MECHANICAL ENGINEERING TECHNOLOGY

DEVELOPMENT OF A PREDICTIVE THERMAL MODEL BASED ON THE EQUIVALENT SOURCE APPROACH FOR SMAW WELDING OF X70 STEEL PIPES

Adel Chouiter, PhD in Mechanical Engineering, HDR, Department of Mechanical Engineering, Laboratory Applied Sciences of Mechanics, Electromechanics and Materials (ASMEM), Mentouri Brothers University Constantine1, Constantine, Algeria, ORCID: https://orcid.org/0009-0003-1064-1805

Lyes Bidi, PhD in Mechanical Engineering, Professor, Laboratory Applied Sciences of Mechanics, Electromechanics and Materials (ASMEM), Mentouri Brothers University Constantine1, Constantine, Algeria, ORCID: https://orcid.org/0000-0003-0621-1274

Hadjer Bensiali, Doctor of Technical Sciences, PhD, Department of Transport Engineering, Laboratory of Transports and Environment Engineering, Mentouri Brothers University Constantine1, Constantine, Algeria, ORCID: https://orcid.org/0009-0000-9182-5005

Rachid Chaib, Doctor of Technical Sciences, Professor, Department of Transport Engineering, Laboratory of Transports and Environment Engineering, Mentouri Brothers University Constantine1, Constantine, Algeria, e-mail: r3chaib@yahoo.fr, ORCID: https://orcid.org/0000-0001-8680-1906

Philippe Le Masson, PhD in Mechanical Engineering, Professor, C. HUYGENS Research Centre, University of Southern Brittany, Morbihan, France, ORCID: https://orcid.org/0000-0003-2721-8504

The object of the research is the scientific approach for modeling thermal phenomena during welding operations in SMAW welding of pipelines. This model can be used to calculate changes in temperature fields as well as stresses and deformations.

Mastering welding processes requires an understanding of the various phenomena involved. This requires numerous tests to be carried out, which are very costly for manufacturers. The ideal solution would therefore be to develop predictive numerical models that would enable the behavior of assemblies to be analyzed. The SMAW process is used to fill a chamfer between two parts. It is therefore essential to define heat input, which can be described using the equivalent heat source approach the equivalent heat source approach. The difficulty in implementing this approach lies in estimating the various parameters of the model. To this end, it was proposed to develop a simple and robust approach, which consists of using the numerical design of experiments (NDE) method.

In this research, it was decided to select four parameters from the model (r_{surf_sup}, r_{surf_inf}, r_0 and λ) and four objective functions characterizing the shape of the fusion zone (L_{sup}, L_m, L_{inf}, H). Preliminary results show good agreement between the direct model and the dimensions recorded on the macrographic sections, with the exception of the width of the median side of the fusion zone (L_m), where there is a significant deviation of 11.4% between the measurements and the model. Furthermore, the NDE shows that r_{surf_inf} is the factor that most influences L_m. Adjusting the r_{surf_inf} factor by 0.5 from its value at the central point changes the L_m value from 3.25 mm to 3.09 mm. This adjustment optimizes the digital model by improving it and reducing the discrepancy between the simulation and the experiment for the L_m function from 11.4% to 1.2%. The results of this research make it possible to increase the reliability of petroleum facilities (pipeline assemblies). The scientific novelty of this research lies in the implementation of a simple and robust scientific approach for optimizing non-physical parameters (equivalent heat source parameters) in the modeling of welding processes.

Keywords: welding simulation, numerical design, SMAW welding, equivalent heat source, adjustments parameters.

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ENHANCEMENT OF THE MEASUREMENT METHOD FOR THE RADAR CROSS SECTION OF UNMANNED AERIAL VEHICLES IN THE X-BAND UNDER ANECHOIC CHAMBER CONDITIONS

Anatoliy Popov, *Doctor of Technical Sciences, Associate Professor, Department of Aerospace Radioelectronic Systems, National Aerospace University "Kharkiv Aviation Institute", Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0003-0715-3870*

Iurii Vorobiov, *Doctor of Technical Sciences, Professor, Department of Aircraft Manufacturing Technology, National Aerospace University "Kharkiv Aviation Institute", Kharkiv, Ukraine, e-mail: i.vorobiov@khai.edu, ORCID: https://orcid.org/0000-0001-6401-7790*

Kateryna Maiorova, *PhD, Associate Professor, Department of Aircraft Manufacturing Technologies, National Aerospace University "Kharkiv Aviation Institute", Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0003-3949-0791*

Mariya Bortsova, *Air Force Research Center, Ivan Kozhedub Kharkiv National Air Force University, Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0001-6644-0875*

The object of research is the process of measuring the effective scattering surface of an unmanned aerial vehicle (UAV) in the X-band of electromagnetic waves in an anechoic chamber. The problem being solved is to obtain reliable initial data for assessing the radar visibility and probability of detecting UAVs based on their backscatter diagrams. The aim of research is to improve the method of measuring the effective scattering surface (ESS) of UAV components in the X-band in an anechoic chamber and its experimental testing. As a result of the research, a technology for measuring the angular dependence of the ESS in the X-band was formed, which includes compensation of the background signal, calibration of the measuring equipment, ESS determination of the object and automation of the measurement process. The technology includes the design of the anechoic chamber, the structure of the measuring stand, the method of compensation of the background reflection, measurement of the reflected signal power, calibration of the measuring equipment, ESS calculation. The conducted field experiments allowed to obtain the characteristics of the secondary scattering of UAV components in the angle sector ±45°, while the measurement error of static reference objects did not exceed ±1 dB. Comparison of experimental results with the data of mathematical modeling based on integral equations and the physical theory of diffraction confirmed the reliability of the improved approach. The obtained results can be used to increase the accuracy of assessing the radar visibility of small-sized UAVs and improve the means of their detection.

Keywords: unmanned aerial vehicle (UAV), radar cross section (RCS), effective scattering surface, backscatter pattern measurement, anechoic chamber.

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DEVELOPMENT OF AN ANALYTICAL MODEL FOR PREDICTING THE TRAJECTORY AND ENERGY DISSIPATION OF BEE BREAD GRANULES IN A ROTARY IMPACT SEPARATOR

Yurii Syromiatnykov, PhD, Assistant, Department of Agroengineering, State Biotechnological University, Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0001-9502-626X

Oleksandr Bielykh, PhD Student, Department of Agroengineering, State Biotechnological University, Kharkiv, Ukraine, e-mail: sashafincol@gmail.com, ORCID: https://orcid.org/0009-0007-5490-4098

Oleksandr Kharchenko, PhD Student, Department of Agroengineering, State Biotechnological University, Kharkiv, Ukraine, ORCID: https://orcid.org/0009-0009-4955-3478

The object of this research is the impact interaction between a bee bread granule and a hammer-type working element in a rotary separator. The practical relevance of the research arises from the need to ensure reliable release of granules while preventing their mechanical damage, since even partial destruction leads to deterioration of product quality and a decrease in its commercial value. Such an approach does not allow reliable prediction of energy transfer during impact or the subsequent trajectory of the granule. As a consequence, rotor speed and hammer mass are often selected without sufficient theoretical justification, which limits the efficiency and controllability of the separation process. To overcome these limitations, an analytical model describing granule impact and its post-impact motion in a rotating reference frame was developed. The mathematical formulation accounts for the combined action of centrifugal, Coriolis, gravitational, and friction forces, which made it possible to derive parametric relationships for velocity and displacement as functions of time. It was established that the post-impact motion follows a damped pattern, with the displacement amplitude decreasing by more than 60% within the first 0.02 s and exceeding an 80% reduction after 0.05 s. It was also found that energy transfer efficiency strongly depends on hammer mass. At a mass of 5 g, the efficiency reaches approximately 0.7–0.8%, whereas at 100 g it decreases to about 0.1%, and at 200 g it falls below 0.05%. These trends are explained by increasing dissipative losses within the rotating system. The proposed model enables prediction of granule trajectory, velocity, and energy dissipation under different operating conditions. Its practical value lies in providing a scientifically grounded basis for selecting hammer mass and rotor speed to achieve efficient and gentle separation of bee bread granules.

Keywords: bee bread, granule, rotor, mechanics, inertia, energy, trajectory, separation, dissipation, efficiency.

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DETERMINATION OF QUANTITATIVE RELATIONSHIPS BETWEEN THE NON-DIMENSIONAL AXIAL LENGTH OF AN ANNULAR PRE-TURBINE MIXING CHAMBER AND THE INTEGRAL CHARACTERISTICS OF TEMPERATURE FIELD UNIFORMITY

pages 32–37

Yurii Tereshchenko, Doctor of Technical Sciences, Professor, Department of Aviation Engines, National University "Kyiv Aviation Institute", Kyiv, Ukraine, ORCID: https://orcid.org/0000-0003-4367-3232

Illia Yudin, PhD Student, Department of Aviation Engines, National University "Kyiv Aviation Institute", Kyiv, Ukraine, e-mail: illiayudin98@gmail.com, ORCID: https://orcid.org/0009-0001-9934-553X

The object of the research is the annular mixing chamber of the pre-turbine duct of a three-stream aircraft turbofan engine, designed to enforce the mixing of hot and cold flows within a confined axial geometry, with particular emphasis on the gas-dynamic and thermal processes occurring within it. The research problem addressed in this research was the determination of the minimally required relative length of the mixing chamber. This length must ensure an acceptable level of temperature uniformity at the turbine inlet without increasing the overall dimensions of the propulsion system. This condition is particularly critical for compact engines, including propulsion systems for unmanned aerial vehicles. A series of three-dimensional CFD simulations was performed using ANSYS Fluent with a Reynolds stress model (RSM) for turbulence. The modeling was conducted for an annular chamber with fixed geometric parameters ($D = 1107$ mm, $d = 492$ mm) within a range of relative lengths $L^* = 0.42$–2.11. The research covered four different engine operating conditions, varying in bypass ratio. The results revealed a clear nonlinear dependence of the temperature non-uniformity coefficient θ on the relative chamber length L^*. It was found that for $L^* < 1.2$, the mixing process remains incomplete, accompanied by a significant increase in temperature non-uniformity. In contrast, within the range $L^* = 1.2$–1.7, nearly complete temperature equalization is achieved ($\theta \leq 0.1$). These results can be explained by the dominance of the turbulent mixing mechanism, as confirmed by low Richardson numbers ($R_i \ll 1$) and the minor influence of operating parameters compared to geometric factors. The findings can be applied in the design of compact mixing chambers for aircraft gas turbine engines, especially under strict constraints on their axial dimensions. This is particularly relevant for propulsion systems of unmanned aerial vehicles.

Keywords: gas turbine engine, annular mixing chamber, temperature non-uniformity, turbulent mixing, CFD modeling.

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MECHANICS

DEVELOPMENT OF UNIVERSAL MODEL FOR OPTIMIZING PARKING SPACES IN COMPLEX GEOMETRIC CONFIGURATIONS

pages 38–43

Mykola Mytko, PhD, Associate Professor, Department of Automobiles and Transport Management, Vinnytsia National Technical University, Vinnytsia, Ukraine, ORCID: https://orcid.org/0000-0002-5484-0510

Serhii Burlaka, PhD, Associate Professor, Department of Engineering Mechanics and Technological Processes in the Agricultural Industry, Vinnytsia National Agrarian University, Vinnytsia, Ukraine, e-mail: ipserhiy@gmail.com, ORCID: https://orcid.org/0000-0002-4079-4867

Oleh Antonuk, PhD, Associate Professor, Department of Automobiles and Transport Management, Vinnytsia National Technical University, Vinnytsia, Ukraine, ORCID: https://orcid.org/0009-0006-5348-4936

Alena Bondar, PhD, Associate Professor, Department of Construction, Urban Planning and Architecture, Vinnytsia National Technical University, Vinnytsia, Ukraine, ORCID: https://orcid.org/0000-0002-8098-1181

Dmytro Datsiuk, PhD, Senior Lecturer, Department of Engineering Mechanics and Technological Processes in the Agricultural Industry, Vinnytsia National Agrarian University, Vinnytsia, Ukraine, ORCID: https://orcid.org/0000-0002-4614-2245

The object of research is the process of designing and optimizing parking areas in complex geometric configurations in conditions of dense development.

The main problem is to solve the use of areas of complex geometric configuration for parking areas. In addition, there are currently no universal models and methods for the corresponding calculation and optimization.

The result of the work was the receipt of a universal mathematical model with which it is possible to determine the number of parking spaces based on the geometric dimensions and area of the plot. A special feature is the possibility of calculating for complex geometric configurations (polygons). For this, the Gauss formula and the JavaScript programming language are used. The initial data are geodetic measurements, and the error in such a calculation is less than 2 %.

The development of JavaScript code based on the shoelace formula was practical importance. The experimental object was the residential area "Vyshenka" in Vinnytsia (Ukraine). The selected plot has an area of 1350 m^2 with an initial number of parking spaces before optimization –50, after –59. In general, the efficiency of using the area increased from 70 % to 88 %. In addition, a 22 % reduction in accidents is noted, which indicates the significant effectiveness of the model and minimal calculation error.

A feature of the proposed solution is also that not only linear dimensions are taken into account, but also the relief, infrastructure facilities and the initial shape of the site. There is also the possibility of integration into web applications and CAD programs for simultaneous planning and construction, which allows for an increase in the number of parking spaces of up to 20 % without expanding the territories.

The results of the modeling can be used by engineers and builders to improve the landscaping of residential areas where there is no possibility for expanding the territories, programmers – by integrating the model into web applications and business.

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METALLURGICAL TECHNOLOGY

DETERMINATION OF THE INFLUENCE OF THE METHOD OF INTRODUCING C$_{60}$ FULLERENES AND FUNCTIONALIZED CARBON NANOTUBE ON THE FORMATION OF THE PROPERTIES OF ALUMINUM ALLOY

Mykola Trenov, *PhD Student, Department of Foundry, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine, ORCID: https://orcid.org/0009-0009-8899-6044, e-mail: djekgor4676@gmail.com*

Olga Ponomarenko, *Doctor of Technical Sciences, Professor, Department of Foundry, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0002-3043-4497*

The object of research is the influence of carbon nanotubes and fullerene nanomaterials C$_{60}$ when introduced into the aluminum alloy AK12 on the formation of the eutectic microstructure.

The problem solved during the research is the insufficient effectiveness of existing modifiers such as Sr, Na, TiC and SiC to improve silicon globularization, as well as the lack of simple and effective methods for introducing carbon nanomaterials.

In the work, two methods for introducing carbon nanoparticles into the aluminum alloy were developed. Improved silicon globularization, mechanical and physical properties were achieved. The thickness of the silicon dendritic axis was reduced to almost 20–25 microns, the size of silicon inclusions was reduced from 2–10 microns, and the microhardness was increased almost twice, depending on the method. The improvement of properties is due to the fact that nanoparticles become centers of crystal nucleation and do not allow them to grow, which leads to a finer, more homogeneous structure of the alloy. Pre-treatment of nanomaterials allows them to be evenly distributed in the alloy, and the addition of magnesium improves the wetting properties.

The features and distinctive features of the obtained results are that two technologically simple methods of introducing nanoparticles into the liquid AK12 alloy have been proposed, without the use of ultrasound. A significant improvement in the mechanical and physical properties of the alloy has been achieved compared to the reference AK12 alloy. Controlled grinding of the silicon structure has been ensured. Available materials and equipment, which are available in Ukraine and suitable for scaling up in industrial volumes, have been used. The modified AK12 alloy allows it to be used for the manufacture of castings of critical importance, such as pistons, transmission mechanisms, and engine housings.

Keywords: aluminum alloy AK12, fullerene C$_{60}$, carbon nanotubes, nanomodification, microstructure, hardness.

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TECHNOLOGY AND SYSTEM OF POWER SUPPLY

PROBABILITY-STATISTICAL APPROACH DEVELOPMENT TO THE SURVIVABILITY INCREACING OF POWER PLANT AUXILIARY GRID

Volodymyr Litvinov, *PhD, Head of Production-Technical Department, Branch "Dniprovska HPP" of Private Joint-Stock Company "Ukrhydroenergo", Zaporizhzhia, Ukraine, e-mail: v.v.litvinov1985@ukr.net, ORCID: https://orcid.org/0000-0003-1974-0976*

Oleksii Stetsiura, *Technician of 2-nd Category, Electro-Technical Workshop, Branch "Dniprovska HPP" of Private Joint-Stock Company "Ukrhydroenergo", Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0009-0007-1164-2358*

Alina Yerofieieva, *PhD, Associate Professor, Department of Electrical Engineering and Cyber-Physical Systems, Zaporizhzhia National University, Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-2981-4118*

The object of research is the operating modes and ways to increase the survivability of the power plant's own needs network under the influence of external emergency disturbances.

The power system of Ukraine today operates in extremely complex conditions. This is a consequence of the fact that the existing problems associated with outdated equipment have been added by external destructive influence due to geopolitical events. These factors cause a decrease in the structural and regime reliability of electrical networks. Under such conditions, the surviv-

ability of power plants and their own needs systems becomes of particular importance. The task of increasing the survivability of the power plant's own needs network is one of the multi-criteria tasks with a large number of uncertainties. To solve it, it is advisable to apply a probabilistic-statistical approach that takes into account the available random factors and makes it possible to make effective decisions. In the course of the research, an approach to assessing the survivability of the power plant's own needs network using a random number generator was developed, and the effectiveness of measures to increase it was determined.

This approach allows for a quantitative assessment of the survivability of the power plant's own needs network under conditions of uncertainties associated with the network and surrounding power system modes. The approach also takes into account the probability of equipment failure over a time interval and the consequences of geopolitical influence on the power system of Ukraine. The risk of an emergency situation occurring in the power plant's own needs network is taken as a quantitative criterion for assessing survivability. The developed approach and its implementation algorithm allow for a comparative analysis of the effectiveness of measures to increase the survivability of the power plant's own needs network and to select the most effective ones among them. According to the results of probabilistic and statistical modeling of the HPP's own needs network, it was determined that when using survivability measures, the risk of an emergency situation is reduced by 32%.

Keywords: survivability, power plant, own needs network, technical condition, emergency situation, probabilistic and statistical approach, risk.

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ELECTRICAL ENGINEERING AND INDUSTRIAL ELECTRONICS

DETERMINATION OF ELECTRICITY QUALITY INDICATORS IN DISTRIBUTION NETWORKS OF INDUSTRIAL ENTERPRISES WHEN USING STARTING DEVICES OF POWERFUL ELECTRIC DRIVES

pages 57–64

Oleksiy Gromovyy, PhD, Associate Professor, Department of Robotics, Electric Power Engineering and Automation named after Prof. B. B. Samotokin, Zhytomyr State Polytechnic University, Zhytomyr, Ukraine, ORCID: https://orcid.org/0000-0002-2761-0736

Smail Arailym, Doctoral Student, Department of Automation of Manufacturing Processes, NPJSC "Abylkas Saginov Karaganda Technical University", Karaganda, The Republic of Kazakhstan, ORCID: https://orcid.org/0009-0003-8395-3826

Smagulova Karshiga, Doctor of Philosophy (PhD), Associate Professor, Department of Automation of Manufacturing Processes, NPJSC "Abylkas Saginov Karaganda Technical University", Karaganda, The Republic of Kazakhstan, ORCID: https://orcid.org/0000-0001-6834-8490

Melikuziev Mirkomil, Doctor of Philosophy (PhD), Associate Professor, Department of Electric Supply, Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan, ORCID: https://orcid.org/0000-0003-3255-9741

Mila Baranovska, PhD, Associate Professor, Department of Electromechanical, Kryvyi Rih National University, Kryvyi Rih, Ukraine, ORCID: https://orcid.org/0000-0002-8082-1305

Andrii Romanets, PhD Student, Department of Electrical Engineering and Cyber-Physical Systems, Zaporizhzhia National University, Zaporizhzhia, Ukraine, e-mail: ivan.van.mi@gmail.com, ORCID: https://orcid.org/0009-0000-9893-8408

Ihor Novitsky, Doctor of Technical Sciences, Professor, Department of Cyberphysical and Information and Measurement Systems, Dnipro University of Technology, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-8780-6589

Anna Humeniuk, PhD, Associate Professor, Department of Robotics, Electric Power Engineering and Automation named after Prof. B. B. Samotokin, Zhytomyr State Polytechnic University, Zhytomyr, Ukraine, ORCID: https://orcid.org/0009-0008-3090-4752

Ilya Kolysnychenko, PhD, Associate Professor, Department of Cyberphysical and Information and Measurement Systems, Dnipro University of Technology, Dnipro, Ukraine, e-mail: kolysnychenko.i.yu@nmu.one, ORCID: https://orcid.org/0000-0003-4495-0895

Dmytro Bilukhin, PhD, Associate Professor, Department of Energy and Economic Process Management, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-2791-617X

The object of research is the processes of electromagnetic transformation in powerful asynchronous electric drives during controlled start-up and their impact on the quality of electricity in the power supply network. Distribution networks of industrial enterprises are considered, which have significant dynamic loads during the start-up of powerful machines.

The problem to which the research is aimed is to ensure proper quality of electricity in distribution networks of industrial enterprises when performing controlled start-up of powerful asynchronous electric drives from soft starters based on a thyristor voltage regulator.

Quantitative indicators of the influence of starting devices on the parameters of electricity quality were calculated using computer modeling in the MATLAB/Simulink environment. Soft start using a thyristor regulator, although it limits the starting current, has a negative impact on the quality of electricity in the distribution network. Reactive power consumption increases, which causes a voltage drop. For the case of starting an asynchronous motor with a capacity of 3500 kW in the network of a sintering factory, it was found that direct start causes a voltage drop of about 350 V. Harmonic voltage distortions with a distortion factor of up to 6% also appear. Power active filters allow to improve the quality of electricity by introducing antiphase currents, which is proven by the application of theoretical methods of electrical engineering.

The results obtained are applicable in the design of electric drive systems of powerful mechanisms during the modernization of the power supply of industrial enterprises, in the calculation of reactive power compensation means and in the development of energy quality standards. This will significantly contribute to increasing the reliability of technological equipment, reducing energy losses, and increasing the service life of electrical equipment at the enterprise.

Keywords: starting devices, power quality, controlled reactor compensator, simulation modeling of the distribution network.

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