical-economic perfection of engine in the powerplant of the technical system «powerplant - airframe» at a light training aircraft.

The scientific novelty of this research is in the formation of a new parametric shape of a turboprop engine for the powerplant of a light training aircraft the type of DART-450, taking into consideration the modeling of the predefined flight cycle of an aircraft and the life cycle of the engine.

Numerical study has established that the maximum flight range of aircraft with different engines at the same takeoff weight is largely determined by a fuel reserve, rather than the efficiency of fuel consumption. Therefore, an engine with the lowest capacity has the advantage in all characteristics except for a takeoff distance, which is the shortest for an aircraft with the engine of maximum power.

The results have substantiated that in order to perform tasks related to training flight personnel it is appropriate to install the engine AI-450SR, which has the lowest life cycle cost. It is obvious that a given aircraft with the installed engine will have the lowest cost per flight hour. However, to perform reconnaissance and strike missions at an aircraft the type of DART-450, it is advisable to install the engine AI-450SR. To perform only the strike missions at an aircraft the type of DART-450, it is expedient to install the engine MS-500V-S, which has more power than the considered motors.

Keywords: trainer aircraft, life cycle, flight-technical characteristics, turboprop engine.

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MINIMIZATION OF POWER LOSSES BY TRACTION-TRANSPORTATION VEHICLES AT MOTION OVER A BEARING SURFACE THAT UNDERGOES DEFORMATION (p. 69–74)

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The paper reports the construction of a method aimed at minimizing power losses by traction-transportation vehicles at motion over a bearing surface resulting in the formation of ruts. The purpose of this study is to improve a traction efficiency coefficient for the off-road traction-transportation vehicles by determining and minimizing power losses related to forming a rut over a bearing surface under the action of a vehicle's running gear. Improving the traction-transportation vehicles efficiency coefficient, which is 55÷65 %, is a priority in the development of agricultural mechanization. Part of the losses that are associated with the structure of a vehicle is almost not controlled in the process of operation. However, those substantial losses in running systems that reach 20 % can be managed. Control over them implies adjusting the settings of running systems in the traction-transportation vehicles to the condition of a bearing surface. Specifically, in the course of the study we analyzed the magnitudes of power required to displace elements in the system «a vehicle's frame – suspension – running system – deformed bearing surface» based on determining the force and kinematic factors.

Based on direct measurements, we determine power losses when running systems form a rut over a bearing surface and when the running system's elements are displaced. It has been proposed to determine the power spent to form a rut by multiplying the share of gravity force related to the respective engine by the destruction rate of the bearing surface. Based on the derived results and an analysis of experimental data, we concluded that the proposed procedure for determining the power losses related to the formation of a rut by traction-transportation vehicles on a bearing surface makes it possible to substantiate the choice of parameters for running systems in order to improve the traction efficiency coefficient.

Keywords: traction-transportation vehicles, running system, power losses, snow cover.

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SUBSTANTIATION OF PARAMETERS FOR THE TECHNOLOGICAL PROCESS OF RESTORING MACHINE PARTS BY THE METHOD OF PLASTIC DEFORMATION (p. 75–80)

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We have studied technological processes related to the restoration of worn-out parts of agricultural machinery (plowshares, cultivator sweeps) that operate under conditions of intensive abrasive wear. We have determined the influence of operating parameters of the technological process on the quality of the restored surface of the cutting elements of machines' working bodies under conditions of regular and vibration deformation. It was noted that the restoration technologies based on vibratory oscillations make it possible to create new machining methods characterized by higher intensity: the physical-mechanical properties of the recovered parts' material, their shape and dimensions, as well as machining regimes. We have performed a strain gauge study of changes in the parameters of cutting elements in the working bodies of tillage machines, which made it possible to determine the magnitude of deformation when parts are machined. We have constructed a mathematical model of the dynamics of abrasive wear of the above-specified working bodies, which allowed us to define the patterns in the wear intensity distribution of a working body's cutting element.

Based on the derived curves of density distribution of wear magnitudes for cutting elements in the specified parts, we have defined a wear law that revealed patterns of change in the strained-stressed state of the working surface in a cutting element. We have estimated the influence of basic factors on the processes occurring in the material of parts during operation. The main factors for vibration machining of the parts' working surface have been established: the amplitude, frequency of oscillations of a machining tool, the time of hardening. The criteria for the threshold condition of parts under conditions of abrasive wear have been defined: the thickness of edge of the cutting element of parts and a change in size. We have established the positive role of compressive stresses when machining the parts' material in their wear-resistance improvement. A dependence of the magnitude of parts' wear on the following key factors has been established: their material, restoration technique, operation duration. It has been proven that the use of vibratory oscillations of the machining working body reduces the intensity of wear of parts in tillage machinery, which is important and relevant to improving the reliability of agricultural machines.

Keywords: hardening treatment, plastic deformation, vibration strengthening, residual stresses, surface roughness, wear rate.

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