ABSTRACT AND REFERENCES

ENERGY-SAVING TECHNOLOGIES AND EQUIPMENT

MODEL OF THE CASCADE THERMOELECTRIC COOLING DEVICES IN THE MODE OF THE LARGEST ENERGY EFFICIENCY (p. 4-11)

Vladimir Zaykov, Vladimir Mescheryakov, Yurii Zhuravlov

We developed and analyzed a model of the interrelation between the reliability indicators of the cascade thermoelectric coolers that operate under regime of the largest energy effectiveness at the serial electrical connection of cascades and the design and energy indicators of cooler.

It is demonstrated that the application of cascade thermoelectric devices, built on the basis of standardized modules, is predetermined not only by attaining maximal possible level of cooling but by the increase in efficiency as well. In this case, it is important to obtain maximally possible energy effectiveness at the assigned temperature drop, to select current regime at the assigned design of cooler and to estimate reliability indicators.

We obtained ratios for determining the optimum magnitude of relative operating current, which corresponds to the maximum value of refrigerating coefficient of the cooler with the assigned design and temperature drop. They are functional dependences, which connect basic parameters of the two-cascade thermoelectric coolers of the assigned design with relative operating current of the first cascade in the form of algebraic equations of the 4th degree.

The conducted analysis of the model demonstrated that there is an optimum ratio of the number of thermoelements in the cascades, which corresponds to the maximum refrigerating coefficient at the assigned temperature drop. The obtained ratios make it possible to determine both the basic parameters and the reliability indicators of the cascade thermoelectric cooler of the assigned design. This provides the possibility to evaluate the efficiency of functioning and prediction of the indicators of reliability in the regime of maximum energy effectiveness under varied conditions of operation.

Keywords: thermoelectric devices, indicators of reliability, temperature drop, energy effectiveness.

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DECREASING THE MASS INDICES OF GAS TURBINE ENGINES REGENERATORS BY MEANS OF CHOOSING RATIONAL PARAMETERS (p. 12-23)

Viktor Gorbov, Denis Solomonuk

The purpose of the conducted research was to develop a method for determining parameters of GTE regenerator, which would ensure at the initial stages of designing a minimum mass of the heat exchanger with the assigned values of efficiency.

We obtained dependences that establish relationships between the regenerator and the GTE, which allow analyzing the influence of effectiveness and pressure losses in regenerator on the efficiency of GTE and the mass of the regenerator.

Relationship between parameters of the regenerator and performance efficiency of regenerative GTE was described by functional dependence, where energy parameters of the regenerator are collected in a single complex. It was established that the magnitude of effectiveness of the regenerator is associated with efficiency by inversely proportional function, and pressure losses – by linear function. Effectiveness of the regenerator is associated with the mass of the heat exchanger and the geometry of heat exchange surface by exponential dependence, and relative pressure losses – by algebraic irrational function.

Based on these dependences, the algorithm for selecting rational energy and geometrical parameters of regenera-

tors of GTE was developed. It was found that by selecting rational values of effectiveness of regenerator and pressure losses, it is possible to provide for a significant decrease in mass of the regenerator with a constant value of performance efficiency of GTE.

The obtained results of calculations of regenerators of GTE with different structural solutions allow a designer engineer to choose rational values of effectiveness of the regenerator, pressure losses, and initial gas temperature. Comparison of complex regenerative GTE by the mass of regenerator at constant values of performance efficiency was conducted. Based on the analysis of results of calculations, the stage dependence of specific mass of regenerator on the assigned increase in performance efficiency of regenerative GTE was obtained, which gives the possibility to estimate the mass of tubular regenerator at the initial stages of designing.

Implementation of the obtained results into the practice of designing regenerative GTE will make it possible to ensure the choice of their rational parameters and to decrease the time of designing.

Keywords: gas turbine engine, regenerator, performance efficiency, mass of regenerator, effectiveness of regenerator.

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THERMOECONOMIC OPTIMIZATION OF SUPERCRITICAL REFRIGERATION SYSTEM WITH THE REFRIGERANT R744 (CO_2) (p. 24-32)

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We developed a thermoeconomic model of refrigeration plant that works by the supercritical CO_2 cycle as refrigerating medium. The model is built for the plant of the "air – air" type and makes it possible at the optimization of design and the selection of economical operating modes to simultaneously consider both thermodynamic and economic parameters. Resulting expenses for the creation and operation of the system over the projected life cycle were accepted as objective function for analysis of the model. The minimum of resulting expenses corresponds to the optimum system characteristics while maintaining amount and quality of produced cold. Development of the model allowed us to represent objective function in the form of expanded analytical expressions, which consider interrelation between all optimizing parameters of the system.

One of the benefits of the method consists in the fact that the obtained unique analytical solution in the form of a system of equations of partial derivatives from objective function of the resulting expenses is applicable for the thermoeconomic optimization of regime parameters of operation of any refrigeration system that works according to the examined scheme and with a similar type of equipment.

Numerical solution of the thermoeconomic optimization problem of refrigeration plant of the "air – air" type (conditioner), with CO_2 as refrigerant, that works in the supercritical region made it possible to find optimum parameters of the system, which provide for the conditions of reaching minimum level of the resulting expenses at different values of tariffs for electric power. We examined effect of the value of tariff for electric power on the character of optimization of the system.

An application of this technique in practice should contribute to the reduction in financial costs for the creation and operation of conditioners that work on CO_2, to an increase in their competitivness compared with traditional freon systems and contribute to the creation of conditions for their large-scale implementation in Ukraine.

Keywords: thermoeconomic model, supercritical cycle, exergy, resulting expenses.

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LIQUID JET COOLER-BASED LIQUID HYDROGEN FUELING AND THERMOSTATING LAUNCH SYSTEM DEVELOPMENT (p. 33-40)

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A variant of modernization is examined of the ground-based system for filling and thermostating by liquid hydrogen of fuel tank of superheavy carrier rocket (CR) "Energy" by using, instead of traditional surface heat exchangers, a jet liquid cooler.

The filling systems that are in operation at present imply the filling of CR tanks with cryogenic components in the boiling state, which limits the period when a rocket is positioned in the launching pad. But the system that was created in the USSR way back in 1987 made it possible to fill the CR "Energy" fuel tanks with the components of rocket propellant in the supercooled state with subsequent thermostating of tanks. Filling the CR tanks with components in the supercooled state with heightened density provided for an increase in the mass of payload by 5 % and allowed prolonging the period, which would rather be used for eliminating the malfunctions in preparing CR for launch, without returning the components to the filling tanks. They used as heat exchange devices the heat exchanger-recuperators of the "boiling bath" type. In this case, the semiclosed scheme of the cryogenic component circulation was implemented.

Using a compact jet liquid cooler as the heat exchange device makes it possible to eliminate bulky heat exchangers, as well as simplify the system through transition to the closed scheme of liquid hydrogen circulation while thermostating the CR fuel tank. Thus, the cryo-component saving is provided for in the process of cooling the structure elements in preparing for the filling.

The procedure for calculating the process of thermostating a fuel tank based on the jet liquid cooler was developed for solving the task of modernization of the filling and thermostating system, which allowed us to calculate attainable parameters of the thermostating system and to determine the range of system working ability. The outlet of external heat flows with power to 1 MW is ensured at pressure at the JCL nozzle exit section 10–30 kPa and temperature of "hot" parahydrogen removal from the tank 18–20 K. In particular, the 73 % increase in the operation period of the system during standard system filling with liquid hydrogen or the savings in liquid hydrogen at the estimated time of CR launch might be regarded as the result of using the modernized filling and thermostating system.

The technical solutions proposed may be applied when designing new and modernizing those existing systems of storage, cooling and filling with liquid hydrogen of the carrier rockets fuel tanks, including promising objects of heavy and superheavy CRs: SLS and Falkon Heavy (USA), CZ-5 and CZ-9 (C.P.R), Angara 5V (Russian Federation).

Keywords: liquid hydrogen, starting complex, evaporative cooling, jet liquid cooler.

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SUBSTANTIATION OF ECONOMIC EFFICIENCY OF USING A SOLAR DRYER UNDER CONDITIONS OF PERSONAL PEASANT FARMS (p. 41-47)

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A new design of a solar dryer for drying fruits is proposed, which includes the use of a flat mirror concentrator to enhance the flow of slant morning and evening sunlight, and a thermal accumulator based on pebble for accumulating over night time the excess heat from the reserve source of energy. This makes it possible to increase economic efficiency of the drying process by 20 %, to reduce energy consumption by 15 %, specific energy consumption by 10 %, direct operating costs by 5 %, electricity consumption by 3,4 kW·h, or 12384 kJ of thermal energy, by using solar energy.

We improved a technique of the substantiation of economic efficiency of the developed solar dryer, the basis of which is a simplified mechanism for calculating direct operating costs, economic effect and payback period of the machine depending on the fluctuation of prices for electricity and dried products, linked to a specific territory of the location of a personal peasant farm.

The results that were obtained can be used when developing and improving technical means of drying fruits, to improve technological, energy, biological and economic efficiency of the process.

Keywords: solar energy, solar fruit dryer, mirror concentrator, thermal accumulator, economic efficiency.

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NUMERICAL INTEGRATION OF THE PROCESS OF COOLING GAS FORMED BY THERMAL RECYCLING OF WASTE (p. 48-53)

Viola Vambol

The present paper describes the results of a numerical integration of the process of cooling gas during thermal recycling of waste. The physical model of such cooling is based on injecting the cooling liquid by centrifugal nozzles. The research object is gas-dynamic interphase interactions in the evaporative heat exchanger. The purpose of the research is to improve the ecological safety of thermal recycling of waste by preventing the formation of highly toxic substances in the generated gas. The mathematical models of the gas and dispersed phases are developed and the mathematical description of the interphase interactions in the heat exchanger is provided on the basis of laws of conserving the weight and the impulse amount in an environment that is inhomogeneous in terms of the composition and phases and includes the generated gas, drops of water, and steam. The mathematical formulation of the conservation laws for viscous gas (steam) is achieved through the Navier-Stokes equations; for drops, it is given as an equation of the balance of forces that affect the drop and equalize the inertia force and the resultant forces of gravity and aerodynamic resistance. The studied computational area covers a space fragment bounded by the walls of the heat exchanger. It has been scientifically proved that such technological equipment can be used to provide a sharp cooling of flue gases. The mode of fast cooling prevents the creation of temperature conditions that would facilitate dioxins formation, and thus it increases ecological safety.

Keywords: wastes utilization, ecological safety, dioxins content reduction, mathematical modeling of gas dynamic processes.

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IMPROVING THE EFFICIENCY OF FUEL COMBUSTION WITH REGARD TO THE UNCERTAINTY OF MEASURING OXYGEN CONCENTRATION (p. 54-59)

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This paper presents a new approach to control and mange the process of fuel combustion in the boiler units. Ways to increase the efficiency of combustion of fuel materials are examined. We proposed a method for indirect measurement of the current concentration of oxygen in the air whose magnitude quantity depends on meteorological environmental parameters: temperature, absolute pressure and relative humidity. Experimental research was conducted to compare direct and indirect methods of measuring the volumetric concentration of oxygen in the air. We calculated the uncertainties of measurement of the volumetric concentration of oxygen in the air for the direct and indirect methods.

An estimation of the extended expanded uncertainty of the indirect method of measurement was carried out by the imitation simulation using the Monte-Carlo method. It is demonstrated that relative air humidity exerts the largest influence on the extended expanded uncertainty of measuring the volumetric concentration of oxygen. A comparison of the methods of measuring the volumetric concentration of oxygen revealed that the extended expanded uncertainty of the indirect method is less than that of the direct method. We proposed functional dependence of an increase in accuracy of the measurement of excess air coefficient that is based on the calculation of the current concentration of oxygen in the air, which will make it possible to ensure highly effective fuel combustion in the boiler units at any regimes of its functioning.

Keywords: excess air coefficient, meteorological parameters, measurement uncertainty, Monte-Carlo method.

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