ABSTRACT AND REFERENCES

APPLIED PHYSICS

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A SIMPLIFIED METHOD FOR THE NUMERICAL CALCULATION OF NONSTATIONARY HEAT TRANSFER THROUGH A FLAT WALL (p. 4-13)

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The nonstationary operation modes of power equipment lead to the nonstationary regimes of heat exchange, in particular heat transfer. The transient processes, related to the accumulation of energy in the heat-transmitting surfaces, which manifest themselves in this case, may affect manageability of the work of equipment.

Although in many cases, with a proper approximation, the heat exchange surfaces can be represented in the form of a simple variant of an infinite plate, the existing methods and tools for solving the problems on nonstationary heat transfer are built from the positions of universalism, introducing unjustified complications and hampering the generalization of numerical results obtained. We developed a simplified discrete analog to solve the one-dimensional problems on nonstationary heat transfer through an infinite plate. The realized approach allowed us to obtain the analog and results of calculations based on it in the dimensionless form, which substantially facilitates their generalization.

A high stability of computational process is demonstrated relative to the selection of a number of nodes in computational grid and calculation step by time. The possibility of using the maximally small computational grids (3 nodes) makes it possible, at the current calculation step by time. To obtain an analytical solution for determining the temperatures at the surfaces of the plate at initial use of boundary conditions of the third kind. As a result, accumulated energy can be defined as a difference in the heat fluxes at the surfaces of the plate. Performing the calculations on the maximally small grids might be useful to solve the inverse problems on thermal conductivity.

Keywords: nonstationary heat transfer, flat wall, simplified numerical computation, small computational grid.

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NUMERICAL MODELING OF PHYSICAL FIELDS IN THE PROCESS OF DRYING OF PAPER FOR CORRUGATING BY THE INFRARED RADIATION (p. 14-22)

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By using a numerical model, developed based on the proposed physical and mathematical models, we performed a numerical study of non-stationary temperature fields and moisture content of the process of infrared radiation drying of fluting. A distinctive feature of present study is a combined consideration of the kinetics of drying process, translucency to the IR radiation of the material using the approximations of the Burgers' models, "gray" medium and diffuse reflection of boundaries. Verification of the numerical model demonstrated a convergence of results of numerical modeling of the fluting surface temperature, duration and speed of its drying with the data of physical experiment within the range of 5 % on the interval of change in the square meter mass of dry fluting from 0.112 kg/m^2 to 0.2 kg/m^2. It is substantiated that the developed numerical model makes it possible to define kinetic patterns and basic parameters required to intensify the process of drying and to design the appropriate equipment.

Keywords: paper for corrugating, fluting, infrared radiation, moisture content, duration of drying, mathematical model.

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EXAMINING THE TEMPERATURE FIELDS IN FLAT PIECEWISE- UNIFORM STRUCTURES (p. 23-32)

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The paper considers linear and non-linear mathematical models for the thermal conductivity process in designs that are described by a plate and a layered plate with a foreign parallelepiped-shaped through-inclusion on whose one boundary surface heat flux is concentrated. Classic methods do not make it possible to solve the boundary problems of mathematical physics that match these models in a closed form. Given this, in the present work we propose an approach that is based on the fact that the thermal-physical parameters for the piecewise uniform environments are described using generalized functions as a single entity for the whole system. As a result, we obtained one equation of thermal conductivity with generalized derivatives for the entire system with boundary conditions at the boundary surfaces of non-uniform environments. In a classic case, the process of thermal conductivity would be described by a system of equations of thermal conductivity for each of the elements of a non-uniform environment with conditions for an ideal thermal contact at the interface surfaces of non-uniform elements and boundary conditions on boundary surfaces of non-uniform environments. For the case of non-linear models, the condition of temperature equality at the interface surfaces of non-uniform elements of the designs is not applicable. With regard to the aforementioned, this work proposed yet another approach, which is in the introduction of linearizing functions that make it possible to linearize corresponding nonlinear boundary problems for these designs, which, as a result, allows us to solve this kind of boundary problems in mathematical physics. We received calculation formulas for determining the temperature field in the examined thermosensitive systems in the case of linearly variable coefficient of thermal conductivity of design materials. By using the obtained analytical-numerical solutions of linear and nonlinear boundary problems for the given piecewise-uniform structures, we created computational programs that make it possible to obtain the numerical values of temperature distribution and analyze the structures in terms of thermostability. As a result, it becomes possible to improve thermal stability of these designs and thus protect them from overheating, which can cause destruction of separate elements and even entire systems.

Keywords: thermal conductivity, temperature field, a foreign through-inclusion, thermosensitive system, heat flux.

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RESEARCH INTO THE INFLUENCE OF AL_2O_3 NANOPARTICLE ADMIXTURES ON THE MAGNITUDE OF ISOPROPANOL MOLAR VOLUME (p. 33-39)

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The results obtained in experimental study of density of solutions of isopropyl alcohol and Al_2O_3 nanoparticles are given. Studies on nanofluid density were carried out using pycnometric method in a temperature range from 250 K to 315 K at weight concentrations of nanoparticles 0.92 %, 1.81 %, 4.01 % and 6.65 %. The obtained data made it possible to reveal temperature and concentration dependences of the studied nanofluids and calculate magnitude of the excess molar volume as well as hydrodynamic diameter of nanoparticles. The data on the value of hydrodynamic diameter obtained from the information on excess molar volume were in good agreement with the data measured by the method of dynamic light scattering. It was shown that the equivalent diameter of the adsorption layer of isopropanol molecules on nanoparticles decreases with an increase in concentration of Al_2O_3 nanoparticles. Based on these studies, a new method for predicting molar volume of nanofluids was proposed. This technique takes into account presence of a sorbed layer of base fluid molecules on the nanoparticle surface. As the studies show, density of the sorption phase is higher than density of isopropyl alcohol at the set-up parameters. Presence of a sorption layer of isopropyl alcohol molecules on the nanoparticle surface determines magnitude of the excess molar volume. This fact has to be taken into account when simulating density of nanofluids.

A simple method was also proposed for determining equivalent diameter of the adsorbed layer of base fluid molecules on the nanoparticle surface. The essence of the method is an assumption that nanoparticles have a shape close to spherical and the surface layer is a spherical layer of sorbed isopropanol molecules on the nanoparticle.

This method allows determination of the equivalent diameter from easily measured data. It is recommended for use in modeling viscosity, thermal conductivity and heat capacity of nanofluids. It is also recommended for use in development of heat exchange models for power equipment.

Keywords: nanofluid, density of nanoisopropanol, molar concentration, hydrodynamic radius, prediction technique, three-phase model.

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INVESTIGATION OF THE INFLUENCE OF TECHNOLOGICAL CONDITIONS OF MICROARC OXIDATION OF MAGNESIUM ALLOYS ON THEIR STRUCTURAL STATE AND MECHANICAL PROPERTIES (p. 39-43)

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We examined the patterns in the formation of MAO-coatings on magnesium alloys. Low density and high specific strength of magnesium alloys is the basis for their widespread use. However, poor corrosion resistance of magnesium alloys limits the scope of their application. This problem is solved by transforming the surface layer of magnesium alloys into the multiphase coatings that consist of crystalline oxides and salts of magnesium. The most effective formulations of electrolytes were selected to ensure obtaining the MAO layers of good quality. We explored the phase composition of coatings, hardness, adhesion between coatings and the base, and their protective properties. It was found that the most effective are the multi-component electrolytes containing alkali NaOH, sodium aluminate $NaAlO_2$ and sodium hexametaphosphate $Na_5P_3O_{10}$. The MAO treatment provides strengthening of surface (hardness of coatings is 2000–6600 MPa) and improves protective properties. It is demonstrated that the highest protective properties are displayed by the MAO-coatings that contain in their composition, along with MgO, the $MgAl_2O_4$ spinel. Protective properties are improved with an increase in the spinel content. This is due to the fact that the occurrence of spinel in the composition of a coating, in contrast to MgO, is accompanied by the increase in specific volume of the coating, resulting in the occurrence of compressive stresses and, as a consequence, in the formation of thicker coatings. The recommendations are given regarding

the changes in the composition of electrolyte and parameters of electrolysis to ensure an increase in spinel in the composition of the coating.

Keywords: structural engineering, microarc oxidation, magnesium alloys, phase composition, adhesion strength, hardness.

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RESEARCH INTO THE ENERGY CONVERSION PROCESSES IN HYBRID PLASMA DEVICES FOR APPLYING THE COATINGS (p. 44-51)

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We investigated the processes of transformation of the incoming energy flows into thermal energy of the jet in the arc channel of plasma generator. As the plasma-forming gases, we used the mixtures of air with hydrocarbon gases. It is demonstrated that plasma generators that employ such gas mixtures have two channels for the introduction of energy (the energy of electric arc and the energy of combustion products of combustible gas in the oxidizer) and can be categorized as hybrid devices. The fact of mutual influence of the sources of energy, which is introduced, is proven. Transition to a more complex gas system increases the power of electric arc that burns inside it.

Experimentally confirmed is the practical possibility to shift the region of combustion of the components of gas mixture beyond the limits of the arc channel of plasma generator. We established effect of the content of combustible component of the original mixture on the magnitude of energy share that is released outside the plasmatron in the plasma jet. The possibilities to control total capacity of the device and its specific energy characteristics by changing operational parameters of plasma generation are estimated. We established a leading role of the composition of original plasma-forming mixture in this process.

Keywords: plasmatron, plasma-forming mixture, combustible gas, plasma, stored energy, jet parameters.

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DETERMINING PARAMETERS OF ELECTROMAGNETIC RADIATION FOR ENERGOINFORMATIONAL DISINFECTION OF WOOL IN ITS PRETREATMENT (p. 52-58)

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The paper is devoted to solution of theoretical and experimental problems in development of electromagnetic (EM) technology in the millimeter wavelength range for disinfection and warming of baled wool during its processing.

Sheared wool is an environment well fit for existence of a variety of microorganisms. It was established that 1 kg of wool contains 400 to 7000 million bacteria. This often leads to workers infection with pathogens of brucellosis, mytero-sis, glanders, toxicoplasmosis, ku-reketmosis, leptospirosis, anthrax and plague.

When storing unwashed wool, especially at low temperatures, its compression and fat hardening take place. Fat softens and the rune easily unfolds at temperatures of

25...30 °C. This improves sorting quality and preserves natural wool properties.

In this regard, the work studied the regularities of influence of EM energy in the millimeter wavelength range on the pathogenic microorganisms existing in wool.

As a result of the studies, a range of changes in the biotropic EMF parameters was determined for destruction of microorganisms. The performed calculations have shown that the biotropic parameters of electromagnetic field include frequency range of 35.3...36.3 GHz; power flux density of 1.25 mW/cm^2, exposure time of $2 \cdot 10^3$ s.

Theoretical analysis of the model of warming up baled wool have shown that the temperature rise up to 24...40 °C is possible when wool is exposed to EMF with the following parameters (frequency; power flux density; exposure time): 36 GHz; 1.25...1.5 mW/cm^2; 120...180 s.

It was established that when wool was exposed to an EMF with certain biotropic parameters, wool breaking load increased by 200...300 cN and relative strength increased by 2...3 cN/tex in comparison with the control runs. The study results make it possible to create an environmentally friendly and efficient technology for primary wool processing by EM energy.

Keywords: electromagnetic radiation of millimeter range, infectious microorganisms, biotropic parameters, wool disinfection.

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DETERMINING THE CHARACTERISTICS OF DIFFRACTED WAVES OF SMALL AMPLITUDE AROUND A VESSEL IN SHALLOW WATER (p. 59-67)

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The vessels at outer anchorage are exposed to the influence of a complex system of waves. This system is formed by the incident and diffracted waves. In order to examine characteristics of a wave field around the vessel, which floats idling at outer anchorage, we solved two problems.

The first problem is determining the velocity potential of diffracted wave motion, caused by the incidence at arbitrary angle of regular waves with small amplitude to a stationary vessel under conditions of shallow water. The solution is executed by the matched asymptotic expansion method (MAEM). The region filled with fluid is conditionally divided into the internal and external zones. In both zones, separate boundary problems are stated, and they are considerably simpler than the initial boundary problem for the entire region. The solutions of the problems are asymptotically merged at the border of zones.

The second problem is defining the characteristics of waves near a vessel. From the expression for a speed potential we derived the equation of perturbed free surface. The calculations are conducted of the waves' amplitudes in the assigned points around the vessel. The variable parameters are the depth of water area, wavelength and a course angle of waves. The examples of wave fields are given.

Determining the characteristics of a wave field transformed by the vessel is important for planning the operation of auxiliary ships (tugboats, bunkering vessels, pilot and port roads boats, as well as oil/garbage collector boats and boom crafts). This work is connected with the safety of traffic in the open sea (transfer of people and loads from one vessel to another) and with ecological safety (elimination of oil and petroleum spills). Wave height is the limiting factor for operating the auxiliary vessels, which is why determining it properly is a necessary task.

Keywords: diffraction of linear waves on a vessel, matched asymptotic expansion method, shallow water.

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