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SUMMARY and KEYWORDS

MECHANICS

Yu. A. Burian, M. V. Silkov
Vibration isolation with quasi-zero stiffness effect

The study relates to an important direction of applied mechanics — the theory of vibration isolation of vibroactive objects, such as generators, engines, pumps, compressors, fans, pipelines, etc. The design is proposed, mathematical modeling questions are considered and expressions are obtained for choosing the necessary parameters simple and promising supports using quasi-zero stiffness. It is shown that the proposed support allows to extend towards low frequencies the range of reduction of the force transfer coefficient to the base and thereby improve the vibration isolation of various technological objects.

Keywords: vibration isolation, quasi-zero stiffness, mathematical model of elastic suspension, pneumatic spring, the coefficient of force transfer to the base.

V. S. Korneyev, V. V. Shalay
Linearized mathematical model of rubber-cord shell

The procedure of linearization of the previously constructed mathematical model of a rubber-cord shell of rotation with elastically deformable cord threads under symmetric loading with internal excessive pressure and axial force is performed. The characteristic specialty of the linearized mathematical model is analyzed, special attention is paid to the correct choice of the unloaded reference configuration, which takes place not at zero excess pressure, but at excess pressure tending to zero. It is noted that the linearized mathematical model is of the greatest practical interest for analytical calculation and design of rubber-cord branch pipes and pneumatic sleeve-type shock absorbers with optimal performance characteristics.

Keywords: rubber-cord shell of rotation, mathematical model, linearization, unloaded configuration.

POWER AND CHEMICAL ENGINEERING

Yu. B. Galerkin, A. A. Drozdov
New version of Universal modeling method for centrifugal compressors calculation development

Similarity theory principles are widely applied in gas dynamic design. But completely new solutions must be realized on a base of engineering approaches to predict performances. The math model of Universal modeling method is a sum of algebraic equations for calculation of head losses. Some Russian and foreign manufacturers realized several dozens of designed compressors with power up to 32 MW designed by Universal modeling method. The experience of programs application allowed to work out the directions of mathematical model development for the new, 9th version of Universal modeling method. For 3D impellers calculation quasi-three-dimensional approach is used. The flow parameters are calculated on 8 blade-to blade surfaces. A new loading factor model was applied. It determines characteristic by the angle of inclination and the value of the loading factor at zero flow rate. A new losses model in a vaneless diffuser based on the results of CFD calculations generalization is used. The new model allowed more accurate calculation of

narrow vaneless diffusers as compared to the previous model. Identification of the new mathematical model by the characteristics of model tests of centrifugal compressor stages is made. The efficiency calculation accuracy was sufficient for the engineering method.

Keywords: centrifugal compressor, loading factor, vaneless diffuser, flow rate coefficient, efficiency, mathematical model, impeller.

V. I. Karagusov, I. N. Pogulyaev
Average daily cooling capacity of radiation conditioning system

Relevance of the main advantages of radiation cooling is autonomy, i.e. independence of radiation cooling systems from electrical and thermal energy. The operation of radiation life support systems does not require significant costs, either during creation or during operation. The purpose of the study is to determine the possibility of using a radiation cooling system for air conditioning in residential or office premises. The task of the study is to determine the cooling capacity of the radiation air conditioning system. Experimental studies have shown that the radiation conditioning system has a cooling capacity in summer from 4 to 7 kW with a radiation cooler of 100 m^2.

Keywords: radiation cooling systems, life-support systems, heat flow, heat insulation, renewable energy, conditioning.

A. A. Malyshev, A. V. Zaitsev, K. F. Kuadio, K. V. Kisser
Experimental research of hydrodynamic characteristics during boiling of refrigerants in minichannels using true parameters of phases

This paper is devoted to the development of an integrated method for calculating heat hydrodynamic characteristics of two-phase flows taking into account the specificity of the flow in minichannels. The proposed approach is based on the methodology for calculating the true volumetric vapor quality and the prediction of two-phase flow regimes. The paper presents experimental data on true volumetric vapor quality and a modified map of flow regimes.

Keywords: minichannel, two-phase flow, steady flow, true volumetric vapor quality, flow regime, diagram of flow regimes, Froude criterion, Weber criterion.

N. A. Raykovskiy, V. L. Yusha, A. V. Tretyakov, V. A. Zakharov, K. I. Kuznetsov
The method for studying temperature deformations of self-lubricating bearing friction units of high-temperature low-flow turbine

In the paper proposes a method for the numerical study of temperature deformations of cooled selflubricating turbo-compressor bearings, the cooling system of which is implemented by the «water jacket» type based on the ANSYS CFX. Approbation of the method is implemented on the example of a low-flow turbine unit with a console arrangement of two bearing units. The method of engineering analysis in terms of temperature deformations, taking into account the temperature field corresponding to the actual operating conditions, provides an acceptable deviation in the calculation results.

Keywords: self-lubricating bearing, cooling system, turbo unit, deformation.

V. V. Karabanova, A. D. Vanyashov, V. L. Yusha
Some features of implementation of design model of high-pressure centrifugal compressor stage with inlet guide vanes

The analysis of implementation features of the mathematical model of a transonic centrifugal compressor stage with an input guide vanes (IGV) and a semi-open axial-radial impeller has been carried out. The flow study is performed using the Navier-Stokes equations, closed by the Shear Stress Transport (SST) turbulence model. The simulation is performed for the regulation mode at a reduced rotational speed of 28,076 rpm and two IGV angles of rotation in a wide mass flow range. In the course of the study, the parameters of the design model (density of the mesh, inter-mesh connection of the two elements of the flow path) are considered and the effect of the tip between the impeller blades and the body on the gas-dynamic characteristics of the stage is evaluated. According to the results of the study, the most significant parameters that affect the accuracy of the results obtained are established.

Keywords: compressor centrifugal stage, semi-open axial-radial impeller, gas-dynamic characteristics, transonic flow, computational fluid dynamics.

T. V. Ryabova, A. B. Sulin, A. K. Rubtsov, S. S. Muraveinikov
Modeling of radiant heat exchange processes

It is proposed to use an imitation model with a black globe thermometer to analyze the processes of the room thermal regime formation. The model is verified by the results of a physical experiment. The indicators of the radiation factor are taken into account in the dependences of the average radiation temperature difference on the deviation of the temperature of the globe thermometer. On the basis of the proposed model, numerical experiments are performed on the example of a room model with heat-emitting panels and a cooled ceiling.

Keywords: modeling of heat transfer processes, ball thermometer, heat flow, thermal conditions of the premises, heat radiating panels.

A. Yu. Uss, A. V. Chernyshev, N. V. Atamasov
Development of calculation method and creation of vortex jet device to control gas flow

Based on the analysis performed and a preliminary numerical calculation of the gas flow in the regulator’s working cavity, a new design of the vortex gas pressure regulator has been developed. With the use of additive technologies, an experimental sample of the device has been manufactured. A number of experiments are carried out on the basis of the developed stand for testing the vortex regulator. The results of experimental studies confirmed the efficiency of the structure. Numerical studies have been carried out and a new design of the vortex regulator has been developed with a distributed flow of the control flow of the working medium, as well as the regulation of the twist of the supply and control flows of the working medium.

Keywords: vortex regulator, vortex amplifier, vortex chamber, the control stream, locking knob.

V. E. Scherba, A. V. Grigor'ev, A. V. Zanin
Mathematical model of working processes of piston hybrid power machine of volumetric action with reduced fluctuations of gas pressure in discharge line

The paper considers a new scheme for reducing pressure fluctuations on the gas injection line in the compressor section of a hybrid power machine, highlights the main control volumes for the compressor and pump sections. Based on the General laws of conservation of energy, mass, motion and the equation of state, a mathematical model for calculating the control volumes of the compressor section of constant and variable volumes is developed. Based on the use of the equation of continuity of motion and energy, taking into account the energy loss for friction and external heat transfer, a mathematical model of the gas flow in the interstage communications of the compressor section is developed. Based on the use of Hooke's equations of mass, volume and motion, a mathematical model of the compressor section in the pump mode is developed. Considering the fluid flow in the connecting pipelines as quasi-stationary, their calculation is carried out on the basis of the Bernoulli equations. The developed mathematical model and schematic diagram can be used in the calculation of new efficient designs of both piston compressors and hybrid power machines.

Keywords: piston compressor, piston pump, pressure fluctuations, hybrid power machine, piston, cylinder.

AVIATION AND ROCKET-SPACE ENGINEERING

V. N. Blinov, A. I. Lukyanchik, V. V. Shalay
The method of investigation of basic project parameters of microsatellite by random search

A significant number of the main design parameters of the small upper stage for the group launch of small spacecraft with a propulsion system with a displacement fuel supply system determines the relevance of the random search method. The aim of the work is to create a method of selecting the main design parameters of the small upper stage by random search. The mathematical model based on the dimensional-mass model of the calculated mass determination provides the choice of the optimal mass of the upper stage, taking into account the complex relationships of the studied parameters.

Keywords: adapter, small spacecraft, small upper stage, basic design parameters, random search method.

V. I. Trushlyakov, V. A. Urbansky
Study of unusable liquid propellant residues evaporation processes parameters in the tanks of launch vehicle worked-off stage in microgravity

A method is proposed for studying the evaporation process of unusable rocket propellant residues in worked-off stage under weightless conditions. Two options are considered as boundary conditions for liquid rocket propellant residues: a) liquid drop distribution in N identical drops, which surface decreases during evaporation and b) the liquid location in the lower tank bottom and the mirror presence, which area decreases during evaporation. A high-temperature stream of hydrogen peroxide decomposition products is used as a heat carrier fed to the fuel tank. The physical and mathematical model of the liquid evaporation process is based on the first thermodynamics law. Based on the analysis of the Frud and Grashof criteria, the assumption that there is no convection movement inside the drop (Rayleigh number is less than critical) for both boundary conditions variants, the heat transfer coefficient of the gas-vapor mixture produced in the tank is determined

based on the regression dependence obtained in ground conditions as a function of from the Nusselt, Reynolds, Prandtl numbers. Comparisons of the gasvapor mixture parameters for the considered boundary conditions variants and the proposed physical mathematical model with the results, obtained earlier, for the boundary conditions variant of uniform fluid distribution over the inner tank wall (third boundary conditions variant) and using the boundary layer theory based on integral impulses, energy and diffusion ratios are given. The thermophysical gasvapor mixture parameters and the gas-vapor mixture exhaust velocity for oxygen, kerosene for two boundary conditions types are given, using the example of Soyuz-2.1.v type fuel tanks. The total rocket propellant residues evaporation system design mass is less than 1,3% of the total «dry» worked-off stage design mass.

Keywords: worked-off rocket stage, liquid propellant residues, hydrogen peroxide, heat carrier, evaporation.

B. T. Suimenbayev, V. I. Trushlyakov, G. T. Yermoldina, Zh. B. Suimenbayeva, A. M. Bapyshev

The concept of reducing the man-made impact of launches of the promising Irtysh launch vehicle in the impact areas of the Baikonur cosmodrome

Scientific and methodological approaches to minimizing the man-made impact of launches of promising carrier rockets of the «Irtysh» type by oxygen-kerosene main liquid-propellant rocket engines of the Baiterek rocket complex in areas of falling of the Baikonur cosmodrome are considered. The basic directions for reducing the anthropogenic impact of the spent booster of the first stage of the «Irtysh» type LV in the areas of falling are: determination of optimal areas for the spent booster to fall in selected areas of the FA with the highest stability and minimum cost of works on restoring the soil state — (A); controlled descent of the spent booster after separation from the LV to the designated section of the fall with an accuracy not exceeding the size of the selected optimal section — (B). To solve problems of direction A, it is proposed to create an additional information and analytical system of the area of falling. To solve the problems of direction B, possible design solutions are proposed based on the evaporation of non-producing liquid propellant residues in the spent booster tanks, and using the resulting vapor-gas mixtures for controlled descent of spent booster to the designated FA zone.

Keywords: worked-off stage, information and analytical system, ecological impact assessment, pyrogenic effect.

V. S. Korneyev, S. A. Korneyev

Calculation-experimental method for determining the initial geometric parameters of rubber-cord shell of rotation

The calculation-experimental method for explicitly definition the initial distributions of the angle of inclination of the cord threads, the pitch between them, the volume fractions of cord threads and rubber in the rubber-cord composite along the rotation shell meridian is presented. A brief theory of the method developed earlier with the participation of one of the authors is set forth. The main attention is paid to the procedure of sample making, the order of measurement and mathematical processing of primary data to establish the average values of the angle of inclination and pitch of the long fiber cords at the equator of the shell. The practical application of the proposed calculation-experimental method is illustrated by the example of a rubber-cord shell of the balloon type of the model N-50. The results of the study are of interest in the design of systems for shock and vibration protection of technical objects, such as underground and mobile complexes of strategic missile launchers, aircraft electronic equipment and general-purpose vehicles.

Keywords: rubber-cord shell, initial distributions, angle of inclination of the long fiber cords, pitch of the long fiber cords, volume shares of a cord and rubber.

V. I. Karagusov
Anaerobic external combustion thermal engines

Anaerobic engines are air-independent engines used in rocket and space technology, in submarines and in regular public service facilities. In rocket and space technology, liquid and solid rocket and jet engines are used. In open and underwater facilities, anaerobic nuclear-powered engines are used, as well as diesel engines with internal combustion with fuel reserves and oxidizing agents, often in cryogenic form. Internal combustion engines with all their advantages have several disadvantages. External combustion engines based on pulsation pipes and thermoacoustic effect are promising for orbital, rocket, underwater onboard and autonomous power plants. They may lack mechanical parts and assemblies, which determines long life, high reliability, minimal noise and vibrations. To operate such engines can use any fuel, they practically do not require maintenance.

Keywords: anaerobic power plants, onboard systems, Stirling engine, pulse tube, thermo-acoustic systems.

V. I. Gorbunkov, V. V. Shalay
Optic evaluation of erosion arcjet tungsten electrodes

The kinetic theory of gases methods has been used to evaluate the erosion DC arcjet tungsten electrodes. Argon is chosen as the process plasma gas. Estimation of the mass flow rate of tungsten due to erosion is performed as a result of determining the gas temperature and the maximum flow rate of arcjet gases.

Keywords: high-pressure argon plasma, gas temperature, erosion of tungsten electrodes, Boltzmann distribution, emission spectroscopy, arcjet thruster.

V. I. Kuznetsov, A. Yu. Shander
Hartmann–Sprenger effect and its application on aircraft

The question of the effect of viscosity on the occurrence of a stagnation temperature in a dead-end cavity above the deceleration temperature of the incident gas flow the so-called Hartmann–Sprenger effect is considered. It is shown that the Hartmann–Sprenger effect can be used to create the design of the anti-icing system of the aircraft. Keywords: Hartmann–Sprenger effect, viscosity, kinetic energy, aircraft, anti-icing system.

E. V. Shendaleva, Kh. I. Khalimov
Design of experiments at bench tests of fuel supplying apparatus

The article questions an experiment design of gas-turbine engine combustion unit at test bench. The relevance of statistical methods use and, particularly, experiment design for increase in reliability and safety of the aircraft equipment is undoubted. The article purpose is the methodological aspect development in uncertainty assessment of fuel consumption measurement in the test conditions at the semi-natural modeling stand. The experiment design use for combustion unit statistical model creation and uncertainty finding of fuel consumption measurement is offered.

Keywords: design of experiments, fuel consumption, gas-turbine engine, semi-natural test bench.