



## MECHANICAL ENGINEERING TECHNOLOGY

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## SUBSTANTIATION OF QUANTITATIVE CRITERIA OF STRUCTURAL PARTS AND UNITS MANUFACTURABILITY EVALUATION

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The object of research is assemblability and maintainability of structures. Criteria for assessing such important parameters of design manufacturability are an extremely complex problem in the design process. The result of the design should be the embodiment of the idea in the form of a product. Low manufacturability significantly complicates this process, or even makes it impossible.

One of the most problematic places in determining the criteria for assemblability and maintainability of structures is that their list differs depending on the design. With the increase in the number of details in the design, the process of determining the criteria and their quantitative assessment are significantly more complicated.

The formalization of the criteria for manufacturability makes it possible to reduce the optimization process to a single algorithm, which has a high degree of automation. The potential for implementing the theory in CAD systems has become the starting point for the research.

The use of research results, namely the formulated theorems of assemblability and maintainability, allows to optimize the design and evaluate the results of optimization qualitatively and quantitatively. It is advisable to use the indicated results for structures, the production of which provides for seriality – mass production and large-scale production. Under such conditions, the economic effect of the optimization is most palpable.

Another advantage of the study is the answer to the question – in which the greatest number of design elements can achieve maximum assemblability and maintainability? The formulated conclusions make changes in the design algorithm and program the level of its optimality already in the design. It is this approach that reduces the level of material costs already at the design stages, technological preparation of production, and, directly, in production.

The actual result of applying the developed optimization technique is increasing the manufacturability of the investigated structures from 30 to 50 %. In comparison with the known analogs, a basis has been created for the establishment and complex analysis of the manufacturability criteria as a result of the interaction of assemblability and maintainability.

**Keywords:** level of technological design of constructions, criteria for assemblability evaluation, criteria for maintainability evaluation.

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## MECHANICS

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### REDUCTION OF TECHNOLOGICAL RISKS IN SUBWAY AND RAIL TRANSPORT

page 12–17

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The aim of research is ensuring the guaranteed safety of passengers traveling on subway trains. The object of the researches carried out by the authors is process of interaction of the subway arriving at high speed to the subway station with the passenger, motionlessly waiting, or, which moves to the edge of the platform as a result of the braking of a close mass of passengers. It is shown that a significant friction of the heel surface of the passenger's shoes and the friction of the upper body in the side surface of the car limits the possibility of human movement in space. Thus, in the simplest case, the upper part and extremities of the legs will form a fixed axis of rotation. But, a powerful blow deforms this axis and directs in such way that it will move over the surface, which is a collection of instantly rotational movements. And, thus, the instantaneous axis of rotation describes a conical surface with a vertex that coincides with the heels of the shoe.

It is revealed that by rigidly tying the coordinate system  $xyz$  to a person it is possible to determine three Euler rotation angles relative to the instantaneous axis and to construct a table of directing cosines that allow determining the kinematic characteristics of the human forced body relative to the axes associated with it –  $\omega_x, \omega_y, \omega_z$ .

The results of the model studies confirm the opinion about the expediency of replacing the translational motion of the side surface of the car with a complex movement, additionally equipped on the side surface of the car with a warning stripe. This stripe moves in the opposite direction to the car side, but with the same speed. Synthesis

of these two movements gives the effect of the appearance of a fixed part of the warning stripe with respect to the passenger standing on the platform and, therefore, maximizes the confidence and reliability of the passengers' transportation by electric trains of the subway.

The laboratory model completely confirms the predicted effect of the danger absence of injury to passengers and the degree of technological risk presence in operating conditions.

**Keywords:** warning stripe, subway train, technological risks, reversed physical pendulum.

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**CONTROL OF VORTEX STRUCTURES OF ABNORMALLY VISCOUS FLUIDS IN THE CHANNELS OF THE EXTRUSION DIE**

page 18–24

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The object of research is the vortex structures arising during the flow of anomalously viscous media in the channels of the forming equipment. One of the most problematic places is insufficient knowledge of the processes of origin and development of circulation flows. This is due to the fact that the hydrodynamic mechanisms of these processes are not completely understood. The reason for this is the lack of precise analytical solutions that allow describing the process model and choose the method of hydrodynamic control of vortex structures and on its basis to improve shaping equipment.

In the course of the research it is established that the most effective way to control the hydrodynamic flow characteristics in the region of the sharp narrowing of the channel is supplying additional fluid flow in the radial direction with respect to the main flow. The design of a extrusion die is developed, which allows to realize the mixing mode of components with improved technological and energy indicators. This is due to the fact that the proposed method for controlling vortex structures has a number of distinctive features, in particular, the extruded medium passes through the die channels in the form of a sudden constriction, and then along the course of the flow, cone expansion. The mixed technological component is fed radially into the region of the vortex structures with a reduced pressure zone. Due to this, it is possible to disrupt the vortex structures, turbulence of the flow and intensive mixing of the main and additional flows. In comparison with similar known equipment, the location of mixing devices and stationary turbulators is not provided in the die channels, which reduces the energy consumption for the extrusion process. In addition, it is possible to use a lower power pump to feed the process component to the base stream.

The developed device for the input of technological components into the extruded material is designed by the patent of Ukraine No. 201503942.

**Keywords:** sudden narrowing of the channel, vortex structures, flow supply in the radial direction.

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**MATERIALS SCIENCE**

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**DEVELOPMENT OF DIRECTED REGULATION OF RHEOLOGICAL PROPERTIES OF FIRE RETARDANT COMPOSITE MATERIALS OF ETHYLENE VINYL ACETATE COPOLYMER**

page 25–31

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The object of research is rheological processes of viscous flow of non-combustible polymeric composite materials. One of the most problematic issues arising in the processing of polymer composite materials is an increased viscosity, which requires an increase in shear stresses to achieve a given speed.

In order to solve this problem, a method has been developed for the directed regulation of the rheological characteristics of polymer compositions by injecting a modifier into their composition. The influence of the modifier on the viscous flow processes of fire retardant materials of an ethylene with vinyl acetate copolymer and fire retardant fillers, has been studied. In the studies, an ethylene vinyl



acetate copolymer is used. The content of vinyl acetate is 18 % and 28 %; MFI 2.5 g/10 min and MFI 5 g/10 min. Modifier is aminosi-lane. Fillers are fire retardants:

- aluminum trihydroxide with an average particle diameter of 1.5 μm and 3.0 μm;
- magnesium hydroxide with an average particle diameter of 3.0 μm and 3.7 μm;
- hydromagnesite with an average particle diameter of 1.4 μm.

Using the method of capillary viscometry, the following characteristics are determined: melt flow index, shear stress, shear rate, effective viscosity and viscous flow activation energy. The melt flow index decreases with the use fire retardant fillers with a smaller average particle diameter. The melt flow rate of the polymer composition using fire retardant fillers of different chemical nature and dispersity increases with the modifier injection. For aluminum trihydroxide 2–8 times, for magnesium hydroxide 2.2–3 times, for hydromagnesite 2.0–2.2 times. The shear stress and the effective viscosity, on the contrary, decrease when the modifier is injected into the polymer composition.

The obtained results allow to increase the productivity during processing of the developed materials due to the decrease of such parameters as viscosity, shear stress, increase in the melt flow parameters and shear rate. This, in turn, will positively affect the reduction of energy costs and the production time of cable products.

The results will be useful in the development of formulations of polymer compositions for cable products and the directed regulation of technological parameters during their processing.

**Keywords:** composite materials, ethylene-vinyl acetate copolymer, fire retardant fillers, rheological properties.

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## ELECTRICAL ENGINEERING AND INDUSTRIAL ELECTRONICS

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### THEORETICAL ANALYSIS OF THE ADAPTIVE SYSTEM FOR SUPPRESSION OF THE INTERFERENCE CONCENTRATED ON A SPECTRUM

page 32–36

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The object of research is the process of interference suppression in a passive radiometric receiver, centered over the interference spectrum, with a random or varying frequency. Noise immunity can be increased by means of special circuits preventing the receiver from overloading and using differences in the characteristics of useful signals and interference to suppress the latter. As a rule, the frequency of noise oscillation is never accurately known and, in addition, the actual interference is never purely harmonic. Therefore, it became necessary to theoretically consider the degree of interference suppression by the input circuit of the radiometer at an unknown value of the interference frequency and the finite width of the spectrum, and also theoretically substantiate possible ways of constructing adaptive devices for suppressing real narrow-band noise.

An expression is obtained for the suppression coefficient of the interference concentrated on a spectrum, which shows that the interference will be suppressed automatically for the optimal choice of the parameters  $k_a$ ,  $\tau$ ,  $T$  of the servo system.

In the paper, a functional diagram of a radiometric receiver is presented, which uses an adaptive system to suppress the spectrum-centered interference. The adaptive system is based on the inclusion in the radiometric receiver circuit of additional compensating circuit interference. The interference compensating circuit makes it possible to increase the sensitivity of the receiver to  $10^{-20}$  W with an accuracy of 0.1 °C and a response rate of 2...4 s. In addition to interference suppression, the compensating link after the intermediate frequency amplifier is provided with interference suppression and an input circuit. In this case, the overall amplification in the noise immunity of the radiometric receiver in comparison with the compensating receiver, as calculations for typical characteristics show, will not be worse than 30 dB.

**Keywords:** radiometric receiver, suppression of the spectrum-centered interference, compensating circuits.

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### EFFECT OF VOLTAGE HARMONICS ON PULSE REPETITION RATE OF PARTIAL DISCHARGES

page 37–44

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The objects of the research are partial discharge processes simulated under the influence of non-sinusoidal voltage. In the context of studying the effect of voltage harmonics on partial discharges, the total harmonic distortion can only be used for rough estimation. The reason for this is that the total harmonic distortion does not take into account the phase angles of the individual voltage harmonic components. Under non-sinusoidal voltage with the total harmonic distortion of 10 % and above, the intensity of the partial discharges in the insulation increases. However, at lower values of the total harmonic distortion, the harmonics can also affect the characteristics of the partial discharges. To solve this problem, it is necessary to carry out a study, increasing the number of voltage harmonics taken into account. To do this, it is possible to use the known three-capacitive equivalent circuit for a dielectric with gas cavity, making appropriate changes to the voltage source.

The model was studied using voltage harmonic of the fundamental frequency together with voltage harmonics from the 2nd to the 30th order included. It was found that for the fixed amplitude the phase angle of the voltage harmonics has a decisive influence on the number of partial discharge pulses. In the presence of voltage harmonics, this number can be the same as under the influence of a pure sinusoidal voltage. It can also be 14.3 % less and 14.3 % or 28.6 % greater. In all cases, the value of total harmonic distortion remains the same. The possibility of using high-voltage reference inductive voltage transformers for voltage distortion measurements was studied experimentally. It was found that this is expedient for the region of the maximum value of the magnetic permeability of their magnetic cores, which corresponds to a range of 80–120 % of the transformer rated voltage.

Mobile laboratories for checking high-voltage transformers on-site with the addition of appropriate equipment can simultaneously be used to measure a number of power quality indices.

**Keywords:** simulation, partial discharge, voltage harmonics, phase angle, pulse repetition rate.

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## TECHNOLOGY AND SYSTEM OF POWER SUPPLY

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### ADJUSTMENT OF AIR LINE STRUCTURE FOR OPTIMAL TRANSPORT MANAGEMENT AND ELECTRICITY DISTRIBUTION

page 45–48

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The object of research is processes in air lines that affect the transportation and distribution of electricity. One of the most problematic places is the wires of overhead lines. The variety of wires with which the lines are made leads to heterogeneity of the network, which is reflected in the technological losses of power.

In the course of the study, the technical and economic model of discounted costs in air lines is used, which is improved due to a change in the analytical connection of investments with wire cross-section. A criteria method is used to analyze this model. This method allows to analyze such models and to make a decision in relative units with incomplete initial information.

It is received that perfection of structure of overhead lines at the expense of optimization of parametrical series of sections of wires allows to reduce influence of heterogeneity of a network. And also to proceed to the unification of overhead lines, to increase the schedule for the reconstruction of the facility, but does not expand the functionality of the lines.

Equipping the lines with a fiber-optic monitoring system allows to monitor the parameters of the object along the entire length of the object. This reduces the loss of active power and provides an opportunity to optimally manage the transport and distribution of electricity in real time.

The proposed direction has a number of features, in particular, shows a consistent improvement in the structure of the lines. In comparison with similar known approaches, the advantage of the proposed approach is the complex justification of the development of overhead lines in the electricity market.

**Keywords:** electric network, overhead line, parametric series, monitoring system, technical and economic model, criteria method.

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### MODELING OF PARAMETERS OF PIPELINES OF CENTRAL WATER HEATING SYSTEM AND THERMAL INSULATION OF THE FACADE OF UKRAINIAN BUILDINGS AND FACILITIES FOR DIFFERENT CLIMATIC CONDITIONS

page 49–58

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The object of research is the design parameters and material for the execution of the elements of the complex thermomodernization of a building or structures, namely the system of central water heating and facade thermal insulation, taking into account the impact of the climatic zones in which these facilities are operated. One of the most problematic places is not enough study and lack of justification for effective design parameters and material for the execution of pipelines of the central water heating system and facade insulation. This is necessary to significantly reduce the energy consumption of existing buildings and structures of the Ukrainian housing stock. In the course of the study, a comprehensive approach to the solution of the set tasks was used, including economic and statistical analysis, analysis of world experience and synthesis of results and retrospectives, a historical-evolutionary and logical approach. Also, system theory and system analysis were used to identify strategic prospects for a significant reduction in the energy consumption of existing Ukrainian buildings and structures. In the long term, the results are expected to be disseminated to foreign buildings and structures that have similar energy efficiency issues, including climatic zones. The effective design parameters and material for the execution of pipelines of the central water heating system have been substantiated to significantly reduce the energy consumption of existing buildings and structures of Ukrainian housing stock. The minimum thickness of the facade thermal insulation layer is determined to be 50 mm for the temperature and operating conditions under study, as well as for the characteristics of the used materials, the geometry of the pipelines and the facade thermal insulation for the first temperature zone. The resulting optimum thickness of the facade thermal insulation layer is 100 mm, and results in 100 % protection against freezing of the pipelines, even if the coolant is completely stopped for more than 24 hours after the coolant ceases to flow. The developed innovative design and design and technological solutions lead to a significant reduction in energy consumption of existing buildings and facilities of the housing stock, is operated for more than 30 years and located in different climatic zones, and helps maintain comfortable conditions for life.

**Keywords:** thermomodernization of buildings and structures, facade thermal insulation, central water heating system.

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### OPTIMIZATION OF THE PLACEMENT OF REACTIVE POWER SOURCES IN THE ELECTRIC GRID BASED ON MODELING OF ITS IDEAL MODES

page 59–65

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The work is devoted to solving the problem of optimizing the flow of reactive energy in electric grids (EG) of electric supply companies (EC). The object of research is the process of transportation and distribution of electric power by electric grids of UES. The subject of the research is methods and means for optimizing the flow of reactive energy in such grids. One of the most problematic locations for the EG operation is ensuring their energy efficiency in the face of constant changes in consumption and generation of electricity. It is known that the most effective measure to reduce power losses in the EG is the introduction of measures to optimize the flow of reactive energy. However, in order to optimize the location of additional reactive power sources (RPS), it is necessary to solve the problems of non-linear multifactor optimization, which is associated with a number of problems.

On the basis of the research it is shown that to optimize the RPS location it is expedient to use the results of modeling «ideal» EG modes for reactive power based on equivalent circuits with active supports. The economic costs associated with the installation and operation of the RPS, it is suggested to list the EG equivalent circuit in the corresponding economic supports. Mathematical relations for economic resistance of established RPSs are developed, as well as the optimization task to be determined based on the results of the solution.

Application of this approach, unlike classical methods, significantly shortens the calculation time and allows obtaining a solution close to the global minimum of production costs. The computational efficiency and reliability of the approach is ensured by the construction of the task of multifactorial optimization of the flow of reactive energy in the design setting in the iterative calculation of the «ideal» EG mode according to the appropriate equivalent circuit and loads.

The program implementation allows to confirm the effectiveness of the proposed approach for a number of practical problems. It is shown that the solutions obtained for optimizing the RPS distribution in grids bring the profitability of investments to a global maximum closer, regardless of the size of the problem and a list of constraints on the parameters.

**Keywords:** electric grid, «ideal» mode, flow of reactive energy, multi-purpose optimization, reactive power source.

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**MODELING OF HEAT TRANSFER PROCESSES IN VENTILATED ENCLOSING STRUCTURES IN STATIONARY CONDITIONS**

page 66–71

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One of the ways to increase the energy efficiency of the housing and communal enterprise and solve the problem of space heating is the construction of «Passive houses», which contain elements of structures that effectively absorb the energy of solar radiation. The object of the study is the «Passive house», which is a building in which thermal comfort (ISO 7730) is achieved solely by additional preheating (or cooling) of the fresh air mass. This is necessary to maintain high quality air in the rooms, without additional recirculation.

The analysis of heat exchange processes in ventilated enclosing structures is carried out and the calculation methods for their design are analyzed. The application of passive solar heating technology in Ukraine's climatic conditions will provide up to 50 % of the heat needs.

It is determined that the movement of outdoor air in the ES (open enclosing structures) along the wall of the house leads to heat loss, but air in the ventilated layer will prevent the formation and accumulation of condensate. This will allow in winter to maintain the thermal properties of the outer layer of insulation at home, reduce the cost of heat for heating and prevent the formation and development of fungal mold.

The peculiarities of heat exchange processes in building structures with ventilated channels are studied. On the basis of the analysis of calculation methods for ES design, it can be stated that the classical method for evaluating heat exchange processes is based on the equations for the thermal balance of air for an infinitesimal volume  $dx$ . But when using this equation, it is impossible to take into account the distribution of radiant and convective heat flows, and also to estimate the effect of energy losses.

The paper proposes a mathematical model that will allow to determine changes in air temperature along the ventilated layer of enclosing structures and to quantify the intake or loss of heat to the room during the cold season.

**Keywords:** stationary heat exchange, ventilated enclosing structures, Trombe wall, heat flow.

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