ABSTRACT AND REFERENCES

ENERGY-SAVING TECHNOLOGIES AND EQUIPMENT

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A STUDY OF NEW LOCAL HEATING AND AIR CONDITIONING SCHEMES BASED ON THE MAISOTSENKO CYCLE (p. 6–14)

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Significant consumption of energy resources in the production of heat in the winter season and air conditioning in the summer season is the main problem of municipal heat-and-power engineering. Therefore, local energy-efficient heating systems and climatic heating and cooling systems based on renewable energy sources are becoming increasingly important. The heat pumps, based on the Rankine cycle, which use the energy of atmospheric air, soil, and wastewater, as well as air conditioning systems, based on the Maisotsenko cycle, using the psychrometric energy of the environment, have become widespread in recent years. Theoretical analysis shows that a combination of these cycles makes it possible to achieve high energy efficiency and create fundamentally new systems of heating and cooling the living spaces. This paper presents the results of a comparative experimental study of two heat supply and cooling schemes based on a combination of the Maisotsenko and Rankine cycles. An experimental bench of the combined cycle with thermal power of 28 kW with the power of the heat pump of 3 kW was developed for the experimental study. A serial M-cycle heat-and-mass exchanger manufactured by Coolerado Corporation, USA, was used in the design of the bench. Studies have shown high energy efficiency of both heat supply schemes which was determined by the coefficient of performance (COP): 6.3–7.21 for the first scheme and 7.44–9.73 for the second one. When conditioning the room air, the Rankine heat pump was not used, so the energy was consumed solely by the fan to pump air through the M-cycle heat-and-mass exchanger and the air conditioning system. In this case, the coefficient of performance was 10.49–16.32.

Keywords: heat supply, air heating, cooling, heat pump, Rankine cycle, Maisotsenko cycle.

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DEVELOPMENT OF A SYSTEM FOR ESTIMATING AND FORECASTING THE RATIONAL RESOURCE-SAVING OPERATING MODES OF TPP (p. 14–23)

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The world energy crisis and environmental problems have prompted a rapid increase in the share of electricity generation by renewable sources. However, the operating modes of such energy facilities are rather uneven over 24 hours. Thus, for the energy sector of most developing countries, and as well as for part of developed countries, such fluctuations in the overall energy production balance lead to the forced limitation of the equipment capacity at TPPs or to the full shutdown of power units.

The insufficient quantity of maneuvering capacities in the overall energy generating balance is a characteristic feature of the power systems of such countries as the Russian Federation, Ukraine, Macedonia, Bulgaria, Romania, Argentina, and others. The shortage of such capacities is often compensated for by the pulverized coal units with a power of 200–300 MW, whose operation is enabled at half-peak and peak modes. This equipment is not designed for such operations. Therefore, the development of a regime method of resource management has been proposed to prevent the premature exhaustion of TPP generating equipment.

Based on technical auditing of the operational documentation of generating companies, a method has been suggested aimed at forecasting the rational resource-saving operational regimes of the high-temperature elements of power equipment by optimizing the ratio of the number of launches of the equipment from various thermal states. An optimization problem has been stated, which implies determining such a distribution of the process structural-technological parameters that would ensure the maximal preservation of equipment resource. The residual resource has been selected as the objective function of the optimization problem. The devised method has been represented in the form of a comprehensive system for estimating and forecasting the rational operational modes of the TPP high-temperature elements, which makes it possible to define individual resource indicators over the entire period of equipment operation for all possible future combinations of operational modes and to compile forecasts for thousands of different variants of power unit exploitation, implying the calculation of resource indicators for each of them.

Keywords: thermal power plant, power unit, damageability, residual resource, forecasting, optimization.

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THERMODYNAMIC ANALYSIS OF THE THERMAL-TECHNOLOGICAL COMPLEX OF SUGAR PRODUCTION: THE ENERGY AND ENTROPY CHARACTERISTICS OF AN ENTERPRISE (p. 24–31)

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This paper reports the approbation of a procedure of thermodynamic analysis of the thermal-technological complex of sugar production using the analysis of an enterprise of typical configuration as an example.

Currently, the thermodynamic analysis of sugar production systems is mainly performed on the basis of a classical energy method. Minor attempts to exploit the potential of the second law of thermodynamics in the form of the adaptation of an exergy method are not systemic.

Underlying the applied procedure is a joint analysis of general synthetic and analytical balances of mass, energy, and entropy. Such a procedure makes it possible to quantify the level of perfection of the existing and proposed thermal circuits, as well as the impact exerted on their perfection by energy efficiency measures, and it could be applied both to optimize the energy characteristics of the existing ones and in designing new enterprises of the sugar industry.

It has been shown that the thermodynamic analysis of the thermal-technological complex of sugar production as a single system makes it possible to analyze the main factors of influence on the energy efficiency of the complex disregarding the course of the processes implemented therein. Such an approach can also be effectively used for the quick evaluation of the thermodynamic perfection of an enterprise and for determining its «energy-saving potential».

Based on the results of energy analysis, the relationship has been established between the fuel and energy resources, supplied to the system, and the sources of their losses; a set of measures has been proposed to reduce the impact of each of these factors on resource consumption.

Entropy analysis has revealed the internal and external causes of the irreversibility of processes; the principle of «energy irreversibility compensation» has made it possible to compile a rating of major imperfections and determine the optimal sequence of resource-saving measures.

The results of the analysis have confirmed the efficiency of the procedure, which allows a comprehensive study, while operating only with the fundamental laws and the principles of classical thermodynamics, as opposed to procedures, based on energy-exergy characteristics.

Keywords: sugar production, thermodynamic analysis, entropy method, energy efficiency, resource-saving measures.

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DEVELOPMENT OF AN APPARATUS WITH INDUCED HEAT-AND-MASS TRANSFER FOR DRYING AND HYDROTHERMAL PROCESSING OF MOIST MATERIALS (p. 32–38)

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The need to solve the problems of efficient use of energy resources in processes of heat-and-mass transfer which are widely used in the food and processing industries and are very power-intensive was substantiated. The prospects of application of the induced processes such as the effect of induced heat-and-mass transfer characterized by high energy efficiency and environmental friendliness were noted.

Drying and hydrothermal treatment of moist raw materials with gas-tight inserts in horizontal and vertical orientations were modeled. It was established that the nature of this effect in the presence of gas-tight inserts in the solid phase inside the thermostat does not differ from the nature of the effect of induced heat-and-mass transfer in absence of such inserts.

It was proved that during the induced heat-and-mass transfer, features of the flow of any volume of internal thermostat medium affect the nature of this flow for other allocated volumes. It was noted that the feature of «artificiality» and controllability of this effect makes it possible to perform certain manufacturing operations in processing different raw materials in one device without their mixing.

A technical solution of an apparatus using the effect of induced heat-and-mass transfer for drying and hydrothermal treatment of moist raw materials was proposed based on the obtained experimental results and established theoretical conclusions. The productivity of the developed apparatus in hydrothermal processing of cereals makes 18 kg/h and the energy consumption is $8.1 \cdot 10^6$ J/kg of dried product. The final product is a quick-recoverable porridge that does not require cooking. It was noted that the economic attractiveness of the developed device with the effect of induced heat-and-mass transfer for drying and hydrothermal treatment consists in the ability to reduce energy consumption for these manufacturing operations by 30 %.

Keywords: induced heat-and-mass transfer effect, drying, hydrothermal treatment, temperature kinetics, phase portrait.

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RESEARCH OF HYDRODYNAMICS AND HEAT TRANSFER DURING THE TRANSVERSE AIR FLOW OF A ROW OF CYLINDERS WITH SCREW GROOVES (p. 39–45)

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Cylinder cross-flow is a common phenomenon in many fields of technology. Technological simplicity of tubular structures makes them attractive, especially when using working bodies that are under different pressure values. However, the cylinders belong to the category of «poorly streamlined» bodies, and there are many opportunities to improve their hydrodynamics and heat transfer. For a circular cylinder, there is a speed range in which its hydraulic resistance can decrease due to the deformation of the cylinder surface. This phenomenon can be used for the rational design of heat exchangers.

In the open-type wind tunnel, heat transfer coefficients and hydraulic resistances of single-row cylinder bundles with several types of spiral grooves on the outer surface have been determined. The largest increase in heat transfer (64 %) was shown by the cylinder with the smallest pitch of the groove (10 mm), the second place was taken by the cylinder with a relatively large step – 40 mm.

Using the best spiral groove allowed reducing the hydraulic resistance by 19 %. Visualization and computer simulation have been used to explain the effects. The conformity of computer simulations to the experimental results was determined by comparing the average heat transfer coefficient (calculated and determined using an ice calorimeter). As a result, the turbulence model RNG_kε has been chosen, which provides a better fit of the experimental model. Computer simulations have explained the physical picture of the flow around cylinders with spiral grooves, including their mutual influence with a different axial orientation in the bundle.

It has been shown that the presence of a spiral groove, which on the one hand increases heat transfer and on the other hand reduces hydraulic resistance, can significantly increase thermohydraulic efficiency (Reynolds analogy factor).

Keywords: heat transfer, hydrodynamics, heat transfer intensification, hydraulic resistance, spiral grooves, Reynolds analogy.

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IMPROVING ENERGY INDICATORS OF THE CHARGING STATION FOR ELECTRIC VEHICLES BASED ON A THREE-LEVEL ACTIVE RECTIFIER (p. 46–55)

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A new structure of the charging station for electric vehicles has been proposed, which was developed on the basis of a three-phase transformer and a three-level active four-quadrant rectifier with the power factor correction. This paper describes the parameters of the proposed structure of the charging station and gives the parameters for the replacement circuit of the battery compartment in the electric car TESLA, model S, which was reduced to a single equivalent battery. We have described a method for fast charging the battery with constant current and constant voltage CC-CV, which ensures a greater number of battery charge-discharge cycles. The mathematical formulae have been given for calculating the power losses components and the efficiency of the proposed structure of the charging station over a full interval of the battery charge.

We have outlined a system of automated control over the charge current and voltage, which is based on the pulse-width modulation of the second order and an integrated regulator. The simulation model of the proposed structure of the charging station, built in the MATLAB/Simulink programming environment, has been presented, as well as the simulation results: the oscillograms of input and output currents and voltages, the dynamics of the charge current regulator operation. The polynomial approximation of the IGBT-modules energy characteristics aimed at calculating the static and dynamic losses in the power switches of an active rectifier has enabled the construction of a loss counter model.

It has been shown that increasing the value of a charge current under the CC mode decreases the resultant integrated value of the charge process efficiency, but, at the same time, the power factor increases and the emission of higher harmonics decreases. We have performed the optimization of power losses in the proposed system of the charging station based on the parameters of the minimal charge current and the modulation frequency in PWM.

Our analysis of the components of energy losses in the proposed structure has confirmed its energy efficiency in comparison with other existing structures. The advantage of the proposed structure is that it enables improved efficiency and power factor while lowering the emission of current higher harmonics. The following system indicators have been obtained: the integrated efficiency value of the electric car full charging process using a CC-CV method is 95.6 %, the power factor is 0.99, the total harmonic distortion coefficient of the input current is 2.5 %.

Keywords: active rectifier, rechargeable battery, electric car charging station, power factor, simulation.

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DEVELOPMENT OF SMART GRID TECHNOLOGY FOR MAINTAINING THE FUNCTIONING OF A BIOGAS COGENERATION SYSTEM (p. 56–68)

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The integrated Smart Grid System of harmonization of production and consumption of electric power and heat with the use of heat-pumping power supply of the biogas plant, which uses fermented wort as a low-potential source of power, was developed. A change in the power factor of the cogeneration system, the temperature of local water is predicted by measuring the voltage at the inlet to the inverter, at the outlet from the inverter and voltage frequency. In the engine cooling circuit, the temperature of cooling water at the inlet to the heat exchanger, at the outlet from the heat exchanger, and the return water temperature are measured. It was proposed to estimate a change in the ratio of voltage at the inlet to the inverter and at the outlet from the inverter. Making forestalling decisions to change the power of the heat pump and the number of plates in the heat exchanger of the engine cooling circuit makes it possible to maintain the voltage at the entrance to the inverter and the temperature of the heated local water. The complex mathematical and logical modeling of the cogeneration system, based on the mathematical substantiation of the architecture of the cogeneration system and mathematical substantiation of the maintenance of functioning of the cogeneration system, was performed. Time constants and coefficients of the mathematical models of dynamics regarding the estimation of a change in the power factor of the cogeneration system, temperature of local water, were determined. Functional estimation of a change in power factor of the cogeneration system in the range of 85–95 %, temperature of local water in the range of 30–55 °C at the compensation of reactive power of up to 40 % was obtained. Determining final functional information provides an opportunity to make forestalling decisions on a change in the power of a heat pump and a change in the number of plates in the heat exchanger of the engine cooling circuit to maintain the functioning of the cogeneration system.

Keywords: cogeneration system, power factor, biogas plant, heat pump, frequency converter.

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