УДК 536.2:519.6

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3D COMPUTER MODEL OF THE DEVELOPED CONTACT SURFACE OF HEAT EXCHANGE OF COMPLEX CONFIGURATION

The method for the describing transport processes on the basis of multifunctional software packages is presented in this work. The proposed method of analysis of thermal parameters of multi-contact heat exchange surfaces is based on the developed computational pattern of software package COMSOL Multiphysics in relation to the actual geometry of industrial heat-exchange surface of the bimetallic sample. The practical application of these model templates enables us to improve the reliability of generalization of test results of heat exchangers and, consequently, reduce the time of their introduction into the market of power equipment.

Introduction. A wide range of heat exchangers which differ in the purpose and configuration of heat transfer surfaces as well as in the ways of their arrangement is available at the power equipment market of the Republic of Belarus. However, the diversity of the heat transfer surfaces requires the individual test bench (both production and certification), which certainly increases their market value and constrains the update lineup.

Oneofthewaystoreducemanufacturingcostsand-simplifytheprocedureofmarketpromotionofaran-geofheatexchangers can be working out the methods of computational analysis of their thermal and hydrodynamic characteristics using the samples of the heat transfer surfaces.

Such methods will significantly reduce the entire production cycle, from design to implementation in the power equipment market of the Republic of Belarus.

Formulation of the research problem and the method of computational analysis. In this study, a procedure for constructing computational domain and the method of solving the basic systems of non-stationary multidimensional conservation equations are made on the basis of formalized templates of the software package *COMSOL Multiphysics* and embedded in the package the finite elements method. Thus, the calculation of the turbulent component of the coefficient of kinematic viscosity was performed according to *k-ε* turbulence model in the interpretation of *COMSOL Multiphysics*.

Problem statement and setting the initial data is performed for the four computational sub domains:

–the area between the finned tubes(the mechanism of heat transfer–convection, medium – air);

–outer tube with fins(heat transfer mechanism–thermal conductivity, medium – aluminum);

–contact area between the out era dinner tube(thermal resistance);

–the inner tube(heat conduction, steel).

An industrial sample of the bimetallic surface of heatex change with external intensifiers [1], which is adapted to the computational model not only on the geometrical parameter, but also on the structure of the contacting surfaces was considered as a geometric analog of the computational domain.

The contact in homogeneous layer was modeled with a porous structure with the given (in accordance with the electronic prototype) characteristics. When solving within the computational experiments the inverse problem of heat exchange the experimental temperature gradients in the contact area of conjugate heat transfer surfaces were used.

Fig.1 shows the structure of the computational domain and a GUI element of 3D model of the bimetallic tube bundle with external fins.

Results of the research. This paper presents the results of the verification of 3D models analyzing thermal and aerodynamic characteristics of the development of the contact surface of the heat transfer of a complex configuration with respect to the tube bundle of bimetallic tubes with external fins.

When conducting computational experiments the following transfer mechanisms were taken into consideration:

– heat transfer by natural convection of the air in the model element of a chess tube bundle with the boundary condition of the 1st kind on the axis of the central tube. The rest of the tubes in the computational domain played a role of propellants to match the profile of the air stream flow to the conditions in the real heat exchanger. The condition of thermal isolation with an infinitely large heat resistance was put on their outer surface;

–heat transfer by natural convection of the air in the above model element of a chess bundle when setting the conditions of symmetry external surface of the temperatures of pipe propellants and the central tube;

–heat transfer by combined (forced and natural) convection of the air in this model element of a chess bundle with the boundary condition of the 2nd kind on the central axis of the tube.

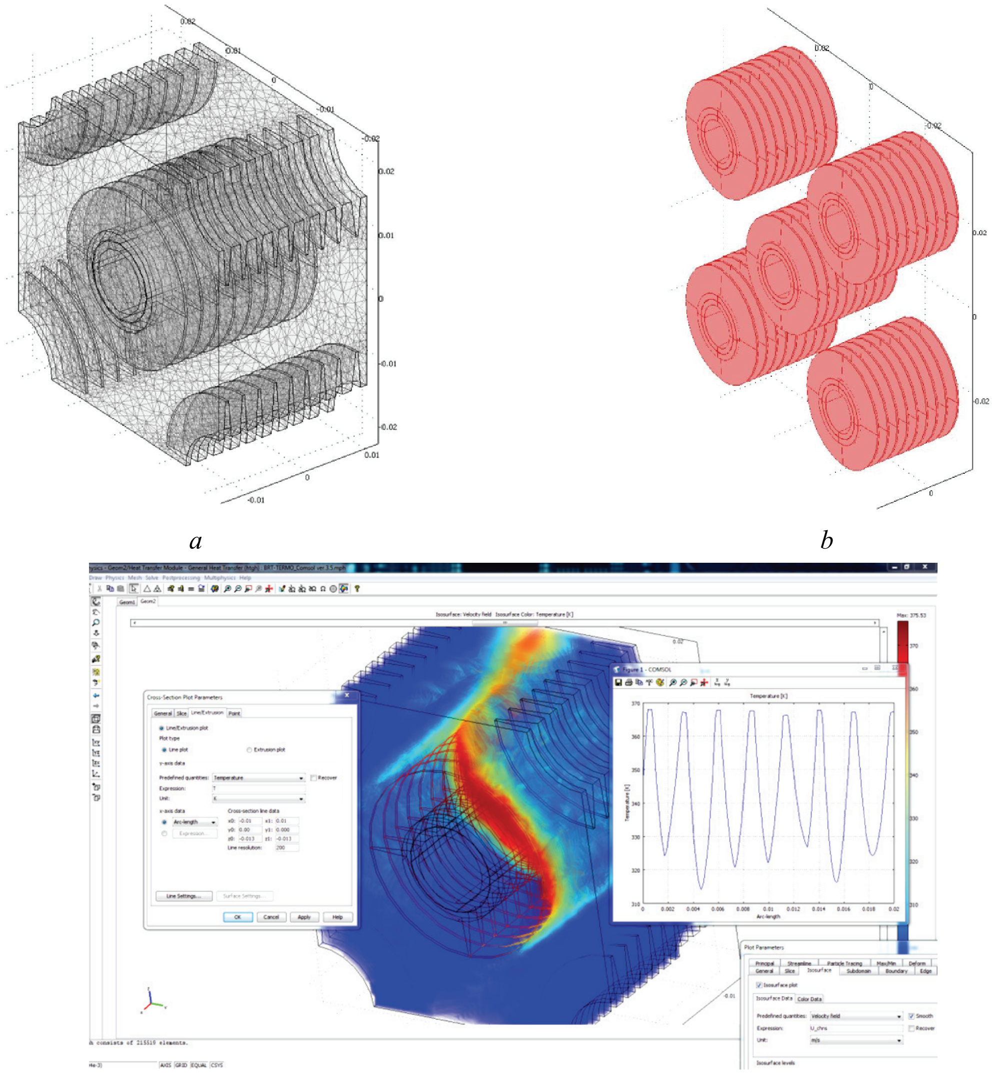


Fig. 1. 3D model of the bimetallic tube bundle:
a – a three-dimensional model of the element of tube bundle; *b* – finite element mesh of the computational domain;
c – GUI component of specialized computing template
(geometric characteristics of the computational domain – 0.04×0.02×0.04 m)

The last of the above modes corresponded to the experimental investigation of the thermal contact resistance of the industrial design of bimetallic pipes with external fins [1]. The results of this work were used in the validation of the computational model in the framework of solving the inverse problem of heat transfer.

According to the results of complex computing experiments it was possible to analyze the profiles of pressure, velocity and temperature in different sections of the calculation template pattern, which revealed a number of features of the processes of heat transfer in the related fields of complex configuration.

Fig. 2 and 3 illustrate respectively streamlines and the velocity field interms of the series of computational experiments.

Fig. 4 and 5 are diagrams of the temperature distribution in the various sections of the spatial computational domain.

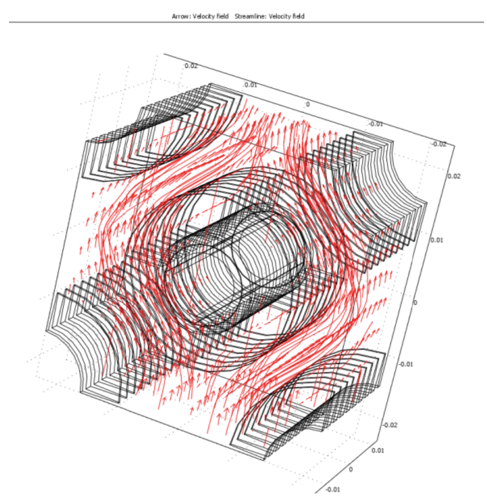
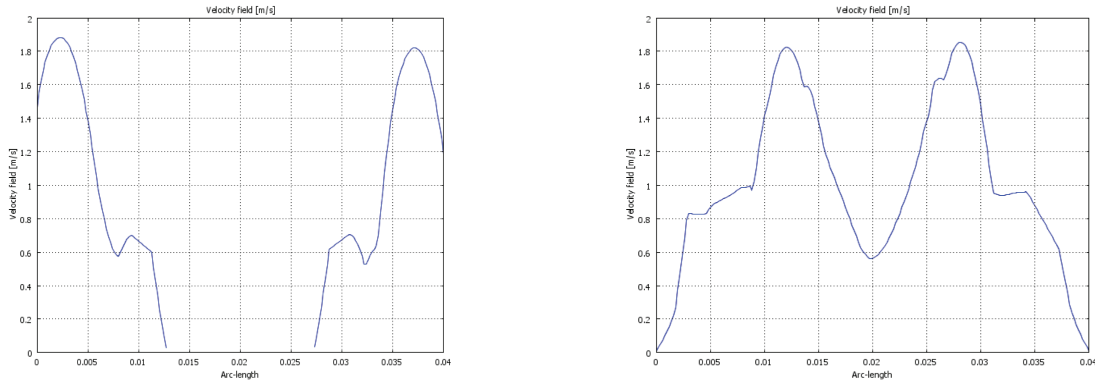
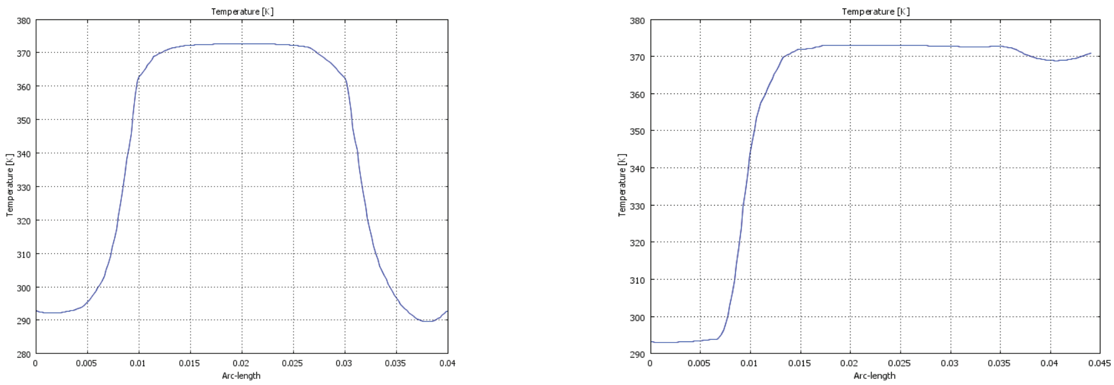


Fig. 2. Streamlines of the aerodynamic flow
(geometric characteristics of the computational domain as shown in Fig. 1)



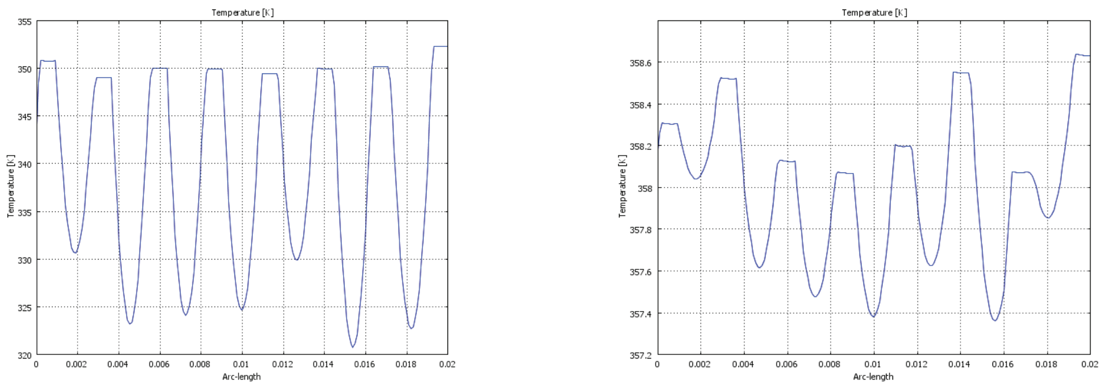
a *b*

Fig. 3. Air velocity fields in different sections of the computational domain:
a – the velocity profile in the central section; *b* – the velocity profile in the inlet area
(the range of speed changes from 0 to 2.2 m/c)



a *b*

Fig. 4. Temperature distribution in different sections of the computational domain (free flow):
a – the temperature profile in the air flow in cross-section; *b* – temperature profile
in the air stream in the longitudinal section (variation range of 293 to 372 K)



a *b*

Fig. 5. The temperature profile in the area of the fins:
a – the longitudinal profile of the temperature in the zone of bottom fin (variation range of 325 to 352 K);
b – longitudinal temperature profile in the zone of top fins (variation range from 357.2 to 358.6 K)

As follows from Fig. 4, the longitudinal profile of the temperature in the zone of the bottom fins is more regular than the corresponding temperature profile at the top. This can be explained primarily by a more stable than the output aerodynamic situation at the inlet to the calculated analog element of a tube bundle. This instability is associated with the formation of vortex structures and the demolition of their downstream out of the computational domain.

On the other hand, the amplitude of temperature change in an array of ribs and the aerodynamic flow along the lower generatrix is higher due to the relatively low temperature of the air flow at the inlet.

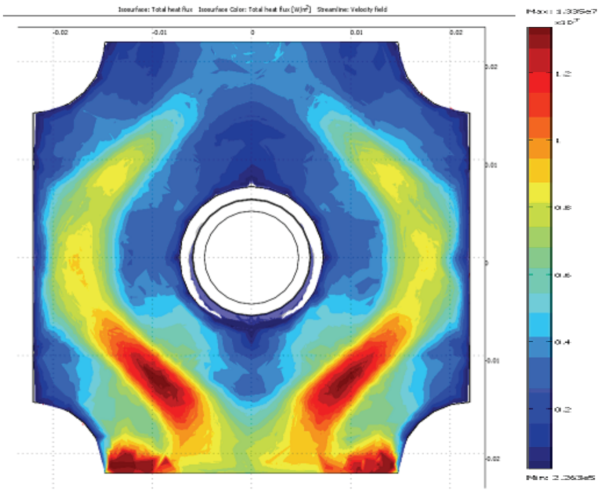


Fig. 6. The distribution of heat flow on the computational domain (the range of variation from $2.3 \cdot 10^5$ to $1.3 \cdot 10^7$ Wt/m^2, the air flow rate at the inlet – 6 m/s)

Besides the above-mentioned characteristics of the processes of transfer in the calculated template, Fig.5 shows that in the rear part of the pipe stagnation zones are formed and, respectively, in this area there is a "failure" of a temperature profile. This, in turn, is indicative of less intensity heat exchange surface in the rear part of the pipes.

Confirmation of this conclusion, to some extent, can be represented in Fig. 6 heat flow distribution in the computational domain.

Conclusion. In general, based on the results of the verification of 3D computing template applied to the real geometry of the industrial bimetallic heat exchanger we can to come to a conclusion of physical coherence and harmonization of the results of the empirical data in the solution of the inverse problem of heat transfer.

The practical use of these templates will improve the computational accuracy of the integral methods of generalization of the results of tests of industrial heat exchangers and thereby reduce the cost and time of their introduction to the market of power equipment.

References

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Received 05.03.2014