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Methods of studying electric-hydrodynamic heater

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Abstract

The paper deals with the study of electric energy conversion into thermal energy that takes place in the electric hydrodynamic heater. The primary mathematical model of the heater which has been implemented and confirmed experimentally on a physical set and estimated by a thermal imager is described. The produced 3D modelling of the working liquid flow movement has led to modification of the experimental electric hydrodynamic heaters for the purpose of increasing their heating capacity.

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1. Introduction

When activating liquid media by external sources (for example, an electric drive) it is possible to obtain thermal energy from internal energy of the liquid. Various trends of increasing energy efficiency of power systems are based on it. In particular, using electric hydrodynamic heaters for autonomous heat supply is one of them [1–3].

There the consumed electrical energy is consistently converted into mechanical energy (pressure developed by a pump), then into hydraulic energy (energy of the moving working liquid) and, as a result, into thermal energy (developing the effect of cavitation on special structural elements), Fig. 1.

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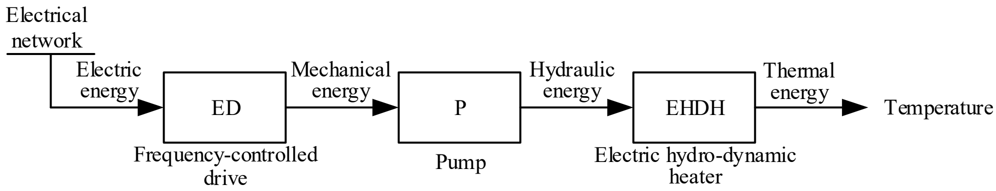

Fig. 1. Design diagram of energy conversion in the electric hydrodynamic heater.

At the same time, the issues of designing and studying heating capacity of electric hydrodynamic heaters (EHDH), the working liquid behavior in these sets [4–6] have not been resolved completely. Let us consider the processes of stage-by-stage energy conversion in the EHDH.

2. Mathematical model for primary assessment of electrical energy conversion into thermal energy

The processes of electrical energy conversion into mechanical energy are widely known and described. All electric motors including the pumps equipped with an electric drive system [7] work according to this principle. The efficiency of this stage of energy conversion for the electric drive of pumping aggregates makes 0.72–0.75 depending on the producer [8, 9]. Increasing the efficiency can be reached due to the optimum control by means of the frequency-controlled electric drive. However, at the first stage of studying the processes of energy conversion in the EHDH the task has been set to develop a mathematical model for assessment of mechanical energy conversion into thermal energy.

When designing the elements of the EHDH system and adjusting their work in actual practice there has emerged the need for calculating the parameters of the hydraulic operating mode. The parameters of the hydraulic operating mode of the pumping aggregate (pressure, flow rate) shall be in its working zone corresponding to the maximum efficiency and the maximum capacity which can be transmitted into the energy carrier flow by means of driving wheels of the pumping aggregate. Besides, when studying the EHDH energy characteristics there is a need for large amount of expensive measurements of temperature, pressure and flow rate of the working liquid. For minimizing the amount of physical measurements of the mentioned values in the pipe network it is reasonable to use indirect mathematical measurements based on the mathematical model of the energy carrier powerflow.

Developing such a model is possible in the information and graphical system (IGS) GID-99w environment developed at the department of Automation of Production Processes of Karaganda State Technical University that has been widely adopted in the largest power supply systems of the CIS. The mathematical apparatus pledged in the GID-99w based on the theory of hydraulic chains [10] is intended for imitation modeling and technological analysis of the operational and emergency hydraulic modes of heat supplying systems of variable technological structure and arbitrary set of the standard heat-mechanical equipment [11, 12].

The design hydrodynamic diagram of a physical analog of the EHDH system developed in the IGS GID-99w is provided in Fig. 2. It is equivalent to the real technological diagram in terms of the theory of hydraulic chains. By T0…T10 symbols on the diagram there are designated control points of sections of the set pipeline.

In the hydrodynamic aspect the EHDH is a section of the pipeline network of the circulating contour in which the loss of energy of the working liquid whirl owing to friction and local resistance takes place. Potential and kinetic energy of the working liquid lost in the EHDH leads to increasing its enthalpy (heat content) that can be observed by the temperature increase. The known value of hydraulic resistance of the circulating contour permits to define such an operating mode of the pump at which the EHDH maximum heating capacity, i.e. the maximum energy conversion of the working liquid flow movement into heat is provided.

As a result characteristics of all the EHDH system objects for finding the maximum values of functions of heating capacity and the coefficient of energy conversion (consumed electrical energy – obtained heat) depending on the design data of the system elements have been simulated. The technique of carrying out pilot studies based on the Latin squares and the multiple-factor equations of Protodyakonov-Teder has also been developed [13]. The methodological benefit of such an approach consists in the absence of the initial connection between the plan of the experiment and the form of a possible mathematical model.

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