

Modeling the Distribution of Temperatures on the Surface of a Heat Exchanger

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Abstract—This paper presents a simulation of the temperature distribution on the surface of a heat exchanger in the ANSYS application package. In the R&D part devoted to the development of a device for converting heat into electrical energy, models of an experimental heat exchanger have been created, including numerical models for calculating three-dimensional distributions of the gas flow velocity, temperature fields, flow turbulence intensity and static pressure. An initial assessment of the parameters of the heat exchanger was carried out and the following predicted indicators were established at the flow rate and temperature of the inlet gases corresponding to data of the technical specifications. A combined analysis of the simulation results allows us to determine the zones for the most efficient installation of thermoelectric converters in electric energy: elements of the thermoelectric converter on the side surfaces of the cone. A prototype of the thermoelectric converter was developed and manufactured in the work, studies of thermoelectric conversion were conducted. The work also carried out the initial assessment of the state after the launch of prototypes of high-ampere electrolyzers of the RA-550 experimental section, namely, the measurement of the material balance of emissions through the housing lantern (outlet) and supply ventilation (inlet). All tasks of the stage have been fully resolved, the goals set and achieved, the results of the planned work received.

Keywords— *modeling; heat exchanger; electrolyzer; ANSYS*

I. INTRODUCTION

The requirements for rational energy and resource conservation are increasing every day at enterprises of various industries around the world [1-10].

A fairly large number of studies have been carried out in the areas of energy efficiency and energy conservation of various industries [11-17]. One of the directions is the development and implementation of heat exchangers [18-24].

II. FORMULATION OF THE PROBLEM. INITIAL DATA FOR MODELING THE OPERATION OF THE HEAT EXCHANGER

The cross section of the working part of the experimental heat exchanger is a square with sides 2x2 m, the length of the working part is 6 m, the heat exchange elements are located only within the working part. Dry air with a temperature of 200 °C and a flow rate of 76,000 nm³ / h are supplied to the inlet.

Cooling is carried out with water with a temperature at the inlet to the heat exchanger of 20 °C.

At the outlet, it is required to obtain an air temperature of not more than 100 °C and a pressure drop of not more than 100 Pa.

Virtual simulation of the experimental heat exchanger, namely, the flows of the cooled gas and heat exchange of gas - material of the heat exchange elements - the cooling fluid, was performed using the ANSYS software package based on the control volume method.

The grid of control volumes for each calculation model of the experimental heat exchanger was prepared on the basis of the geometric and dimensional features of the models to ensure a sufficient level of numerical convergence of the problems.

Each of the problems was solved in a static formulation iteratively until the computational models achieve a completely equilibrium and stable state in the velocity fields and the simulated fluids costs, the heat brought and carried away from the simulated space, and also the stabilization of viscosity and turbulent parameters:

- by the mass flow rates of gas and liquid at boundary conditions;
- by the consumption and arrival of heat into the model on boundary conditions;
- by the energy of viscous resistance and turbulent resistance by the volume of the model.

These conditions correspond to the achievement by the calculated models of a fully stationary state in the velocity fields and the simulated fluids costs, the heat brought and taken from the simulated space, and also the stabilization of viscous and turbulent parameters.

III. DESCRIPTION OF THE DYNAMIC MODEL OF GAS FLOW

Virtual simulation of the experimental heat exchanger, namely, the flows of the cooled gas and heat exchange of gas - material of the heat exchange elements (HEE) - the cooling fluid was performed using the ANSYS software package based on the control volume method.

The grid of control volumes for each calculation model of the experimental heat exchanger was prepared based on the geometric and dimensional features of the models to ensure a sufficient level of numerical convergence of the problems. [6-9]

Each of the problems was solved in a static formulation iteratively until the calculated models achieve a completely equilibrium and stable state in the velocity fields and the simulated fluids costs, the heat brought and carried away from the simulated space, and also the stabilization of viscous and turbulent indicators:

- by the mass flow rates of gas and liquid at boundary conditions;
- by the consumption and arrival of heat into the model on boundary conditions;
- by the energy of viscous resistance and turbulent resistance by the volume of the model.

The account model of the heat exchanger is a longitudinal cutout from the full geometric model in the form of a longitudinal channel corresponding in size and position to the periodic section of the entire structure (Fig. 1).

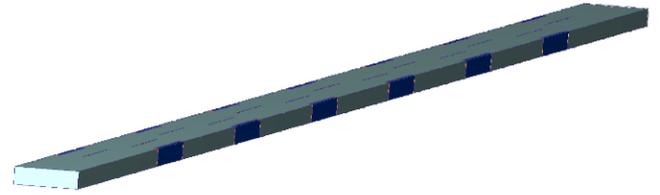


Fig. 1. A geometric model of a longitudinal cutout of a heat exchange

The model has the following external (boundary) conditions:

- the condition of a given mass flow through the inlet surface, calculated from the ratio of the total flow through the simulated heat exchanger to the area of the flow-through section of the heat exchanger;
- the condition of periodic symmetry at all boundaries of conjugation (symmetry);
- the condition of openness (lack of back pressure) on the output surface;
- the condition of a given temperature of the gas entering the model at the input surface;
- the condition of the set temperature of the coolant.

Similarly to previously prepared models, the following values were estimated:

- static pressure at the inlet surface (required pressure to ensure a given mass flow through the model);
- average gas temperature at the outlet surface.

Additionally, distributions of flow temperatures over the model volume (Fig. 2) and distributions of flow velocities over the model volume (Fig. 3) were obtained.

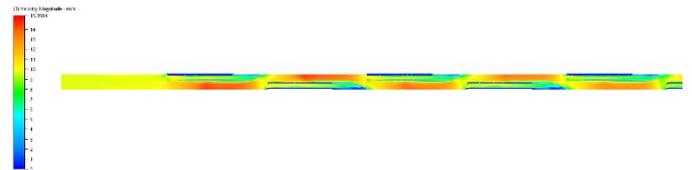


Fig. 2. Distribution of flow rates (part of the model is shown)

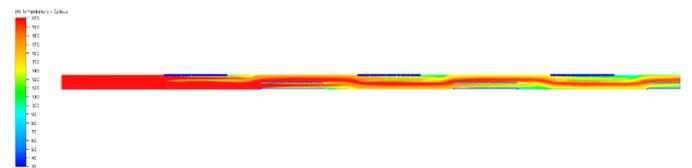


Fig. 3. Distribution of flow temperature (part of the model is shown)

As a result of processing, the following values were obtained:

- hydraulic resistance of 20.2 Pa;

- gas temperature at the outlet section 98 °C.

The temperature obtained at the outlet section satisfies the requirements of the technical specifications for the designed heat exchanger.

The resistance shown here (20.2 Pa) is the resistance of the heat exchange part itself, the resistance of the heat exchanger body itself is about 80-120 Pa, depending on the design features and characteristics of individual elements of its design.

Thus, from the design of the heat exchanger corresponding to this model, one can expect the following indicators at the flow rate and temperature of the inlet gases corresponding to the data of the technical specifications:

- decrease in gas temperature to 98 °C;
- impedance of the order of 100-140 Pa.

IV. MODEL OF TEMPERATURE DISTRIBUTION ON THE SURFACE OF THE HEAT EXCHANGER

The modeling task was to determine the temperature distribution on the outer surface of the cone, to provide zoned information by temperatures for the subsequent selection of the sections for installing the thermoelectric converters.

As initial data are provided:

1) CD for the case of a thermoelectric converter:

2) the results of previous calculations and studies (for details, see the previous stages of design and simulation of a laboratory heat exchanger and the experimental heat exchanger):

- mass flow rate of cooled gases through experimental heat exchanger 27.314 kg / s;
- the maximum temperature of the cooled gases at the inlet to the experimental heat exchanger is 200 °C.

The calculation model contains two hydraulic domains: for street air and for cooled gas (Figure 4).

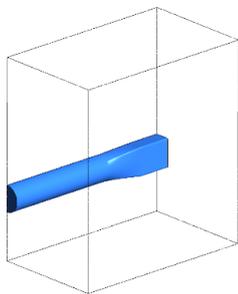


Fig. 4. General view of the estimated model; the domain of the cooled gases is shown in blue, the domain of the outside air is shown by the contour

The heat transfer between the domains is calculated from the conditions of the known thermal conductivity of the material and the cone wall thickness, the heat transfer in the boundary layers of gas media from two sides of the cone walls

is calculated by means of a simulation system [6, 9].

The relief of small structural elements (connecting flanges, stiffeners, and others) was not taken into account due to the small influence.

As the initial geometry, the existing geometric model was used, on the basis of which the documentation provided in the initial data was performed.

Using the ANSYS DesignModeller geometric modeling tools, additional constructions were completed:

- dissection of the model along the plane of symmetry;
- minor geometry elements are discarded in accordance with the assumptions made;
- built the volume (geometric body) of the domain of the surrounding air;
- a part of the pipeline to the transitional cone (zone of the thermoelectric converter installation) and part of the experimental heat exchanger casing behind it were built.

For the subsequent model building, the following boundary conditions are accepted:

- flow rate through the input boundary of the domain of the cooled gas - in accordance with the source data;
- symmetry conditions at the boundaries of the model cross section (one plane of symmetry was used);
- free boundaries conditions for the upper and lower planes of the outdoor air domain;
- the condition of zero excess pressure at the outlet boundary of the domain of the cooled gas;
- temperature of the cooled gas at the inlet boundary - in accordance with the source data;
- the temperature of the incoming gas at the open boundaries of the external air domain is 20 °C;
- atmospheric pressure corresponds to normal conditions (101.3 kPa).
- the heat transfer between the contact surfaces of the domains was determined taking into account the thickness and material of the separating them - the thickness of the shell of the experimental heat exchanger and the material (steel), the characteristics of the material were taken from the complete ANSYS CFX library.

Also, the characteristics of the cooled gas and outside air corresponding to the characteristics of the model of the medium supplied with ANSYS CFX software were taken as initial data.

V. CONCLUSION

Calculation models are presented in the ANSYS computer system designed for the subsequent design of a device for converting heat into electrical energy. Within the framework of the work, numerical models for calculating three-dimensional distributions of the gas flow velocity, temperature fields, flow turbulence intensity and static pressure were performed.

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