

## ABSTRACT AND REFERENCES

## ENGINEERING TECHNOLOGICAL SYSTEMS

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**INFLUENCE OF THE HARDENING TREATMENT OF A MACHINE PARTS' MATERIAL ON WEAR-RESISTANCE (p. 6–11)****Anatolii Dudnikov**Poltava State Agrarian Academy, Poltava, Ukraine  
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Here we consider a task on improving resource of machinery and parts by employing more efficient technologies in mechanical engineering, both in the manufacture and repairing production at restoration. The main objective of present study is to substantiate and choose a more efficient method for increasing the durability and reliability of parts in piston assembly of internal combustion engines with respect to structural and materials-science factors. We have developed a technological process for the restoration of parts using a vibratory deformation whose special feature is the periodic action of a working body on the machined surface. We defined the following parameters for the technological process of vibratory hardening: deformation rate  $v=0.030$  m/s, machining tolerance  $A=2.0$  mm, a working body is the punch with inclination angle  $\beta=11^\circ$ , calibration belt height  $h=4$  mm. The conditions and duration of the examined parts operation were analyzed, as well as methods for pre-treatment, restoration techniques, and materials. An analysis of the factors that determine the wear intensity of parts' working surfaces allowed us to develop a technological process of hardening both when manufacturing in mechanical engineering and while restoring in repairing production. We have investigated structural designs of a vibratory installation in order to choose higher efficiency of the technological process. The plasticity of parts increased by 21...27 % when using vibratory oscillations. The result of the conducted set of studies and experiments is the proposed technology for the restoration of bushings in connecting rods upper heads using a method of vibratory hardening. The essence and special features of the technology imply that a worn-out working layer is compensated for by a plastic vibratory deformation with a punch dispensing a non-working layer. The use of a given technology makes it possible to obtain a surface with enhanced wear resistance. The results obtained in the course of present research could be used in machine building in order to harden the indicated parts during manufacturing.

**Keywords:** plastic deformation, vibratory machining, wear resistance, surface roughness, intensity and rate of deformation.

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We have constructed three-dimensional solid models for tool storage of the disk type (for 14 instruments) and the chain type for 32 tools, mounted onto the side surface of a machine column. We propose a 3D model of the tool positioner with a hydraulic cylinder that performs an automated tool change. The generated set of models for tooling, in combination with models of tool storage and tool positioners, represents the entire complexity and special features of design and technological preparation of machining processes at machining centers of standard size III and IV.

We have developed models and algorithms for parametric modeling of basic elements of profile cutting tools. Using the built-in

parametrizer in the APM Graph module makes it possible to implement a simpler approach to constructing models for unified profiles of tools in order to speed up the process of creating specialized application libraries. We have built analytical models for determining the rigidity of shape-forming machine nodes. Such an approach is most effective for typical circuits of double-support spindles that are equipped with various tooling. In contrast to the generally accepted procedure, the proposed analytical models (static backlogs) provide for obtaining express estimations for the optimum correlation between design parameters of spindle nodes.

Such an approach to research is defined by a tendency toward expanding technological possibilities of machining centers equipped with a constantly changing range of tooling. The emergence of new kinds of industrial tooling must be provided with methods and algorithms that interrelate the stages of constructing models of designs and assessment of their performance for the criterion of rigidity.

Under conditions of machine-tool industry, the toolset proposed in this work is aimed at improving the quality of creating the three-dimensional models of structures, their photorealistic imaging, rapid adaptation to changing conditions and operative estimation of rigidity of the shape-forming nodes. Implementation of the proposed toolset is directed towards improving the competitiveness of the designed projects.

**Keywords:** 3D modeling, technological tooling, parameterization, rendering, tool storage, auxiliary tools, rigidity.

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### INVESTIGATION OF THE PROCESS OF SMOOTHING WITH ULTRASOUND (p. 22–33)

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We studied and simulated the ultrasonic smoothing process. We carried out the analysis of the contact interaction of a tool with a part in the process of ultrasonic smoothing with a preceding gap. The analysis provides an opportunity to calculate a change in a size of a part during the treatment depending on modes. We derived the dependences of a contact area at the ultrasonic smoothness with a preceding gap. We performed the experimental study of an influence of parameters of the process of ultrasonic smoothing on parameters of a quality of a surface layer of a part. We established that in order to ensure the required roughness and accuracy, the depth of introduction should not exceed 7  $\mu\text{m}$ , especially when treated parts are made of materials with a low modulus of elasticity.

We developed an installation for experiments based on the high precision automatic screw machine 16B05AF10. All additional devices and tools were attached to the tool holder of a given machine.

We developed a technique to measure the time of contact between a tool and an article under ultrasonic smoothing with a preceding gap.

We established that deformation of micro roughnesses occurs due to a pressure of projections of micro roughnesses to cavities since we excluded shift deformation by using a solid lubricant. The fact that there was no texture on the microsection of the treated surface, although we could observe hardening of a surface, indicates that there is no shift deformation. Based on this conclusion, it is possible to disregard a non-contact wave of deformation.

We obtained analytical dependences of contact area under ultrasonic smoothness with a preceding gap on treatment parameters, namely, the treatment speed, the feed rate, the radius of an operation surface of a tool. The results of mathematical modeling and experimental data are quite close. We defined the region of optimal feed, which makes it possible to obtain surfaces with minimal roughness or microrelief.

**Keywords:** surface plastic deformation, ultrasonic smoothness, part, depth, feed, treatment speed.

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### DETERMINATION OF THE OPTIMAL PARAMETERS OF A TUBULAR BELT CONVEYOR DEPENDING ON SUCH AN ECONOMICAL (p. 34–42)

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We have investigated the influence of belt operation durability on the cost of transporting a ton of cargo. The study revealed that the longer the durability of a transporting installation, the lower the cost of transporting a cargo; the full service life of a tubular conveyor defines the service cycle of the belt. In turn, the service life of the belt is affected by the conveyor parameters, as well as the parameters of a transported cargo. We have identified significant parameters that can be altered by a designer when designing a tubular conveyor, specifically: the radius of the belt rolled into a tube and the belt motion speed. The radius and the belt motion speed can be proportionally changed relative to the specified conveyor productivity thereby altering the belt lifespan and the cost of transporting a cargo. We have established calculation dependences of the integrated economic indicator – the cost of transporting a ton of cargo, which includes the expenses for salaries, electricity, depreciation, supplies, repairs and other expenses, the mass of displaced cargo over the entire period of service cycle of the conveyor.

We have proposed a procedure for determining the optimal radius and the speed of belt motion for a designed tubular conveyor at which the average cost of transporting a ton of cargo over the entire period of conveyor operation would be minimal. Based on the dependences derived, we constructed charts of change in the average cost of transporting a cargo by conveyor depending on the radius and the speed of belt motion. Analysis of the charts allowed us to determine the optimal radius and belt speed motion for a designed conveyor at which the cost of cargo transportation is minimal. For the assigned operating conditions, given as an example, we have obtained the recommended parameters for the radius and the speed of belt motion, which grow with an increase in the conveyor productivity.

**Keywords:** tubular conveyor, cost of cargo transportation, procedure for determining, radius, belt speed.

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**DEVELOPMENT OF THE POSITIVE ENGAGEMENT CONTINUOUSLY VARIABLE TRANSMISSION DESIGN WITH THE APPLICATION OF GRAPH THEORY (p. 43–50)**

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Various designs of CVTs were explored from two points of view: analysis of the design itself and analysis of the methods and techniques, used in the process of creation of the CVT. To solve the problem of finding new designs of mechanisms, the graph transformation method was developed. It includes the following heuristic techniques: a decrease in the number of graph nodes at simplification of a design or to remove non-essential elements; a change in location

of graph edges and comparison of a new location of edges and necessary changes in a design; a search for all possible options for location of the parts that correspond to the same graph; introduction to the graph of the nodes, corresponding to the property, for implementation of which a part (a node) can be added to a design or, vice versa, can be removed from a design, and the property it implemented will be implemented by other parts.

The original design of the CVT, in which load is transmitted by gear engagement without using friction disks and flexible sections, was developed. A continuously variable of transition ratio is ensured by a gear wheel with a variable pitch. The gear wheel consists of three gear sectors, two of which are involved in meshing. The third unloaded sector performs a turn with angular velocity that is higher than velocity of rotation of the output shaft until it takes a position before coming into engagement. The CVT does not have such drawback as fluctuations of transmission ratio. Based on the analysis of the bond-graphs, efficiency was determined, which depending on velocity of the output shaft is in the range of 95...97 %. The disadvantage of the developed design is an insufficiently wide gear ratio range  $R=1.5...1.6$ , which is limited by transverse contact ratio  $\epsilon_\alpha$ .

Keywords: graph model, gear wheel with variable pitch, positive engagement CVT, method of graphs transformation.

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#### DEVELOPMENT OF CALCULATION SCHEMES FOR THE COMBINED EXTRUSION TO PREDICT THE SHAPE FORMATION OF AXISYMMETRIC PARTS WITH A FLANGE (p. 51–59)

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We have developed calculation schemes for the process of combined radial-reverse extrusion of parts with a flange. Based on the energy method, we have derived formulae for calculating the reduced pressure of deformation and a phased increase in the dimensions of a semi-finished product. Relevance of the research is based on ensuring the simplification of estimation of the application of a given deformation process to obtain parts with a required configuration. In addition, we have proved the efficiency of determining the limit of using the derived calculation scheme for ratios  $2h_1R_2/(R_2^2-R_1^2)<1$ .

We analyzed a product range manufactured at the enterprises of machine-building and instrument-making, which includes a significant number of hollow parts with flanges and branches of various shapes. It was substantiated that the use of combined extrusion schemes in the manufacture of parts of the type «a cup with a flange», when compared to employing simple deformation techniques, improves technological possibilities of the process. That is achieved through the reduction in energy costs, as well as in the number of technological transitions, and through making the shape of the parts obtained more complex. We confirmed the lack of proper studies into technologies for the implementation of combined extrusion schemes and the absence of appropriate technological recommendations. We determined the power mode of extrusion that corresponds to reality and estimated a possibility to control the outflow of metal at deformation. A study was conducted into the process of cold combined extrusion of hollow parts with a flange; the calculation schemes of the process were proposed. We modeled the process of combined extrusion based on the experimental-analytical method and established patterns in the shape formation of parts with a flange due to the geometrical and technological parameters. Data were acquired on the phased form change in a semi-finished product in the process of deformation. It was confirmed that the proposed models simplify the development of technological recommendations to determine the power mode of extrusion and to control the outflow of metal during deformation process.

**Keywords:** combined extrusion, parts with a flange, phased form change, process of deformation.

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### SPECIFYING THE PROCEDURE FOR DESIGNING THE ELEMENTS OF THE CRANKSHAFT SYSTEM FOR A SMALL HIGH-SPEED DIESEL ENGINE (p. 60–66)

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Development of the model range of high-speed inline small diesels by designing a six-cylinder version based on the already adjusted four-cylinder one, entails a decrease in the rigidity of the crankshaft. This in turn reduces its reliability due to the enhanced impact of torsional vibrations. To assess this impact, we performed a series of calculations for determining the amplitudes and tangential stresses in the crankshaft system.

In order to reduce maximum values of angular amplitudes and tangential stresses, the most expedient is to use a silicone damper for absorbing the torsional vibrations. When designing it, one must take into consideration such structural parameters as the efficiency of damping and overall dimensions.

In the course of this study, we performed the estimation of torsional vibrations using the new simple method for calculating the real amplitudes and mechanical stresses of torsional vibrations in the crankshaft of the internal combustion engine. A given method is based on the numerical solution to the high-level system of nonlinear differential equations in the form of a model in the state space.

In addition, in the process of determining the initial data, we proposed a formula for determining the rigidity of the crank shaft. The improvement implied the introduction of a coefficient that approximates values obtained by calculation to those derived experimentally. This adjustment applies only for the crankshafts with similar parameters of cranks.

During our study, we selected criteria that are used when designing the elements of the crankshaft system. That made it possible to determine, based on these criteria, the following structural characteristics for the designed diesel engine: the mass moment of inertia of the damper flywheel, the mass moment of inertia of the damper casing, as well as the diameter and rigidity of the crankshaft front end.

Our research helps create an algorithmic support that can be employed when designing diesel engines with similar geometrical dimensions and forcing in the future.

**Keywords:** high-speed small diesel engine, crankshaft, torsional vibrations, silicone damper, design criteria, amplitude, tangential stresses.

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## DESIGNING THE FLOW-THROUGH PARTS OF DISTRIBUTION SYSTEMS FOR THE PRG SERIES PLANETARY HYDRAULIC MOTORS (p. 67–77)

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Improved efficiency of using the self-propelled machines is defined by the existence of hydraulic machines for the actuators of active working elements and running systems. Hydraulic drives of self-propelled machines exploit planetary hydraulic motors. The advantage of these hydraulic motors is a possibility to install them directly to the actuators of drilling machines, conveyors, winches, motor-wheels, etc. The basic node, limiting the work of a planetary hydraulic motor, is the distribution system. A distribution system creates a rotating hydraulic field that enables the working cycle of a planetary hydraulic motor. Therefore, improvement of the structural parameters of the distribution system is an important field of research aimed at improving the output characteristics of the planetary hydraulic motor. We have developed a design diagram and proposed a mathematical apparatus which make it possible to explore the influence of structural parameters of the distribution system on the output characteristics of the planetary hydraulic motor. The study we conducted has established that the synchronicity of a hydraulic field rotation depends on the number of working chambers and is characterized by a kinematic diagram of the distribution system. Dependence of change in the total area of the flow section in the distribution systems for different kinematic circuits is cyclical in character with a fluctuation amplitude dependent on the kinematic diagram. We have substantiated rational kinematic diagram of the distribution systems. We identified a zone where hydraulic losses are formed. The losses are caused by local resistances, when the working fluid passes along the distributing windows of the sleeve valve and the distributor. We have developed an algorithm for designing the flow-through parts. It enables the application of rational kinematic diagrams of the distribution system in order to improve the output characteristics of the planetary hydraulic motor.

**Keywords:** planetary hydraulic motor, distribution system, structural parameters, flow-through parts, throughput capacity.

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**INFLUENCE OF STORAGE DURATION AND DENSITY OF RAW COTTON ON THE MECHANICS OF THE INTERACTION PROCESS BETWEEN FEEDING ROLLERS IN THE CLEANERS OF LARGE IMPURITIES (p. 78–83)**

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We have examined influence of storage duration and the density of cotton in bale on the adhesion between impurities and cotton. We found the effect of raw cotton storage, as well as the fiber, in a compacted state, which contributes to the more rapid penetration of weedy particles into the material. For raw cotton stored in a bale for 1 month, with a density of 150–200 kg/m<sup>3</sup>, the elements of large impurities interacted with fiber at an effort of 63–91 sN/g for leaf, stem, and bract; for small impurities – 714–1,000 sN/g. Upon cleaning, when only small impurities remain, this effort increased to 714–1,053 sN/g. These data correspond to the raw cotton of grade I. For grade III, the force of adhesion is slightly different: for large impurities – 76–96 sN/g, for small impurities – 714–1,267 sN/g; after cleaning – 857–947 sN/g.

In a three-month storage in bale at a density of 250–300 kg/m<sup>3</sup>, the degree of interaction between impurities and fiber for the cotton of grade I was 109–137 sN/g, for grade III – 103–175 sN/g for large impurities. We have developed a technological mode that determines the multiplicity of cleaning; we also proposed a method for determining the spreading efforts that act on the feeding rollers and which are one of the most important factors for the process energy intensity. We analyzed the mechanics of the interaction process between a feeding roller blades and the transported layer of raw cotton. The results of research allow us to choose the required mode in the process of raw cotton cleaning from weedy impurities.

**Keywords:** raw cotton, bale of cotton, roller, bale density, adhesion, weedy impurities, cleaning, fibers.

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