MECHANICAL ENGINEERING TECHNOLOGY

DOI: 10.15587/2706-5448.2026.356852

DETERMINATION OF FORCE AND ENERGY PARAMETERS IN IMPACT FRACTURE PROCESSES OF MATERIALS OF VARIOUS STRENGTHS AND RHEOLOGY PROPERTIES

pages 6–16

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The object of research is the processes of impact fracture of materials of different strengths and rheological properties.

The problem of determining the force and energy parameters remains the lack of a generally accepted model of the processes of fracture of materials of different strengths and their rheological properties. In most crushing machines in the crushing chamber, the destruction of materials is accompanied by impact loads or is generally shock (impact crushers).

The work includes studies of material destruction using the example of granite. The analysis of Johnson-Holmquist models was carried out, according to the plastic fracture model, which is designed to model the behavior of brittle materials, according to the fracture model of porous materials, especially concretes, which are subjected to large deformations, high strain rates and high pressure. It was found that during impact loading, maximum stresses arise on the impact surface, and also spread along the beam to the inner edges of the supports. The difference between the internal and kinetic energies for the JH2 body was 9.2 J, while for the JH1 body it was 15.3 J. The study on the pendulum impactor allowed to estimate the energy spent on the fracture of the material sample. It was established that if the crack crosses the intergranular boundary due to the action of local stress concentration, new cracks appear in the corresponding cleavage planes of neighboring grains, which require additional energy input to the sample. To estimate the dissipated energy in the fracture process, it was proposed to introduce an appropriate resistance coefficient. Based on experimental data, the resistance coefficient value was established for various rocks. The obtained research results can be used in the development and study of equipment for crushing materials. The value of the specific fracture energy can be used to study dynamic processes in building structures under excessive loads.

Keywords: impact fracture modeling, pendulum impactor, Johnson-Holmquist rheological model, sliding contact energy, impact strength, energy dissipation factor.

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DOI: 10.15587/2706-5448.2026.357903

QUANTITATIVE ASSESSMENT OF WHEAT MECHANICAL INJURY DURING FREE FALL IN TRANSPORT AND PROCESSING LINES

pages 17–24

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The object of research is the process of gravitational fall of grain during its movement along a typical transport and technological line at the enterprise. The problem of the lack of a comprehensive analysis of operational deficiencies of transport equipment, which leads to mechanical damage to grain, was solved. The results of a comprehensive research of the impact of free fall of grain from different heights on surfaces with different physical and mechanical properties are presented. The relevance of the work is due to the need to minimize post-harvest losses of grain, which due to equipment imperfections can reach 55–65% of the total volume.

The nonlinear nature of the change in the speed of grain fall under gravity was experimentally established: on a section of up to 10 m, the speed increases to 12.4 m/s, after which it stabilizes within 13.3 m/s under the influence of air resistance. It is proven that the type of material of the surface in contact with the grain is a determining factor in the intensity of damage. The highest injury rates (up to 0.6%) were recorded in contact with Hardox 450 steel, while the use of polyurethane lining reduces the level of damage by 12%. The most trauma-saving method was recognized as the "grain on grain" method, which provides a reduction in injury by 54–57%. A direct correlation was established between the angle of inclination of the surface and the degree of destruction of the kernel: a direct impact (90°) is critical, which increases the level of macrotrauma by 2–2.4 times. Using the method of staining with aniline dyes, a hierarchy of vulnerability of the grain structure was identified, where endosperm microtrauma occurs in any fall regime. This difference in injury can be explained by the ability of materials to absorb kinetic impact energy. The appearance of endosperm microtrauma in any regime indicates the fragile nature of the starch structure of the kernel.

Scientifically based recommendations are provided on limiting the height of free fall to 4 meters and introducing grain gravity-braking devices to preserve grain quality.

Keywords: mechanical injury to grain, influence of free fall, speed of wheat flight, experiment, angle of impact.

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DOI: 10.15587/2706-5448.2026.359283

IMPROVING THE EFFICIENCY OF FAULT-FINDING WORK DURING CAMSHAFT REPAIRS

pages 25–31

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The object of this research is the process of inspecting the camshafts of internal combustion engines in the context of vehicle repair production. As the inspection of a camshaft is a highly labor-intensive process due to the need to measure a large number of its components, there is a pressing need to improve the efficiency of inspection work.

An approach is proposed for inspecting components with multiple worn surfaces, which involves determining the wear on one surface and calculating the wear on another using a regression model that establishes a quantitative relationship between the wear on the surfaces. This allows for a significant reduction in the labor intensity of defect detection work without compromising the reliability of the technical condition assessment of the component. This approach has been implemented using the example of defect detection on the camshaft of a KamAZ lorry engine.

A hierarchical diagram of the camshaft structure as a system, where its individual elements are subsystems, is examined. It is noted that, among the surfaces of the camshaft, the cams and journal necks are subject to the most intense wear. A statistical model of camshaft wear has been constructed in the form of a linear regression equation, establishing a quantitative relationship between the wear of the journal necks and the cams.

The practical significance of the proposed approach lies in improving the efficiency of defect detection work by reducing the volume of measurements by a factor of 2.6, which reduces the labor intensity of defect detection by 40%. When inspecting a batch of 100 camshafts, this results in a saving of 3,200 measurements, or over 36 hours.

The results of this research have practical significance and are important for automotive repair enterprises engaged in the repair of internal combustion engine components.

Keywords: distribution shaft, defect detection, wear measurement, statistical model, regression equation, quantitative correlation.

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ISSN-L 2664-9969; E-ISSN 2706-5448

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METALLURGICAL TECHNOLOGY

DOI: 10.15587/2706-5448.2026.357430

DEVELOPMENT OF A HYBRID TECHNOLOGICAL SCHEME FOR MANUFACTURING PATTERN EQUIPMENT FOR PUMP IMPELLERS

pages 32–37

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The research deals with the technological process of manufacturing pattern equipment for pump impellers with curved blades. Pattern equipment is a key element of foundry production, since it determines the geometry and quality of the future casting.

The paper addresses the problem of ensuring the dimensional accuracy and quality of pattern equipment for pump impellers. It is shown that three-axis CNC machining is limited in the manufacture of curved blades, whereas the use of five-axis machining centers involves significant costs and higher qualification requirements. Under these conditions, a transition to hybrid technological schemes becomes justified, combining three-axis CNC milling with additive 3D printing.

The research aimed to develop and substantiate a hybrid technological scheme for manufacturing pattern equipment. The scheme is based on a rational division of operations: base surfaces are produced by CNC milling, while complex-geometry elements, namely negative blade sections, are manufactured using 3D printing and digital inspection. The research employs CAD/CAM design, three-axis CNC machining, additive manufacturing, and measurement-based control methods. A comparative analysis of conventional and hybrid approaches was carried out. The hybrid technology ensures geometric deviations of the base surfaces within 0.1–0.3 mm, while additively manufactured blade elements achieve deviations within 0.1–0.15 mm. Due to the combination of CNC milling and 3D printing, the technological route is reduced by 30–40%, and the cost of pattern equipment decreases by 20–30% compared with five-axis machining.

The proposed scheme can be implemented at industrial enterprises equipped with three-axis CNC machines and additive manufacturing systems, without expensive five-axis machining centers.

Keywords: model equipment, working wheels, CNC milling, additive technologies, digital control.

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MATERIALS SCIENCE

DOI: 10.15587/2706-5448.2026.359181

IMPROVEMENT OF THE ELECTROSLAG SURFACING TECHNOLOGY FOR THE WORKING PARTS OF THE SOIL TILLAGE MACHINES THROUGH COMPREHENSIVE MODIFICATION OF COATINGS

pages 38–45

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The object of research is wear-resistant electroslag coatings formed on the working bodies of the soil tillage machines in an electric-driven crystallizer.

The research conducted in the work focuses on eliminating the rapid wear of plowshares and cultivator paws, which is observed when they are exposed to abrasive abrasion and impact wear. Farmers have to replace their plowshares and cultivator paws frequently due to damage, which leads to higher costs for the farmer's own capital during his field work.

To increase the service life of plowshares and cultivator paws, 65G and 45 steel were used in various experiments, and various methods were also applied, including X-ray phase analysis and hardness measurement using HV10. The results show that the structure of the coating has changed. Laboratory tests have shown that the matrix has been crushed by 35–40%, with an increase in the amount of fine carbide by 25%. This change resulted in approximately a 20% increase in microhardness, which resulted in a significant reduction in wear intensity from the initial point of 0.73 to 0.79. Field reports show that the modified part lasts 40% longer than the serial part, and the best sample lasts 100% longer than the serial part. This result demonstrates that stability is provided by a fine-grained structure and uniform distribution of carbides, which prevents the delamination process.

The proposed approach combines thick-layer electroslag deposition with complex modification of the flux-cored wire. The technology can be used in agricultural repair enterprises and allows to reduce the total costs of repair and maintenance of machines by 35–40%.

The obtained results are recommended for the restoration of plowshares, cultivator paws and other working bodies of the soil tillage agricultural machines operating under conditions of intensive abrasive wear.

Keywords: electroslag surfacing, wear resistance, microhardness, carbides, microstructure, plowshares, abrasive wear, resource.

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ISSN-L 2664-9969; E-ISSN 2706-5448

TECHNOLOGY AND SYSTEM OF POWER SUPPLY

DOI: 10.15587/2706-5448.2026.354467

APPLICATION OF ULTRA-HIGH FREQUENCY ELECTROMAGNETIC RADIATION ENERGY TO INCREASE THE EFFICIENCY OF GAS PREPARATION PROCESSES IN HYDRATE FORMATION CONDITIONS

pages 46–54

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The effective operation of modern gas systems requires new approaches to combat hydrate plugs, which limit the flow and cause emergency shutdowns. The object of research is the process of formation and destruction of gas hydrates in industrial pipelines under the influence of microwave radiation. The research is aimed at solving the problem of excessive use of methanol to combat hydrates. This reagent is very toxic and expensive, and its real costs in the fields of Ukraine are often 15–20% higher than the norm due to outdated dosing methods.

The results of the work are based on modeling the technological processes of the Machukhske field (Ukraine) in the Aspen HYSYS program. The most dangerous zone of hydrate formation was identified in a 20-meter section immediately after the throttle when the gas temperature drops to –30.11°C. To protect this unit, a new design of a removable insert with a magnetron has been developed, which provides thermodynamic decomposition of crystal hydrates by directly transferring the energy of the microwave field to water molecules in the flow volume.

A distinctive feature of the development is the creation of a resonant zone between the choke and the diaphragm, which allows concentrating the field and accelerating the dissociation of hydrates by 1.5–3 times compared to thermal heating. The optimized geometry of the diaphragm provides high wave reflection without a significant increase in the hydrodynamic resistance of the gas flow.

The practical value of the work lies in the possibility of integrating the developed design of the ultrahigh-frequency electromagnetic radiation device into low-temperature gas separation units and hydrocarbon collection systems with a complex temperature regime. The introduction of the device allows maintaining a stable hydrate-free mode of pipeline operation, reducing the consumption of chemical reagents and increasing the environmental safety of gas production in Ukrainian fields by minimizing the use of toxic methanol.

Keywords: hydrates, low-temperature separation, microwave radiation, inhibitors, methanol, gas preparation, energy efficiency.

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ELECTRICAL ENGINEERING AND INDUSTRIAL ELECTRONICS

DOI: 10.15587/2706-5448.2026.356688

IMPROVEMENT OF THE METHOD FOR ASSESSING LOAD REACTIVITY BASED ON ENERGY FLOWS WITHIN A SINGLE VOLTAGE PERIOD

pages 55–63

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The object of this research is the process of assessing reactance and compensating for reactive power in single-phase electrical networks containing both linear and nonlinear loads.

The problem addressed is the limited applicability of classical reactive power definitions based on the fundamental harmonic when current waveforms are distorted by nonlinear loads, which complicates correct reactive power assessment and compensation control.

An energy-based approach for estimating load reactance is proposed. The method introduces a dimensionless reactance coefficient determined from the ratio between the energy value over one voltage period and the total area of instantaneous energy flow components associated with the bidirectional energy exchange between the source and the load. For sinusoidal conditions, an analytical relationship between this coefficient and the phase shift angle between voltage and current is obtained. This relationship allows reconstruction of the phase shift angle from discrete voltage and current measurements using Newton's iterative method.

To validate the method, a simulation model of a single-phase electrical network with linear and nonlinear loads was developed in the Simulink environment. Simulations were performed for linear, nonlinear, and mixed operating modes with different ratios of active and reactive power.

The results show that when the nonlinear load dominates or when the capacitive reactive component of the linear load is small, compensation based on the proposed criterion provides higher power factor values than the classical reactive power approach. For loads with a significant inductive component the classical method remains more effective. The proposed improved method can be applied in power quality monitoring systems and adaptive reactive power compensation devices for networks with nonlinear loads.

Keywords: reactive power, power factor, harmonic, energy flows, electrical network, power system.

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DOI: 10.15587/2706-5448.2026.356937

DEVELOPMENT A MATHEMATICAL MODEL OF PROCESSES INSIDE RF HOLLOW CATHODE TAKING VISCOSITY INTO ACCOUNT IN ELECTRON DYNAMICS

pages 64–69

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The object of research is high-frequency hollow cathode as electron sources in plasma-ion thrusters and Hall effect thrusters with relatively low-power.

Publications devoted to high-frequency (helicon) thrusters consider Trivelpiece-Gould waves, helicon waves, as well as ion-cyclotron and electron-cyclotron resonance, as mechanisms for absorbing electromagnetic energy. In this case, electron scattering by atoms and ions within the thruster channel is considered a factor in plasma thermalization. The discharge conditions and the dimensions of the low-power cathode cavity virtually eliminate the occurrence of these effects, while significantly enhancing the relaxation of electron momentum due to non-mirror reflection from the potential barrier in the boundary bipolar layer. The parameters describing the results of this reflection within the cavity volume are the axial-azimuth and radial-azimuth components of the electron viscosity tensor, corresponding to the electron momentum flux in the direction of zero mass flow. It is shown that viscous electron momentum transport facilitates magnetic field penetration deeper into the plasma than is predicted by classical skin-layer theory, which considers the relaxation of electrons motion only because of collisions in the volume. Conditions under which rotation-cyclotron resonance is possible are identified. The input of viscosity into electrons thermalization process is shown.

The results obtained in the work can be used in predicting operating parameters and narrowing the range of parameter variations when developing laboratory models.

Keywords: high-frequency cathode, viscosity tensor, potential barrier, skin-layer, bipolar layer.

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DOI: 10.15587/2706-5448.2026.358421

DEVELOPMENT OF METHODS FOR OVERCOMING SELF-OSCILLATORY MODES IN AN ASYNCHRONOUS ELECTRIC DRIVE WITH A THYRISTOR VOLTAGE REGULATOR

pages 70–80

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The object of research is the processes of electromagnetic transformation in powerful asynchronous electric drives during controlled starting using a thyristor voltage regulator.

The problem to be solved by the research is overcoming the self-oscillating modes of powerful high-voltage asynchronous electric drives during controlled starting in the nominal slip range.

A design feature of powerful high-voltage induction motors in comparison with general-purpose motors is a small value (up to 1%) of the nominal slip. Also, such electric motors have a relatively small value of their own moment of inertia. These features create conditions for the occurrence of self-oscillations when entering a steady-state operating mode.

A mathematical model of an induction motor has been developed taking into account the influence of the rotor current displacement phenomenon to study the modes of controlled starting of an asynchronous electric drive of an industrial mechanism taking into account the influence of the enterprise's distribution network.

From the point of view of the power supply network, an induction motor is a nonlinear active-inductive resistance, the phase angle of which can quickly change over a wide range in the vicinity of the nominal slip. The mechanism of the occurrence of self-oscillations during controlled start-up of high-voltage induction motors from a thyristor voltage regulator is disclosed. Self-oscillations occur in the nominal slip region due to the transition of the thyristor voltage regulator to an uncontrolled operating mode, when the load phase angle becomes greater than the thyristor control angle, including in the quasi-generator operating mode.

To prevent the occurrence of self-oscillation modes, it is proposed to use a controlled reactive power compensator between the motor and the thyristor voltage regulator, which stabilizes the total load phase angle, which helps to improve the controllability of the electric drive.

Keywords: starting devices, self-oscillation modes, controlled reactor compensator, simulation modeling.

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