ABSTRACT AND REFERENCES

APPLIED PHYSICS

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RESEARCH OF A MICROWAVE RADIOMETER FOR MONITORING OF INTERNAL TEMPERATURE OF BIOLOGICAL TISSUES (p. 6-15)

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Currently, there is growing interest among specialists in the use of non-invasive no-dose technologies for diagnosis and monitoring treatment of various diseases. Microwave radiometry enables non-invasive detection of thermal abnormalities of internal tissues of the human body. The current level of development of the method of microwave radiometry makes it possible to non-invasively detect malignant tumors at early stages according to characteristics of the person's own radiothermal fields. For a wider implementation of the method, it is necessary to overcome a series of scientific and technical barriers that impede its development. First of all, it is necessary to ensure miniaturization of the device used.

An analytical review of the current state of development in the field of medical radiometers has been performed. Miniaturization of device is an important area for studies. It was shown that application of the proposed scheme for designing a null balance radiometer with a sliding circuit of reflection compensation with two matched RF loads will enable creation of a miniature highly stable radiometer. The measurement error of this device does not depend on the ambient temperature, ambient temperature of the device and impedance of the studied area of the body. The device calibration procedure was considered and noise signal calculations were performed. Results of experimental verification of correctness of choice of the way of designing the miniature radiometer circuit were presented. Introduction of thermal compensation has made it possible to reduce measurement error associated with the device heating to 0.2 °C when ambient temperature of the radiometer changed by 20 °C. It was shown that a radiometer operating in the frequency band 3.4–4.2 GHz can be used to detect various diseases and monitor internal temperature of tissues during treatment. With introduction of autonomous power supply and wireless communication with a smartphone, the miniature radiometer can be used as a wearable device to monitor temperature of internal tissues in everyday human life.

Keywords: microwave radiometry, temperature monitoring, medical radiometer, brightness temperature, medical robotics, printed antenna.

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DEVISING A PROCEDURE TO CHOOSE OPTIMAL PARAMETERS FOR THE ELECTROMECHANICAL SHOCK ABSORBER FOR A SUBWAY CAR (p. 16-25)

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A procedure for determining basic estimation parameters has been devised for the proposed structure of the electromechanical shock absorber. The procedure is based on a simplified mathematical model for determining the electromagnetic and electromotive force for the electromechanical shock absorber. Feature of the model is taking into consideration the operational modes of permanent magnet based on the calculation of a magnetic circle. The model devised makes it possible to perform approximate calculation of the shock absorber operational modes and could be used for solving the problem on the optimization of parameters for an electric shock absorber. We have verified adequacy of the constructed simplified mathematical model by comparing the results from calculating the mechanical characteristic for a shock absorber based on the simplified procedure and those obtained using a finite element method in the axial-symmetrical statement of the problem. There is a good match between the results from calculations based on the simplified procedure and from modeling a magnetic field using the method of finite elements. We have determined the geometric relationships between the elements of the structure that ensure the optimal uniform magnetic load on the elements of the magnetic circuit. The problem on the conditional two-criteria optimization of parameters for the electromechanical shock absorber has been stated. We have chosen constraints that are divided into the three following categories. Constraints for a permanent magnet demagnetization that make it possible to maintain operability of the permanent magnet. Constraints for a current density, which ensures the thermal modes in the shock absorber operation. Constraints for assembly and constraints for the parameters of an optimization problem, which enable the arrangement of a structure within the running part of a carriage. It has been proposed to choose the reduced volume of a shock absorber as a criterion, which predetermines the cost of constructing a shock absorber, and its efficiency as a criterion, which predetermines the recuperated energy of oscillations. The parameters were convoluted to a single objective cost function; the weights were defined. We have chosen, as an optimization method, the combined method that includes a genetic algorithm at the preliminary stage of the search. At the final stage of an optimization procedure an optimum is refined by using the Nelder-Mead method. The result from solving the optimization problem on the shock absorber's parameters is the defined optimal geometric dimensions and the number of turns in the winding of the electromechanical shock absorber.

Keywords: electromechanical shock absorber, subway car, magnet, convolution of parameters, genetic algorithm, the Nelder-Mead method.

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EXPERIMENTAL RESEARCH INTO THE INFLUENCE OF TWOSPARK IGNITION ON THE DEFLAGRATION TO DETONATION TRANSITION PROCESS IN A DETONATION TUBE (p. 26-31)

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The paper reports a study into the initiation of detonation in pulse detonation engines. The chosen direction to resolve this issue is the use of detonation tubes with multifocal ignition. We applied two spark discharges as a source of ignition, which ignited synchronously. The spark discharges were ignited at a distance, which provided for the intensive gas-dynamic interaction between the discharges. The interaction implied a collision between shock waves generated by the spark discharges. As a result, the growth in temperature of gas was ensured in the region between spark intervals, due to a collision between the oncoming shock waves.

The influence of dual spark ignition on the time and length of the section where deflagration transfers into detonation along a detonation tube was studied by comparing the transition parameters for cases of single-spark and dual spark ignition all other conditions for research being equal. The study involved a detonation tube with a length of 2.3 m and an inner diameter of 22 mm. Spark plugs were located at the closed end of the tube. We applied a stoichiometric mixture of propane with oxygen, diluted with nitrogen by 50 % at the initial pressure in the mixture equal to 50 kPa. To register the time of propagation of the flame front and to measure the process rate, the tube was equipped with 22 ionization sensors. Distance between the sources of ignition was 6 mm. Length of the discharge interval at each source of ignition was 2.5 mm. Sources of ignition in the form of spark plugs were connected to high-voltage units with a total discharge energy of 3.3 J.

The results of our study helped establish a reduction in the distance of deflagration to detonation transition by 1.6...2 times, and in the time of transition – from 3.9 ms to 1.2 ms for the case of the transition from single-spark to dual spark ignition.

The results obtained could be used when designing ignition systems for pulse detonation engines.

Keywords: detonation tube, multifocal ignition, deflagration to detonation transition, spark ignition.

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RESEARCH INTO THE RECOVERY OF EXHAUST GASES FROM ICE USING AN EXPANSION MACHINE AND FUEL CONVERSION (p. 32-38)

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We have devised a scheme for the energy-generating unit based on the internal combustion engine 1Ch 6.8/5.4 with a spark ignition and a two-stage system for the recovery of heat from the exhaust gases. The basic elements for the first and second stages of the heat recovery system have been selected. A first stage involves a rotary piston expansion machine while a second stage employs the fuel conversion.

We have studied effective parameters for the engine 1Ch 6.8/5.4 with a system of the deep two-stage recovery of heat from exhaust gases under different modes of operation. The dependences were established for change in the specific effective fuel consumption on the power of the energy-generating installation using only the conversion of fuel and in a combination with the expansion machine.

The dependences have been derived for the operational parameters of a rotary piston engine on consumption of a working body. We have determined temperatures of the working bodies in a reactor and the heat capacity of exhaust gases depending on the load on the engine, as well as the necessary amount of energy to convert ethanol into synthesis gas. The dependences have been obtained of the degree of ethanol conversion on the reaction temperature and the mass flow rate through the reactor. We have established the dependence of specific heat of the chemical reaction on the degree of conversion.

It was established that when reaching full conversion in line with the reaction of decomposition the entire liquid ethanol is completely converted into combustible synthesis gas, whose main components are hydrogen, carbon monoxide, and methane. The estimated specific lower combustion heat of the synthesis gas is 28.79 MJ/kg. Obtaining 1 kg of synthesis gas requires 4.0 MJ of thermal energy.

It was determined that under condition of applying the conversion of fuel and, accordingly, the addition of synthesis gas, the specific effective ethanol flow rate, depending on the mode of engine operation, decreases by up to 12 %. The amount of energy that needs to be used in the reactor for obtaining synthesis gas is 50...65 % of the heat released with the exhaust gases under a given mode of operation.

It has been established that the application of a rotary-piston expansion machine that acts as the first stage in the recovery of heat from exhaust gases has made it possible to gain an increase in the capacity of the energy-generating unit of 27 %.

It has been found that the use of two stages of heat recovery leads to a decrease in the specific effective fuel consumption by 29 %

Keywords: conversion, ethanol, synthesis gas, exhaust gases, fuel, rotary piston expansion machine.

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DETERMINING THE CHARACTERISTICS OF DIFFRACTED SEA WAVES OF FINITE AMPLITUDE AROUND A VESSEL IN CONSIDERABLE SHALLOW WATERS (p. 39-48)

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Vessels at shallow-water outer anchorage are exposed to a complex system of waves. This system results from the diffraction of sea-incident waves against a ship. When entering shallow waters, three-dimensional waves turn into two-dimensional ones. The wavelengths decrease while their periods are retained. Crests of the waves grow higher and become sharpened. A vessel at outer anchorage is surrounded by the emerging transformation zone where the waves become three-dimensional again. Defining characteristics for the sea waves, transformed by a vessel, is important for carrying out operations on eliminating oil spills. Tugboats, oil garbage collectors and boom crafts should work at any point around a vessel in emergency, in particular, from the side of incidence. That is why dimensions of the zone of waves' transformation and the height of the waves in this zone define the safe operation of auxiliary ships. The available solution to the linear diffraction problem should be reworked to enable application of the nonlinear theory of waves.

The paper gives an equation of a wave profile at the preset points of observation around a stationary elongated vessel in considerable shallow waters. The equation was derived from the expression for the potential of velocities of the diffracted wave motion caused by the incidence of oblique regular waves with finite amplitude. The characteristics for incident waves were determined from the Stokes theory of fifth order. The non-linear problem has been transformed to a combination of five linear problems. It was solved using the method of matched asymptotic expansions (MAEM).

Based on the derived formulae, we calculated wave profiles at the assigned points around a vessel at the predefined time. There are variations in the depth of water area, the slope of waves, the course angle of waves. Examples have been provided for the profiles of nonlinear and linear waves in the plane of a vessel's cross section. We have demonstrated the similarities and differences between the linear and nonlinear waves around a vessel at shallow-water outer anchorage.

Keywords: diffraction of nonlinear waves against a vessel, method of matched asymptotic expansions, considerable shallow waters.

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MODELING THE PROCESS OF OIL DISPLACEMENT BY A HEAT CARRIER CONSIDERING THE CAPILLARY EFFECT (p. 49-55)

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The manuscript is aimed at improving the mathematical model of oil production in a heterogeneous environment with the use of a thermal mode of displacement considering the action of capillary effect. We have constructed an algorithm to solve numerically the respective nonlinear boundary value problem on multiphase filtering by introducing the function of quasi-potential φ and the respective, conjugated thereto, flow function ψ. In this case, the quasi-potential is represented in the form $\varphi = -p_o + \int_0^{s_w} f(\tilde{s},T)\frac{dp_c(\tilde{s})}{d\tilde{s}}\mathrm{d}\tilde{s}$, thereby having essentially simplified the overall strategy to split the algorithm for solving the original problem.

Owing to the algorithm, which is based on the ideas of methods for quasiconformal mapping and staged registration of parameters, we have carried out calculations of the hydrodynamic grid, velocity fields, temperature, saturation, taking into consideration the impact of a capillary effect and when ignoring it. In particular, the charts of saturation fields demonstrate a difference in the ratio of percentage content of a displacing fluid up to 15 % at temperatures above 80 °C, which explains the effect of capillary forces. Instead, at temperatures from 50 °C to 70 °C the difference is not noticeable, though at 50 °C and below the results of flooding slightly differ (to 5 %) for the worse in terms of the actual representation of the process. In this case, it is believed that the dynamic viscosities of phases change with a change in temperature, the fluid movement is slow and occurs without phase transitions, while functions of relative phase permeabilities and capillary pressure are the known and unambiguous saturation functions.

Numerical calculations of multiphase non-isothermal filtering in the symmetry element at a five-point system of flooding have been presented. In this case, it was found that taking into account the capillary effect makes it possible to not only predict the location of stagnant zones, but also to more accurately estimate the time when a displacing reagent breaks through in an operational well in order to effectively perform respective waterproofing operations.

Keywords: oil production, cracks from hydraulic fracturing, numerical methods of quasiconformal mappings, nonlinear problems.

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IMPROVING THE DIAGNOSTICS OF UNDERGROUND PIPELINES AT OILANDGAS ENTERPRISES BASED ON DETERMINING HYDROGEN EXPONENT (PH) OF THE SOIL MEDIA APPLYING NEURAL NETWORKS

(p. 56-64)

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A set of key parameters and information flows has been formed to simulate stages of probing the outside surface of underground metal pipelines (UMP) taking into account pH of the soil contacting with the pipe metal.

Specimens of 17G1S steel placed in acid, alkaline and neutral media were examined using a polarization potential meter in a complex with a contactless current meter. Principles of application of neural networks (NN) in processing experimental results were formulated. A database has been developed. It meets the initial conditions for controlling the soil pH at the boundary with the metal under real conditions.

Elements of the optimization approach for assessing pH of a coated UMP in the soil medium were proposed. The approach is based on the multiplicative qualimetric criterion of quality for the UMP section taking into account two groups of coefficients. The first group of coefficients refers to the internal coefficients and characterizes the metal pipeline and the second group refers to the external medium (i.e., soil electrolyte). Elements of the optimization approach for assessing pH of the coated pipeline in the soil medium were proposed.

An NN was presented for the "pipeline-coating" system, which:

1) is capable of solving the problem of cluster analysis and image classification;

2) makes it possible to process data without their prior spectral transformation operating with discrete counts of information signals.

The proposed NN type allows it to dynamically expand its own knowledge base of possible types of defects in controlled objects (pipelines) in the process of operation. With the help of the NN, soil pH was assessed for an UMP of 17G1S steel for three situations.

The above information is important for improving the methods for controlling oil-and-gas enterprise UMPs, in particular, the methods for a correct assessment of anode current density in metal defects taking into account nonlinear character of informative parameters.

Keywords: underground pipelines, oil-and-gas enterprises, corrosion currents, polarization potential, hydrogen exponent, neural network.

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DESIGNING A SYSTEM OF LIQUID COOLING FOR INDUSTRIAL MICROWAVE INSTALLATIONS (p. 65-70)

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The paper considers the issue on ensuring a thermal regime of the magnetron's anode unit by replacing an air-cooling system with the system of liquid cooling. It has been argued that a liquid cooling system is most suitable for magnetrons, for which currently an air-cooling system is implied, although they are not designed for a continuous operation in the structure of industrial microwave installations. Arranging the system of liquid cooling would makes it possible for a magnetron to work over long time without overheating and under favorable conditions, which rule out a possibility to clog the heat exchange surface with particles and dust, as well as the occurrence of overheating of the anode unit's surface. The basic element of the proposed system for liquid cooling is a cooling jacket, which represents an annular channel made from a heat-conducting material. Cooling jacket is mounted directly on the anode unit; in this case, a compression ratio of surfaces and the thickness of an air gap must ensure a minimum total thermal resistance. In order to determine heat transfer coefficients, an empirical dependence was established, which reflects the fact that when cooling the anode units the rational regimes are the viscous and transitional motion modes. The basic thermal characteristics of the cooling process have been defined, which include a coefficient of heat transfer, change in a heat-carrier temperature, the maximally permissible temperature at inlet. Calculations were carried out for two types of heat-carriers: water and a 54 % aqueous solution of ethylene glycol. A circuit for the system of liquid cooling has been proposed, which implies cooling from 1 to 6 magnetrons. Applying a given circuitry and choosing the rational estimated modes make it possible to solve the task on improving production efficiency, as well as reliability of microwave equipment.

Keywords: cooling system, anode, magnetron, thermal resistance, heat-carrier, heat-carrier, heat transfer coefficient.

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