ABSTRACT AND REFERENCES
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CONTROLLING THE PRESSURE FORCE TO OBTAIN A BETTER QUALITY OF ALUMINUM 6061 FRICTION STIR WELDED JOINT (p. 6–10)

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Friction stir welding (FSW) is one of the mechanical joint methods that need no filler metal. The heat is obtained from the friction force between the base metal and friction tool. The FSW is proposed by The Welding Institute – TWI in 1991 which is hoped to overcome problems to weld metals with low weldability. Parameters of FSW determine the quality of the joint and in this paper the normal force as an independent parameter varied at 13,000, 14,000 and 15,000 N. The rotation and feeding speeds are controlled at 1,092 RPM and 200 mm/min respectively. From the experimental results, it is found that 15,000 N provided the strongest joint (specimen 1). The highest heat input was claimed to cause a better joint. This high heat input provides enough weld nugget and time for the aluminum to grow its grains, which in turn increase the tensile strength of the FSW joint.

However, from the average values and the trend line it cannot be assumed that the greater pressure force always produces higher tensile strength. The tensile strengths were almost at the same level (115.44±1.56 MPa) meanwhile the calculated heat input is linearly dependent on the pressure force: 73.59, 79.25 and 84.91 J/mm for pressure forces equal to 13,000, 14,000 and 15,000 respectively. The recorded temperature, which indicates heat input showed the same trend with tensile strength, it was on the same level, those are: 491.55±2.22 °C. There must be some aspects which were not taken into account in the heat input mathematical model. Or maybe, the assumption of higher heat input is not always accomplished by the higher pressure force. Based on the literature, it is found that the yield strength is mitigated at a higher temperature. This lower yield strength decreases the friction force for a constant normal force which in turn causes declining heat input which contradicts the previous assumption.

Another literature that inspected the coefficient of friction as a function of temperature showed that the coefficient is altered due to temperature.

And finally, the higher normal force does not mean a stronger joint can be produced by means of Friction Stir Welding.

Keywords: Friction stir welding, normal force, friction force, coefficient of friction, tensile strength.

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DEVELOPMENT OF A TECHNOLOGY FOR THE SURFACE STRENGTHENING OF BARREL CHANNELS IN THE LARGE-CALIBER ARTILLERY GUNS (p. 11–18)

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High temperatures and exposure to the chemical effect of powder gases that accompany artillery salvos actively destroy the surface layer of a barrel channel material. This disrupts the geometry of a barrel channel, thereby reducing the accuracy of an artillery gun aimed firing. We have proposed a technology of surface

plastic deformation of the channel inner surface for strengthening the barrels of large caliber artillery and tank guns. The strengthening implies the cold-work hardening of a barrel channel metal with spherical deforming bodies that are mounted onto a massive cylindrical reinforcer. During machining, the reinforcer is driven into a rolling motion over the treated inner surface of a barrel channel and moves along the geometrical center of the machined gun's barrel. As a result of such a hardening treatment, the residual compression stresses form in the thickness of a barrel channel material, thereby improving its surface microhardness. That contributes to an increase in the resistance of a barrel channel material against its burn-out and wear during artillery salvos.

The reinforcing equipment for the implementation of such a treatment includes a reinforcer in the form of a cylinder with deforming bodies, an electric motor of the drive, and a mechanism to transfer the torque from the motor shaft to the reinforcer. During strengthening treatment, the set-up moves along a gun barrel channel, cold-working its material. The ensured hardening thickness is 0.15–0.20 mm.

The hardened surface layer of a gun barrel material, due to the heightened microhardness, firmly opposes the formation of operational microcracks within it. The compression stresses, formed in the thickness of a barrel channel metal, resist the temperature propagation of microcracks. Owing to this, the resistance of the hardened barrel metal against operational destruction increases, thereby improving the reliability and durability of costly artillery armament.

Keywords: artillery gun, gun barrel channel, high-temperature burnout, wear, surface hardening, microhardness improvement.

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APPLICATION OF INDEX ESTIMATES FOR IMPROVING ACCURACY DURING SELECTION OF MACHINE OPERATORS (p. 18–26)

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The methods proposed in this paper for calculating index ratings when selecting machine operators provide greater accuracy than the selection based on expert estimates and integrated indicators for groups of expert estimates.

Index estimates are calculated based on the algorithm that combines self-assessments and expert estimates into the Quality index of professional competence of a machine operator (I_{PC}) while expert estimates and standardized assessments are combined into the Quality index of a machine operator training (I_{QT}). The proposed methods for computing the index estimates comprehensively characterize an element in the functioning of the social subsystem in the system «Machine operator – Machine with numerical control – Part manufacturing program», OMMP.

Index estimates characterize the degree of coherence/imbalance among self-assessments and expert estimates, as well as expert estimates and standardized assessments, as well as systemic interrelations between a machine operator and elements of the social, technical, and information subsystems within an open system.

Advantages of index-based selection of machine operators over that based on expert estimates were assessed by comparing the two series of rankings in a list of names. The series of rankings were obtained using such methods as linear convolution and multiplicative convolution. It has been proven that the selection of machine operators using linear convolution is considerably more accurate if carried out based on the index estimates, when compared with expert estimates. It is appropriate to use a binary search method to select machine operators in accordance with a customer's requirements.

Keywords: self-assessments, expert estimates, standardized estimates, objective assessments, index estimates.

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RESEARCHING THE INTERACTION OF DIFFERENT PRINTED MATERIALS TYPES WITH LIQUIDS (p. 26–34)

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The interaction of papers and films with the testing liquid was researched. Measurements of the contact angle were taken depending on the substrate and its morphology. Linear dimensions of the paper were determined while wetting the samples with distilled water, also the dynamics of water penetration into the paper's structure was researched. The quality control of liquid absorption by the paper was conducted. The research of mentioned parameters is required while creating absolutely new materials to be a printing surface. These measurements allow determining the possibility of current existing materials use in a particular technological process of printing.

The relationship between printed surface wetting and its technical-printing parameters is determined. The interaction of the «printed surface – liquid» system is predicted. The component pairs mutual influence onto the printing process is determined. The ability of materials to be used as the printing surface in the inkjet printing and their ability of being used in the offset printing with the printing plate's dampening are researched. The possibility to ensure the normalized color difference of imprints was taken into account.

The stated hypothesis was checked for correspondence to the mathematical-statistical certainty statements. The correlation values and correlation ties were calculated. It was mathematically confirmed that the greatest water repellency depends on the porosity and surface liquid volume values. Also, it more significantly depends on the paper's wetting if comparing to surface liquid volume value. So, while selecting the printed surface, it is necessary to take into account the substrate's porosity, and its liquid wetting degree. The data obtained while measuring the set parameters allows making a decision about printing on the material via several printing types. The research results allow setting the stability of the technological process and getting the reproductions with the normalized values of optical density and with the color difference no more than 5 units.

Keywords: printed surface, printed product, inkjet printing, contact angle, surface wetting.

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IMPROVING STEEL MELTING INTENSITY IN THE PROCESS OF ELECTROSMELTING FROM WASTE AND PELLETS (HBI) (p. 35–42)

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The paper addresses the issue on improving the intensity of melting in the production of steels using hot briquetted iron (HBI) in the charge that mostly consists of metal waste. An analysis has been performed into the features of melting that uses charge of complex composition. To ensure the boiling of metal bath, it is recommended to introduce to the bath carbon-containing raw materials in the form of steel waste in the amount exceeding 80 %. It was established that applying HBI almost does not reduce the yield of usable metal due to a high content of metal waste that makes up the charge.

At the same time, the paper analyses the role of silicon and manganese oxidation process in the refining of liquid steel at melting the alloy wastes used as charge materials in an electric arc furnace. The dependences of equilibrium concentrations of oxygen and silicon at different temperatures in the system Fe–Si–O have been given. In addition, the dependence diagram of manganese oxidation products in a liquid iron on the temperature and concentration of manganese in the alloy MnO–FeO has been constructed. The equilibrium concentrations of oxygen and silicon with carbon deoxidizing capability have been defined, in the field of liquid silicates and in the field of solid SiO_2.

The high-quality silicon and manganese oxidation when smelting steel made from metal waste and hot briquetted iron (HBI) contributes to the fullest refining of liquid steel through the phases metal-slag or metal-gas.

It has been shown that the content of silicon during electrical steel refining drops to traces. Thus, when using metal waste and pellets as charge in the steel-making process, a silicon oxidation reaction does not reach equilibrium. If a sour process is performed, then the oxidation of silicon reaches equilibrium and, under certain conditions for melting the charge under the influence of heat from an electric arc, there may occur a significant reduction of silicon that takes place at a higher temperature (a silicon-reducing process). The basic process of melting the charge from metal waste and hot briquetted iron in an electric arc furnace has been recommended. In this case, the reducing period of melting is aimed at metal deoxidation, sulphur removal, at bringing the chemical composition of steel to the preset composition, at controlling the process temperature. All these tasks are solved in parallel throughout the entire reduction period. The complete removal of oxidative slag was followed by adding to the furnace of slag-forming mixes together with deoxidizing agents, that is the new slag (carbide or white) was introduced.

A rise in the furnace bath temperature decreases the equilibrium constant of manganese. Therefore, in the absence of ferromanganese additives in the bath in the process of melting refinement, the behavior of manganese in the bath can be an indicator for the metal temperature.

Keywords: hot briquetted iron, electric arc furnace, melting intensity, mechanical properties of steel, alloyed waste.

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MODELING THE TECHOLOGICAL PROCESS OF PIPE FORGING WITHOUT A MANDREL (p. 42–48)

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A broaching technique for thick-walled pipes has been investigated. The proposed technique implies the deformation of a hollow workpiece without a mandrel. The procedure has been devised to conduct theoretical studies using FEM. The procedure is aimed at determining the thermal, stressed state and a shape change in the workpiece while forging pipes without the use of a mandrel. The variables applied were the internal diameter of a hollow workpiece, which ranged in the interval of 0.30; 0.55; 0.80. Based on the finite-element modeling, the following was established: the distribution of temperatures and intensity of logarithmic deformations within the volume of a pipe after broaching without the use of a mandrel. The diameter of a pipe's hole has been determined, which is formed at broaching when applying a given technique. The dependences of intensity of lengthening and thickening of the wall of a pipe have been established. A special indicator was devised to estimate the elongation rate of a pipe. It was determined that increasing the inner diameter increases the lengthening of a pipe and decreases the intensity of the hole forging. The common dependence for the simulated broaching schemes is that the magnitude of elongation of a hollow workpiece changes insignificantly for different degrees of reductions at constant relative sizes of a pipe. It has made it possible to establish a recommended feed in order to increase the elongation of a hollow forging and to decrease the degree of closing a hole. The rational feed shall be (0.05...0.15)*D*. The results from the finite element modeling were verified by experimental study using lead samples. An experimental modeling procedure has been devised. It was established that at an inside diameter of the workpiece of (0.5...0.6)*D* one observes a maximum of the wall thickening. It was established that the results for a workpiece shape change, obtained from a theoretical study using FEM, exceeded those acquired experimentally by 9.14 %. The validity of results from theoretical modelling is confirmed by data from experiments on decreasing the internal diameter of the pipe. Difference between the theoretical and experimental results amounts to 9...12 %. The established patterns make it possible to determine the resulting diameter of a pipe's hole. It was found based on the results from modeling that it is impossible to broach pipe workpieces without a mandrel. This technique extends the possibilities of technological processes aimed at manufacturing pipe workpieces.

Keywords: thick-walled pipe, broaching without a mandrel, forging, forge a hole, workpiece lengthening, FEM, thermal state, strained state.

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DESIGN OF WORKING BODIES FOR TILLAGE TOOLS USING THE METHODS OF BIONICS (p. 49–54)

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This paper reports a procedure for borrowing the principles of body structure of sea creatures to design tillage tools. Work of tillage tools under conditions of low soil consolidation necessitates improving the streamlining, that is, the crushing and loosening must be ensured not by undercutting, but by cutting with sliding. The adopted criterion for design rationality is the magnitude of traction resistance. The analytical part of the general procedure makes it possible to calculate its magnitude. The novelty is the fact that the overall traction resistance is split into components whose magnitudes is calculated separately. This element is important because it makes it possible to proceed, during calculation, to rectilinear infinitesimal sections of the perimeter and to separately adapt the components of a cutting perimeter to the tilled environment.

The following elements in the identification of a biological analog and a technical prototype are given: frontal part (snout) → chisel-shaped ripper's tip; lateral fins → pointed wings; vertical keel fin → crumbler. The result from identifying a biological analog and a technical prototype is the derived regression model of the cutting perimeter and working surface.

Based on the results of analytical studies, a mathematical model has been proposed of the interaction between a working body and soil. Special feature of the analytical model of interaction with a soil environment is that it is based on the conditions for unsupported cutting. The main provisions of the performed analytical studies have been confirmed by results from model experimental research, which showed a decrease in the traction resistance by 20 % on average, compared with the model of a standard working body. Such a result can only be obtained by reducing the friction forces, that is by improving the streamline capacity of a working surface. The novelty of the scientific results obtained is the complete adaptation of the working surfaces of a biological analog to working under conditions of a soil environment.

Keywords: tillage, working surface, traction resistance, shape streamline capacity, methods of bionics, tillage tools.

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STUDYING THE INFLUENCE OF STRUCTURAL-MODE PARAMETERS ON ENERGY EFFICIENCY OF THE PLOUGH PLN-3-35 (p. 55–65)

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Current research addresses improving the effectiveness of the technological process of tilling the soil for agricultural crops. Based on the experimental study into the technological process of plowing, we have determined the efforts that act on the mechanism of a tractor's attachment and a landside. It was found that universal casings for ploughs enhance plowing effectiveness by improving their stability. It was established that this leads to a decrease in the energy intensity of a plough casing during soil tilling, as well as provides for a uniform wear of the friction surface due to changes of its surface. It was determined that it is necessary to improve the components of tillage machinery in order to prolong the mean time between failures for working bodies and to reduce their traction resistance. It was established that the influence of a transverse pressure force that acts on a plough's landsides has not been sufficiently studied. Not enough attention has been paid to determining the magnitude of a traction effort for each link in the mechanism of an attachment to a tractor's assembly. One of the reserves for enhancing technological indicators and reducing energy intensity of a plowing assembly is the structural improvement of a standard plough's landside. In the course of experimental study, we used a system for measuring the dynamics and energy efficiency of mobile machines, which refers to the tools for technical diagnosing and operational control. The strain gauges were placed on a plough's landside, at the middle, left, and right links in the mechanism of a tractor's attachment. It was determined that the mean value for a shear force of pressure acting on a landside installed at the bearer of a first plough's casing is 1,610–1,668 N. At the bearer of a second casing, it is 1,525–1,630; at the bearer of a third casing, it is 1,848–1,870 N. It has been proposed to use, instead of a standard landside for the mounted ploughshare PLN-3-35, a flat-rounded element in the form of a disk with a hub that has a horizontal axis of rotation. The disk transforms the sliding friction forces into rolling friction forces. The application of disk reduces energy intensity of the plough by 13–15 %. That leads to a decrease in the traction effort of the plough's casings, improves their stability, and lowers consumption of petrol, oil, and lubricants.

Keywords: flat-rounded element, landside, plough's casing, wheel furrows, plough.

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RESULTS OF NUMERICAL MODELING OF THE PROCESS OF HARVESTING THE SEEDS OF FLAX BY A HARVESTER OF THE STRIPPING TYPE (p. 66–74)

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The purpose of the current theoretical study is to improve the efficiency of the technological process of harvesting flax seeds with a harvester of the stripping type by substantiating its structural-operational parameters. The goal has been accomplished by constructing an appropriate physical-mathematical model that takes into consideration the technological parameters for operation of the harvester, as well as the physical-mechanical properties of a flax pile. The theoretical study has been performed by means of numerical simulation using the software suite STAR-CCM+. The physical-mathematical apparatus is based on the k–ε conjugated flow turbulence model, a van der Waals model of real gas, averaging by Reynolds, a Navier-Stokes equation, a Lagrangian multiphase model, and a discrete element model.

The undertaken theoretical research has established the effect of structural-technological parameters of the stripping-type harvester on the quality of the process in its region when harvesting flax by direct harvesting when stripping plants at the root. It has been proven that the course of the process is substantially affected by an air flow resulting from the operation of a beat-reflector and a harvester's stripping rotor. The result of numerical modeling of the process of separating a flax pile in the stripping-type harvester is the derived distribution of an airflow in its region. We have determined the dependences of maximum speed of an airflow on the rotation frequency of the beat-reflector and stripping rotor. The maximal air flow speed is V_{max}=30 m/s, predetermined by the rotation frequency of the beat-reflector and stripping rotor: n_1=n_2=800 rpm. We have substantiated the position of an air grid and approximated the shape of the casing. The following rational structural-technological parameters have been obtained, which contribute to improving the quality of the process of pile separation: the rotation frequency of beat-reflector n_1=782 rpm, the rotation frequency of stripping rotor n_2=671 rpm, the position of a transparent zone border L=0.82 m and its width B=0.45 m. The constructed physical-mathematical models allow targeted control over the operational parameters of the stripping-type harvester in the process of harvesting flax seeds.

Keywords: harvester, technology of plant stripping at the root, flax, structural parameters, airflow, separation process.

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