ABSTRACT AND REFERENCES

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FORECASTING THE RESULTS OF HYBRID LASER-PLASMA CUTTING OF CARBON STEEL (p. 6–15)

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The prospects of hybrid laser-plasma cutting of metals have been justified, a design of an integrated plasmatron for hybrid cutting was proposed and the results of laser-plasma cutting of carbon sheet structural steels using such an integrated plasmatron were forecasted. It was shown that in order to minimize losses of laser radiation and obtain maximum penetration, it is advisable to assemble the integrated plasmatron according to a coaxial scheme with an axial arrangement of laser radiation and a minimum inclination of non-consumable electrodes (one or more), the distance from the working end of which to the axis of the laser beam should lie in the range of 2...3 mm. The diameter of the plasma-forming nozzle should lie within 2–5 mm and depth of focus under the surface of the cut sheet during hybrid cutting should be 1–2 mm. To simulate the processes of laser, plasma, and hybrid cutting, the SYSWELD software package was used which became possible due to taking into account the characteristic for cutting effect of removing sections of molten material in the cutting zone, performed by replacing the maximum overheating temperature during the calculation with the initial temperature (20 °C). The main parameters of the regimes of laser-plasma cutting were established which has made it possible to obtain minimum HAZ size with cut quality approaching that of the laser cut. At the same time, hybrid cutting requires an energy input of approximately half that of the air-plasma one. An increase in the speed of hybrid cutting by increasing the pressure and consumption of working gases makes it possible to compare energy input with the same indicator of gas laser cutting with more than a three-fold increase in the productivity of the process.

Keywords: hybrid laser-plasma cutting, integrated plasmatron, structural carbon steel, thermal cycle, heat-affected zone (HAZ), mode parameters.

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EFFECT OF THE TOOL GEOMETRY ON THE FORCE MODE OF THE COMBINED RADIAL-DIRECT EXTRUSION WITH COMPRESSION (p. 15–22)

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A possibility has been investigated to use an energy method to calculate the energy-force parameters for the cold extrusion processes involving components of complex configuration. A mathematical model has been proposed for the process of combined sequential radial-direct extrusion with compression with the presence of triangular kinematic modules. The use of the triangular kinematic modules with curvilinear and straight-line boundaries has made it possible to describe the sites of intense deformation, which correspond to the steady stage of the deformation process. It has been proposed to apply an upper estimate of the power of forces that deform a kinematic module of the triangular shape of the transition zone from the radial flow of metal to direct extrusion. This has made it possible to derive the magnitude of the reduced deformation pressure in the analytical form as a function of the geometric and technological parameters of the extrusion process. The margin of error, compared to numerical calculations without the use of the upper estimate, does not exceed 0.2–1 %. The role of an optimization parameter belongs to $\alpha \in (0, 1)$, which is responsible for the shape of the curvilinear boundary of the inner triangular kinematic module. We have derived an analytical expression for the optimal value of the α parameter and analyzed a change in the magnitude of the reduced deformation pressure at different ratios of the process geometric parameters. It has been established that the optimal values of the angle of inclination of the forming mandrel β lie between 20° and 30° for different ratios of the deformation process.

It has been justified that the use of combined sequential extrusion in the manufacture of hollow components with a flange, when compared to the application of simple deformation schemes, improves the process technological possibilities. The lack of study of the schemes of the combined radial-direct extrusion process with the compression of components of the type of sleeve, as well as the lack of recommendations for calculating the energy force parameters of the process, have been confirmed. The calculation scheme of a given process, developed on the basis of an energy method, makes it possible to predict the force mode for the steady stage under different technological parameters of the deformation process. The data acquired on the estimation of the optimal parameters for tool configuration would help devise appropriate design and technology recommendations.

Keywords: combined extrusion, upper estimate, kinematic module, energy method, deformation process, components with a flange.

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DESIGNING THE SHAPE OF THE COMBUSTION CHAMBERS FOR GAS ENGINES CONVERTED ON THE BASIS OF THE DIESEL ENGINES (p. 23–31)

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This paper describes the advantages of using gas motor fuels by vehicles, in particular liquefied petroleum gas, co MPared to conventional diesel fuel. The expediency of converting the diesel-based vehicles to gas internal combustion engines with spark ignition has been substantiated.

The ways to reduce the degree of compression of the diesel engines when they are converted into gas internal combustion engines with spark ignition have been analyzed. It has been shown it is expedient, in order to convert the diesel engines into gas internal combustion engines with spark ignition, to use the Otto thermodynamic cycle with a decrease in the geometric degree of compression. Techniques to increase the combustion chamber volume have been analyzed, as well as the expediency of applying each of them to reduce the compression degree of the diesel engines with different types of non-separated combustion chambers.

An open combustion chamber has been substantiated and designed in the form of an inverted axisymmetric «truncated cone», which made it possible to reduce the geometric compression degree only by increasing the volume of the combustion chamber in the piston. The designed shape of the combustion chamber allows the use and refinement of standard diesel pistons instead of producing special new gas pistons.

The gas internal combustion engine of model D-240-LPG has been designed and fabricated, in which the liquefied petroleum gas is fed to the inlet pipeline. The engine is equipped with a contactless electronic ignition system with a movable voltage distributor, as well as pistons with the newly designed shape of the combustion chamber. The engine has been converted based on the D-240 diesel engine.

The bench testing of the model D-240-LPG diesel engine has confirmed the expediency of converting the diesel engines to gas internal combustion engines using the Otto cycle. The tests have shown that the energy and economic parameters of the gas engine with the proposed shape of a combustion chamber correspond to the parameters of modern internal combustion engines with spark ignition.

The results obtained make it possible to optimize the technology of re-equipping the diesel engines with gas ICEs and thus reduce its cost.

Keywords: gas internal combustion engines, combustion chamber shape, liquefied petroleum gas.

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EXPERIMENTAL STUDY OF RESONANCE VIBRATIONS OF THE VIBRATORY MACHINE EXCITED BY A BALL AUTO-BALANCER (p. 32–40)

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A prototype of the universal resonance vibratory machine of wide use has been designed. The base of the vibratory machine is a vibratory table. Elastic supports make it possible for the platform of a vibratory machine, which has three degrees of freedom, to execute three main vibrational motions corresponding to three resonant frequencies. The vibration exciter is shaped in the form of a ball auto-balancer. It is assumed that the balls in the auto-balancer would get stuck at the first resonance shaft rotation velocity. The first form of resonance oscillations would be induced in this case.

The vibratory table can be used on its own. In addition, the platform can host attachments with sieves for sifting or separating a loose material, a tumbling container, molds for bricks, slabs, etc.

The experimental study has established that the proper choice of the number of plates in the supports, the number and mass of the balls could ensure almost matching dynamic characteristics of the vibratory machine in the configurations including a vibratory table and vibratory separator. At the same time, when the shaft rotates at speeds exceeding the first resonance frequency, the platform executes (almost undisturbed) vertical progressive oscillations. As the shaft's rotation speed increases, the platform's oscillation amplitude increases while the frequency practically does not change. If the shaft rotation speed exceeds the first resonance frequency by 15–20 %, the accelerations of the platform become sufficient to form a boiling layer at the surface of the platform. As the shaft's rotation speed increases, the growth of the amplitude of oscillations slows down, which is due to both the sliding of the balls along the track and the non-linearity of the supports at large deformations.

The current study has confirmed the efficiency and versatility of the designed vibratory machine, thereby providing the basis for its further improvement.

Keywords: resonance vibratory machine, vibration exciter, vibratory sieve, vibratory separator, vibratory table, resonance vibrations, Sommerfeld effect.

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COMPUTER IMPLEMENTATION OF A RECURSION ALGORITHM FOR DETERMINING THE TENSION OF A THREAD ON TECHNOLOGICAL EQUIPMENT BASED ON THE DERIVED MATHEMATICAL DEPENDENCES (p. 41–50)

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The current study of computer implementation of the algorithm for determining a thread tension on technological equipment using recursion has established the values of thread tension before a zone where fabric and knitwear form on the technological equipment. It has been proven that the magnitude of thread tension before the formation zone is influenced by the number of guides in each particular technological machine, the curvature radius of each guide, the angle at which a thread wraps the guide, the angle of a thread's radial wrap, the thread's physical-mechanical and structural characteristics. The values of the angles at which a thread wraps the guides and the radial angles at which a thread is wrapped by the surface of a guide are defined by the geometric parameters and the design of both the thread feed system on technological equipment and specific guides. As a result, it has become possible at the initial stage of designing a technological process to determine thread tension before the formation zone, depending on the equipment geometric and structural parameters and the thread physical-mechanical and structural characteristics. The difference of 2–6 % between the experimental and calculated values of the tension confirms the correctness of the assumptions made when constructing the model of interaction between the thread and the guide, taking into account its physical, mechanical and structural characteristics, and the possibility of using recursion to sequentially determine the tension in the zones of technological equipment from the entrance zone to the fabrics and knitwear formation zone. Specifically, it has been established that the thread tension increases from a zone to a zone and reaches its maximum before the formation zone. It has been shown that the increase in tension by 9–15 % leads to a disruption of the technological process and the break of the thread.

Thus, there is reason to argue about the possibility, at the initial stage of designing the technological process of fabric and knitwear production, to regulate the thread tension before the zone where fabric and knitwear form. This could be achieved by adjusting the geometric parameters and design of both the thread feed system on the technological equipment and specific guides, which would minimize the value of thread tension.

Keywords: recursion algorithm, thread tension, guiding surface, curvature radius, wrap angle.

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IMPROVING AIRCRAFT FUEL EFFICIENCY BY USING THE ADAPTIVE WING AND WINGLETS (p. 51–59)

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Improving the aircraft's fuel efficiency is one of the main requirements for prospective and modernized aircraft. This paper reports the assessment of change in aerodynamic quality resulting in the improved fuel efficiency of a long-range aircraft when using promising means to enhance aerodynamic quality. These means include the abandonment of the mechanization of wing edges and conventional controls through the use of an adaptive wing, the artificial laminarization of the flow around the elements of a glider, the application of winglets. The abandonment of conventional wing controls and wing mechanization is predetermined by the need to ensure a seamless surface of the glider elements to prevent the premature turbulization of the flow that consequently leads to a decrease in the profile drag of an aircraft. The use of winglets is aimed at reducing inductive drag. Determining a change in the aircraft's fuel efficiency would make it possible to estimate a change in the operating costs during its life cycle.

The study employed the known modular software complex «Integration 2.1». The engineering and navigational calculation was performed for a typical flight profile of a long-range aircraft. The possibility of reducing fuel consumption by up to 20 % has been shown. The largest impact on the decrease in fuel consumption is exerted by the flow laminarization on the surface of the glider elements; the reduction in fuel consumption was 17.1 %. The abandonment of mechanization and ailerons decreases fuel consumption by 3.9 %, while the abandonment of ailerons, slats, and flaps reduces fuel consumption by 0.4, 1.5, and 0.4 %, respectively. The use of spiroid winglets made it possible to reduce fuel consumption by 1.95 %.

Keywords: aerodynamic quality, fuel efficiency, adaptive wing, artificial laminarization, spiroid winglets.

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PRESSING TECHNOLOGY AND BURNING QUALITY OF SPHERICAL FUEL BRIQUETTES MADE FROM AUTUMN LEAVES (p. 60–72)

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A process has been developed to press fuel briquettes from autumn leaves. It has been shown that a spherical shape of a briquette is optimal since even dense packing of balls provides air access to each individual ball. This is especially important in the initial phase of burning when briquettes touch each other and gain a certain temperature, because of the quality of burning increases. The technology of briquette pressing has been devised. We studied dispersion of particles of dry leaves of nutwood, maple, and oak after grinding and found that particle size distribution of powders of different leaves is not the same, and their bulk density is proportional to size with the highest content.

A new method for pressing briquettes in a round closed matrix has been proposed. The difference of the method is in the fact that the process takes place at the creation of a scheme of all-embracing uniform compression with a spherical application of force and obtaining of a ball-shaped briquette in the final phase. The method makes it possible to compress ground leaves radially and evenly and thereby to ensure equal burning conditions for a briquette in a radial direction from any point on the periphery. We derived a mathematical model of the dependence of the density of dry briquettes on the bulk density of ground leaves and the degree of compression of a briquette. It has been shown that the bulk density of ground leaves (65 %) has the greatest influence on the density of dry briquettes. An increase in the bulk density of ground leaves leads to an increase in the density of dry briquettes. The influence of the degree of compression of a briquette is much smaller (35 %) but it is significant. Its increase leads to an increase in the density of dry briquettes. The density of dry briquettes was from 0.67 to 1.07 g/cm^3 during studies. We proposed a design of a round closed matrix with a variable wall thickness, which makes it possible to reduce its metal consumption and cost by 20–30 %. It has been shown that it is expedient to use spherical briquettes of leaves as an alternative environmentally friendly fuel.

Keywords: pressing technology, spherical briquette, autumn leaves, briquette density, briquette burning.

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IMPROVING THE TECHNOLOGICAL PROCESS OF RESTORING THE TILLAGE MACHINE WORKING PARTS (p. 72–77)

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An analysis of the wear of machine parts has made it possible to establish characteristic requirements for the technological process of restoring worn surfaces. Experimental studies on hardening the working surfaces of plowshares have made it possible to determine processing parameters: oscillation frequency of the processing tool of 1,400 min^{-1}, the oscillation amplitude of 0.5 mm and processing time of 20 s. Studies of the influence of conventional and vibration working on strength characteristics were carried out first on models and then on actual parts. New shares served as models. Experimental studies of these shares provided the identity of the nature of the cutting element wear. The sameness of the model and the actual part deformation degree was provided by the same conditions of the passage of the hardening processes.

The trustworthiness of the results of experimental studies was assessed in accordance with the law of theoretical distribution at a given value of confidence probability $\alpha=0.95$. The studies have established that the share width of 116–117.5 mm which has a certain effect on the share efficiency corresponds to the highest probability of 0.39.

It has been experimentally established that the degree of hardening of the shares made of L-53 steel and surfaced with sormite and vibration hardened is 1.85 times greater than in conventional processing. The studies have made it possible to determine the nature of change in the share shape and thickness of the cutting edge and choose a more efficient process of its restoration by vibration hardening. A method of recovering shares by welding strips of 45 steel with automatic hard surfacing and vibration hardening was proposed.

Keywords: deformation, wear dynamics, vibration processing, surface wear resistance.

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ESTABLISHING CHANGES IN THE TECHNICAL PARAMETERS OF NIPPLE RUBBER FOR MILKING MACHINES AND THEIR IMPACT ON OPERATIONAL CHARACTERISTICS (p. 78–87)

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Nipple rubber is an important part of a milking machine, one of its key elements. This is the only component of a milking plant that has direct contact with the surface of a cow udder. In addition, nipple rubber is the most loaded component of a milking machine. During the milking process, it is compressed and unclenched more than 400 times. In order to maximize the effect of the use of rubber, it is necessary to calculate the conditions of its use correctly, to monitor technical parameters in due time. The task of the study is to establish changes in the technical parameters of the nipple rubber of milking machines and their impact on the performance of the article.

In the course of the research, it was established that the service life of all kinds of nipple rubbers was 1,000 hours, which, if used for 8 hours a day, corresponds to 125 days or 4 months of operation. When used for 1,000 hours, the rubber stiffness varies within significant limits and an average is: for products made of silicone 2,849.61±52.23–3,343.76±51.26 N/m; made of the material of rubber mixtures – 2,597.76±78.26–2,821.43±55.24 N/m. The readiness coefficient of all products is 1. Using electron microscopy, it was possible to establish the changes of the inner surface of nipple rubber after operating for 125 days/1,000 hours and after operating for 250 days/2,000 hours. It is proved that all its basic parameters change during operation. The weight of an article changes by 8.5 %, the depth – by 37 %, the wall thickness – by 2.5 %, and the stretching length – by 27 %. The high positive correlation dependence (r=+0.939) between the nipple rubber stiffness and milking intensity was found.

The studied indicators are important for determining the performance and nipple rubber suitability for use. The conducted research offers a real possibility of taking into consideration the qualitative parameters of nipple rubber during their selection and subsequent operation.

Keywords: nipple rubber, milking machine, milking cup, control of rubber parameters, operation of nipple rubber.

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