ABSTRACT AND REFERENCES

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ANALYTICAL METHOD FOR COMPILING AND APPLYING A BALLAST MAP FOR THE TRACTION UNIT PE2U (p. 6–14)

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Under practical operation, electric locomotive traction units of series PE2U quite often require, especially in recent decades, various kinds of repair, necessitating the restoration of fleet of these machines that are rather worn-out. That changes the most important indicator in the work of the machine – the distribution of masses; the resulting imbalance of the machine can reach 30 %. Further operation of such a locomotive leads to a decrease in its traction by 40–100 kN, shortens the service life of the undercarriage by 8–10 years on average, as well as requires that the speed of the machine during operation should be reduced by 10–15 km/h.

Given the lack of an appropriate regulatory framework and of recommendations in the specialized literature, such balancing operations are actually performed iteratively, with an arbitrary arrangement of ballast elements, which often delays the duration of operations and leads to their poor quality.

One of the possible solutions to resolve this issue is the development and implementation of a special theoretical method that would make it possible to analytically substantiate the proposed structural-technological solutions related to the arrangement of a ballast at the electric locomotive traction unit PE2U. In this case, the ballast is composed of individual small-size elements that are stacked in rows into existing structural cavities in a bearing frame. The result is a compiled so-called individual ballast map for each machine.

The proposed approach includes two stages of calculations and makes it possible to not only obtain practically acceptable ballast location diagrams, but to also significantly reduce the number of weighings required for the machine. The approach has been tested on several machines at electric locomotive traction units of PE2U over 2010–2012 and could be officially used in the specialized regulatory documentation. Its practical error does not exceed 3 % and is mainly predetermined by technological factors.

Keywords: locomotive, electric locomotive, traction unit PE2U, machine balancing, ballast map

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INTENSIFICATION OF THE PROCESS OF DOSING BULK CONCENTRATED FEEDS BY SIEVE HOPPER (p. 14–20)

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The study addresses the development and substantiation of parameters for the hopper that is installed in the technological process for producing concentrated bulk feeds. The structures of hoppers, the ways of improving productivity and the quality of their operation were analyzed and the prospects for the development of this direction were determined. The effectiveness of dosing was enhanced by the modernization of the sieve hopper with a rarefied discharge of dosed material due to the use of the openings in the form of a five-petal epicycloid.

To determine the rational design and kinematic parameters of the modernized sieve hopper, mathematical modeling of the movement of bulk medium was carried out, conditions of the process were selected and final mathematical expressions were found. In addition to the parameters of the moving hopper in expressions and during the experiments, the properties of bulk feeds were explored. The ranges of variation in the sizes of the holes of the bottom and upper sieves were determined, the amplitude and frequency of their oscillations, which are the important parameters of the process of dosing bulk feed on the proposed hopper.

The modeling results were proved by the conducted experimental research. The dependences of the performance of a sieve hopper on its design and kinematic parameters in its basic and upgraded versions were experimentally established. The adequacy of the developed modeling was proved by admissible discrepancy of the results with the experimental results.

Using these dependences on the condition of maximum effectiveness of dosing, the ranges of variation in the performance of the upgraded hopper, which amounted to 0.75...2.6 t/h were determined. It was established that the use of sieves with activators enhances the performance of the hopper by 15...44.4 %. The adequacy of the developed mathematical modeling was proved by admissible discrepancy of the results and experiments, which did not exceed 5 %.

The result of our research is the devised procedure for studying the sieve-type hoppers, which implies a possibility to explore the impact of shapes and sizes of openings on the effectiveness of dosing bulk feeds.

Keywords: hopper, concentrated feed, vibratory sieve, uniformity of dosing, sifting activators, diameter of openings, oscillation amplitude.

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DETERMINING THE MOTION CHARACTER OF LOOSE MATERIALS IN THE SYSTEM OF CONTINUOUS ACTION «HOPPER – RECIPROCATING PLATE FEEDER» (p. 21–28)

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This paper reports methods for modeling the movement of bulk material in dispensing equipment of continuous action. It was established that modeling the pulsations and fractures in the flow of bulk material can be performed using the discrete element method. On its basis, a model has been constructed of the system consisting of a cylindrically-conically-shaped hopper and a reciprocating plate feeder of continuous action. Particles of bulk material are represented in the form of spheres with a constant radius between which the forces of friction and elasticity act.

The result of modeling is the determined movement speed and position of each particle in the transverse section of the system «hopper – reciprocating plate feeder» and at the surface of a feeder's plate. The regions have been defined with typical movement speeds of bulk material, as well as the system's performance. The maximum speed of the particles is observed in the region of the outlet branch pipe of the hopper, along its central axis, and in the outer layer of the material that is found at the surface of a plate. Minimum speeds are observed near the walls of the hopper and at the center of a plate. It was established that in the course of a feeder's operation there is an increase in the radius of the cone of bulk material that resides at the surface of a plate, by 15.2 %.

The system was experimentally studied using a testing bench, consisting of a conical-cylindrical hopper, a reciprocating plate feeder of continuous operation, and a data acquisition system. The feeder's performance under a steady operation mode has been determined. It was established that it is pulsating in character that matches the results from analytical calculations based on the constructed model. The conclusion about correspondence of the obtained results has been drawn based on the equality of variances in performance, which was checked using a Fisher criterion.

The resulting model could be applied in order to analyze steady operational modes of reciprocating plate feeders of continuous action for the case when bulk material arrives to the center of a plate.

Keywords: cylindrical-conical hopper, reciprocating plate feeder, bulk material, discrete element method, particles interaction.

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DEVELOPMENT OF TRENCHLESS TECHNOLOGY OF RECONSTRUCTION OF «PULLING PIG P» PIPELINE COMMUNICATIONS (p. 28–38)

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The technology of trenchless reconstruction of pipeline communications has been developed by pulling a new polyethylene pipeline into a worn-out steel traction by the pig. The pig moves under the pressure of air supplied into the trans-pig space by the compressor.

Mathematical and CFD modeling of the process of pulling the pipeline by a pig is performed. Formulas for calculating the resistance forces acting on the moving system, the pressure at the compressor outlet, at which the pig will extend a new polyethylene pipeline with the entire length of the reconstructed worn steel pipeline, are derived. The resistance forces acting on the moving system on horizontal sections of the route are: the force of mechanical friction of the pig cuffs against the walls of the steel pipeline; friction force of polyethylene pipe to steel; friction force of the polyethylene pipe in the ring cuffs of the sealing system.

The results of CFD simulations are visualized in the post-processor of the Ansys Fluent software package by drawing

flow lines, speed vectors, pressure fields on the contours and in the longitudinal section of the annular and rotary space. The exact values of speed, pressure at various points of the annular and rotary space are determined. The structure of the air flow in the trans-pig and annular space is investigated. Places slowing down and accelerating the flow of air, falling and rising pressure are identified. The pressure losses in the annular space are determined.

After performing experimental tests, it is found that the developed «Pulling pig P» technology can be used for the reconstruction of pipeline communications. According to the results of experimental measurements, graphs of changes in air pressure at the beginning of the pipeline in time are constructed when the pulling a polyethylene pipe into worn-out steel by the pig. The pressure at the beginning of the pipeline before the start of pulling increases, due to the force of static friction. After the start of pulling, the pressure decreases by a small amount, and during pulling, its slight increase occurs. The graphs of dependence of the pulling speed on the air volume flow and on the length of the pulled section of the polyethylene pipe are constructed. At the initial stage, the pulling speed increases dramatically and after such growth stabilizes.

Keywords: pressure loss, volume flow, friction force, traction force, pulling speed.

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DEVELOPMENT OF A NEW PROCESS FOR EXPANDING STEPPED TAPERED RINGS (p. 39–46)

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A new method for expanding large-size tapered rings with a stepped profile has been considered. The proposed method consists in expanding the blank with the help of a stepped die. A procedure for conducting studies by the method of finite elements was proposed. The procedure is intended to determine dependences of the stress-strain state and shape change during the expanding process by means of a stepped die. Variable parameters included relative height of the stepped blank protrusion which varied in the range of 2.2...2.5. Based on the finite-element modeling, distribution of deformation rate in the forging section after expanding with the help of a stepped die was established. The forging taper formed by expanding in this way was determined. Results of finite-element modeling were verified by experimental studies with lead and steel specimens. A procedure for conducting experimental studies

was proposed. The finite-element modeling has allowed us to establish that expanding with the help of a stepped die results in a tapered forging shape. This is explained by the fact that when the wall is reduced, tangential deformation of the annular blank in the wall zone is larger than that in the protrusion zone because of different height of the stepped blank. The results of finite-element modeling were confirmed by experiments in laboratory conditions with lead and steel specimens. Increase in diameter of the blank protrusion leads to an increase in rate of the protrusion deformation which causes an increase in diameter of the protrusion bore. Analysis of macrostructure of the annular forging with a tapered stepped profile has made it possible to establish that when the stepped blank is shaped with the help of a stepped die, metal fibers repeat the target part contour which prevents their cutting during machining. The study has established that expanding of stepped tapered blanks is realizable. It expands technological potentials of the process of expanding large-sized forgings.

Keywords: stepped tapered ring, expanding, stepped die, distribution of deformations, shape change, taper.

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DEFINITION OF ENERGY EFFICIENT LAW OF MECHANICAL IMPACT IN VIBRATORY STRESS RELIEF OF METAL PARTS (p. 47–54)

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The study is based on the method of vibratory stress relief, which is used to reduce the residual stresses in cast and welded parts, and is an alternative to thermal deformation methods, because it is unpretentious to the mass, shape and dimensions of the part.

Vibratory stress relief is usually carried out using unbalance electromechanical systems, which are simple in design of the power section and control system. In such systems, processing occurs simultaneously at only one resonant frequency. The workpiece, as a rule, is characterized by several resonant frequencies that have a tendency to shift to the low-frequency region during the implementation of the vibration effect. The technological process of sequential processing at each variable resonant frequency is rather time-consuming and not efficient in terms of the cost of electrical energy. In order to reduce the cost of time and energy, this study proposes the use of the most advanced processing methods at several resonant frequencies. Based on the algorithms of sequential vibratory stress relief at several resonant frequencies of the part and their changes towards low ones, it was proposed to carry out processing by a polyharmonic perturbing force in a limited frequency band. This effect has a bandwidth that contains all the possible frequencies of the part where vibratory stress relief occurs. Such an effect can be realized with the help of an electrodynamic linear motor as an executive body. The advantage of an electrodynamic linear motor is the proportionality of the generated force to the current supplied to the moving conductor and its repetition in form.

By means of mathematical modeling for the selected example, it was found that narrowing the frequency range in the low-frequency region by 5 times reduces energy costs by more than 4,000 times as compared with the broadband law of mechanical action on a part. A theoretically determined energy-efficient law can be software-implemented in control systems for electrodynamic linear motors that implement vibratory stress relief.

Keywords: vibratory stress relief, resonant frequency, energy efficient law, amplitude spectrum, electrodynamic linear motor.

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CONTOUR MILLING PROGRAMMING TECHNOLOGY FOR VIRTUAL BASING ON A CNC MACHINE (p. 54–60)

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A new technique and an application program for automating the programming of the milling operation during virtual basing of the workpiece on the CNC machine table is presented, when precise installation of the workpiece along the coordinate axes of the machine is difficult. The solution of such a scientific and technical problem allows you to perform contour milling of parts with their arbitrary location on the table of the CNC machine with guaranteed alignment of the allowance along the forming path. The method involves the sequential implementation of three stages with parallel use of the created application program. At the first stage, an electronic copy of the part drawing is prepared, which contains the selected part and workpiece contour highlighted in different colors. Thus, the scanning provides automatic creation of digital two-dimensional arrays of geometric images necessary to solve the problem. At the second stage, the coordinates of three points of the workpiece measured by the probe on the machine are entered into the created program. Based on the entered data, the created program solves the problem of alignment of the allowance using the Gauss-Seidel method using the Hausdorff dimension. This approach allows us to obtain a quantitative estimate of the similarity of polygonal objects, which is necessary to solve the problem of minimax location of the allowance. The task is to determine the correction of the control program for two linear coordinates and one angular around the center of mass of the workpiece. At the third stage, the correction values calculated in the program are entered into the CNC rack of the machine and the processing of the contour begins. The proposed technique and the created application program were tested when processing the part contour on a VF-3 HAAS milling machine. Practical testing has shown the effectiveness of the technique, which is to ensure milling without overloading the tool and reduce the processing time during virtual basing of the workpiece.

Keywords: virtual basing, contour milling on a CNC machine, preparation of a control program.

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IMPROVING EFFICIENCY OF MACHINING THE GEOMETRICALLY COMPLEX SHAPED SURFACES BY MILLING WITH A FIXED SHIFT OF THE CUTTING EDGE (p. 60–70)

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In order to improve efficiency of machining by milling geometrically complex shaped surfaces, mainly the methods

related to improvement of properties of the tool material, change of composition and properties of the tool surface layer, application of thin film coatings, reduction of roughness of the working surfaces and improvement of operating conditions of the tool using lubricant-cooling media are mainly used.

Proceeding from the above stated, scientifically grounded technical and technological solutions consisting in development of a new highly effective method for machining geometrically complex shaped surfaces by means of disk rotary cutters with a reciprocatively rocking feed motion were studied and set forth in this work. This machining method can increase the period of durability of tools by 1.7 times and milling performance by 1.6 times by means of a fixed kinematic shift of the cutting edge relative to the machined surface.

A mathematical apparatus of the method of milling with a fixed shift of the cutting edge was proposed. Analysis of this method with the help of numerical functions has enabled establishment of analytical dependences for determining thickness and volume of a unit cut-off layer. Thickness of the cut-off layer is mainly affected by feed per tooth, Sz, and the angle υ influences its volume which determines normal cutting conditions. A model of distribution of heat flows in the cutting wedge for the method of milling with a reciprocatively rocking feed motion taking into consideration the amplitude of rocking motion of the workpiece was studied. A temperature decrease to 330.2...395.5 °C was established, that is by 80.6...181.6 °C for the stamp steel 9CRSI and to 193.8...285 °C, that is, by 56.6...120.2 °C for steel 45 compared to conventional milling. It was found that total length of the cutting edge increases 2.4 times with 1.5 times temperature decrease.

Keywords: milling, kinematic cutting scheme, cutting tool, cutting edge, geometrically complex shaped surface, CNC.

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