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# DEVELOPMENT AND VERIFICATION OF SPATIAL COMPUTATIONAL ANALOG OF BI-METAL CONTACT SURFACE OF HEAT EXCHANGE

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

**Introduction.** There is a wide range of heat exchanging devices on the Belarusian power equipment market, which are different in their intended use, as well as configuration of heat exchanging surfaces and the methods of their arrangement. One of the ways to decrease production costs and simplify the procedure of promoting heat exchangers on the market can be development of methods of computational analysis of their heat and hydrodynamic characteristics using industrial samples of heat exchanging surfaces. Such methods will considerably reduce the entire production cycle from projection to implementation.

**Problem formulation.** In the basis of technique analysis of heat – hydraulic characteristics of multilayered surfaces of heat exchange lays the procedure of analysis of real configuration of these surfaces and its usage for implementation of these constructions.

One of the key moments of the similar analysis is definition of heat resistance of contact surfaces. The given problem can be solved by means of return or direct problems of heat exchange on the basis of multidimensional computing analogues with use of the given test studies of industrial samples of heat-exchange surfaces or direct determination of thermal resistance in specialized experimental researches.

Currently, a number of software functional packages with respect to the 2-D and 3-D modeling of processes in channels of complex shape are worked out. For example, LS-DYNA (Livermore Software Technologies Corp.- DYNAmic) [1], ANSYS+CFX (Computational Fluid dynamiX) [2], FlowVision [3], Star-CD (Computational Dynamics) [4], COMSOL Multiphysics [5].

At present multipurpose software packages ANSYS and COMSOL Multiphysics are widely used which are based on the numerical method of final elements. Both packages allow to solve a wide range of problems, they contain modules for various problems such as electrodynamics, hydrodynamics, thermal mechanics, etc.

Basic difference between ANSYS and COMSOL Multiphysics is in their concept.

In COMSOL Multiphysics the equations describing process and regional conditions in an explicit form at use of any module are always accessible to the user. In ANSYS, on the contrary, mathematical statement is hidden from the user behind the element choice. In ANSYS the choice of element means the choice of the equations, describing the process which narrows the circle of probable statements of problems being solved. Besides, COMSOL Multiphysics contains various resolvent, and a simple application framework provides simple consumption and flexibility.

**Computational approach.** Accordingly, the formalized structure and a computing method of software package COMSOL Multiphysics are chosen as the basic environment of construction of computing analogues.

The following system of preservation of the equations is chosen as a base model of processes:

$$\rho\frac{\partial U}{\partial t}-\nabla\left[\left(\eta+\rho\frac{C_\mu}{\sigma_k}\frac{k^2}{\varepsilon}\right)\left(\nabla U+\left(\nabla U\right)^T\right)\right]+$$

$$+\rho U\nabla U+\nabla P=0;$$

$$\nabla U=0;\ \frac{\partial T}{\partial t}+U_j\frac{\partial T}{\partial x_j}=\frac{\partial}{\partial x_j}\left(\lambda\frac{\partial T}{\partial x_j}\right)+J_T,$$

where ρ – density of the fluid; $U$ – component of the velocity; $x$ – the spatial coordinate; $P$ – hydrostatic pressure; λ – thermal conductivity; $J_T$ – volumetric heat source. Index $j$ – the projection on the axes.

Calculation of the turbulent component of coefficient of kinematics viscosity is carried out according to $k$-ε-models of turbulence in interpretation of COMSOL Multiphysics:

$$\rho\frac{\partial k}{\partial t}-\nabla\left[\left(\eta+\rho\frac{C_\mu}{\sigma_k}\frac{k^2}{\varepsilon}\right)\nabla k\right]+\rho U\nabla k=$$

$$=\rho C_\mu\frac{k^2}{\varepsilon}\left(\nabla U+\left(\nabla U\right)^T\right)^2-\rho\varepsilon,$$

where $k$ – the kinetic energy of turbulence; ε – dissipation of turbulent energy; $C_\mu$, $\sigma_k$ – model constants.

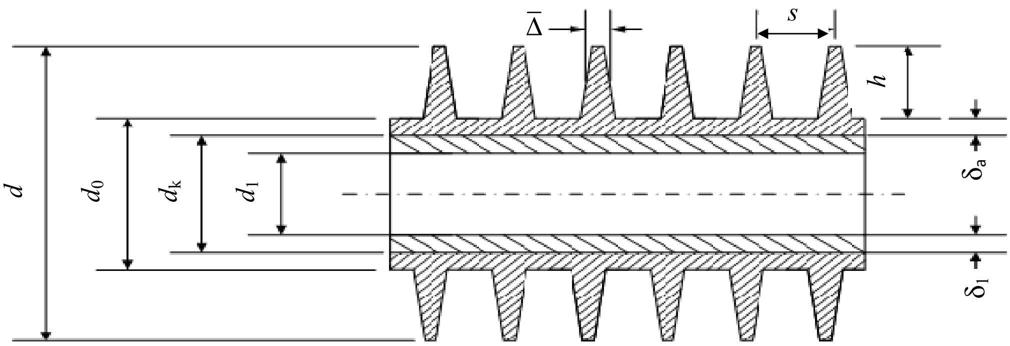
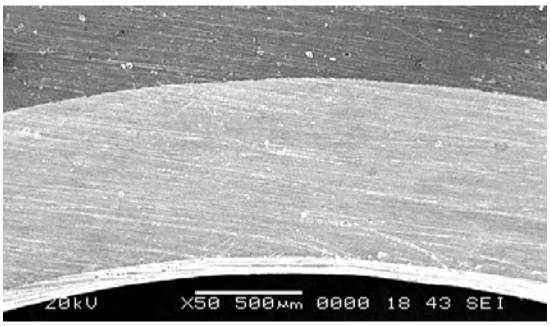



Fig. 1. The scheme of the simulated sample:
$d$ = 26 mm; $d_0$ = 14.5 mm; $d_k$ = 12 mm; $d_1$ = 9.5 mm; $h$ = 5.75 mm;
$s$ = 2.7 mm; $\Delta$ = 0.33 mm; $\delta_1$ = 1.25 mm; $\delta_a$ = 1.25 mm

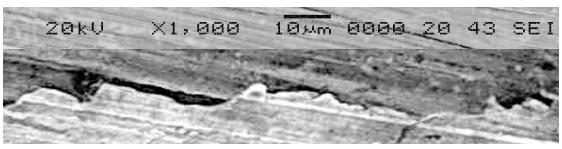
The results of verification (within the limits of noted above method) of spatial computing model of the description of processes of conduction through a bimetallic contact surface of heat exchange of a pre-production model are given in the presented work (Fig. 1).

The electronic prototype of a contact surface of the sample under consideration is represented in Fig. 2, 3. As it is seen in Fig. 4, *b*, the contact surface has complex structure with mutual penetrations of separate layers and air layers.

Fig. 2. Sample of industrial heat transfer surface



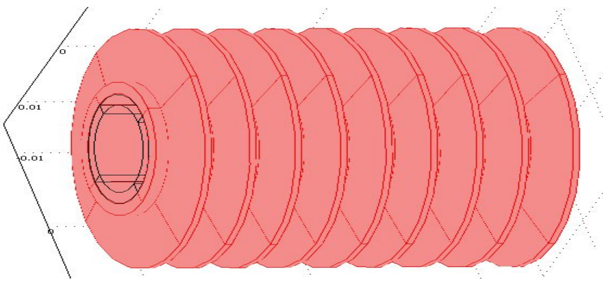

*a*



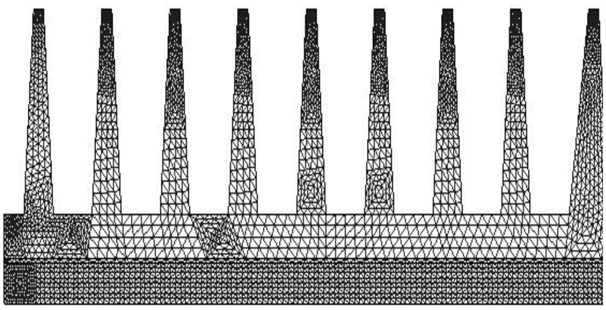

*b*

Fig. 3. Electronic prototype of contact surface at different magnifications: *a* – 50 times; *b* – 1,000 times

In accordance with the parameters of an experimental site on studying of heat engineering indicators of the industrial sample of a bimetallic surface of heat exchange, geometrical and modeling calculating templates are developed with reference to spatial statement of problems of heat-and-mass transfer (Fig. 4).The given computing templates include the multilayered contact surface of heat exchange consisting of an internal steel pipe, area of contact thermal resistance and an external aluminums pipe with ribbing (Fig. 4). Contact heterogeneous porous layer was modeled with the set (according to the electronic prototype) characteristics.

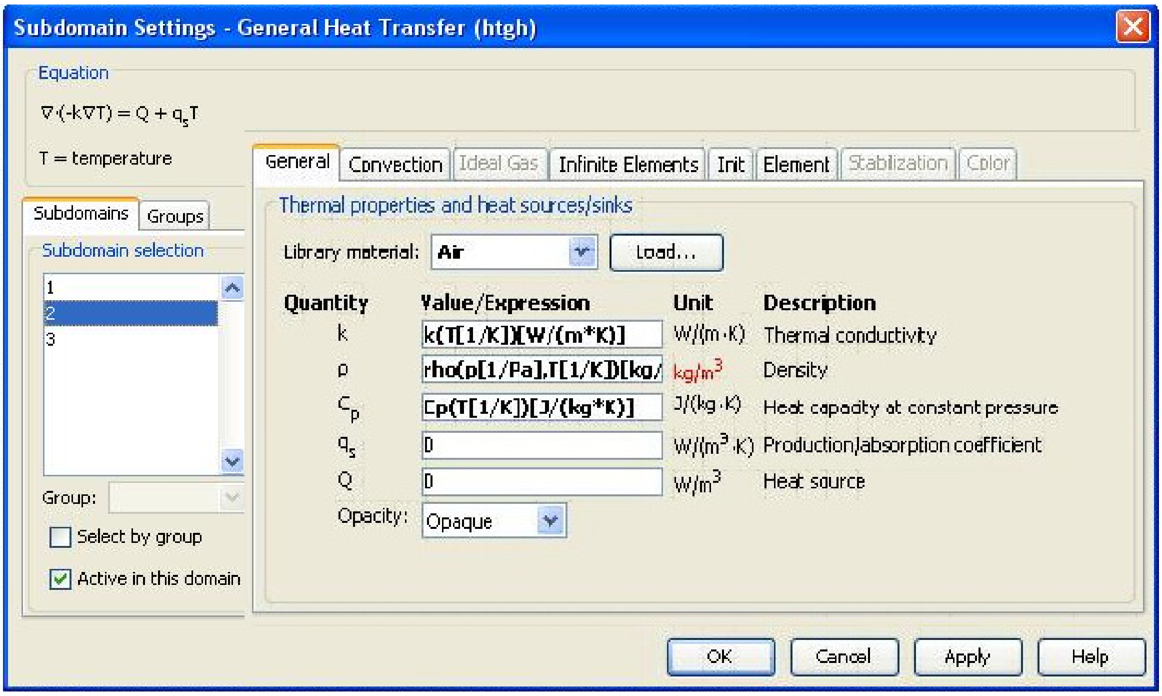


*a*

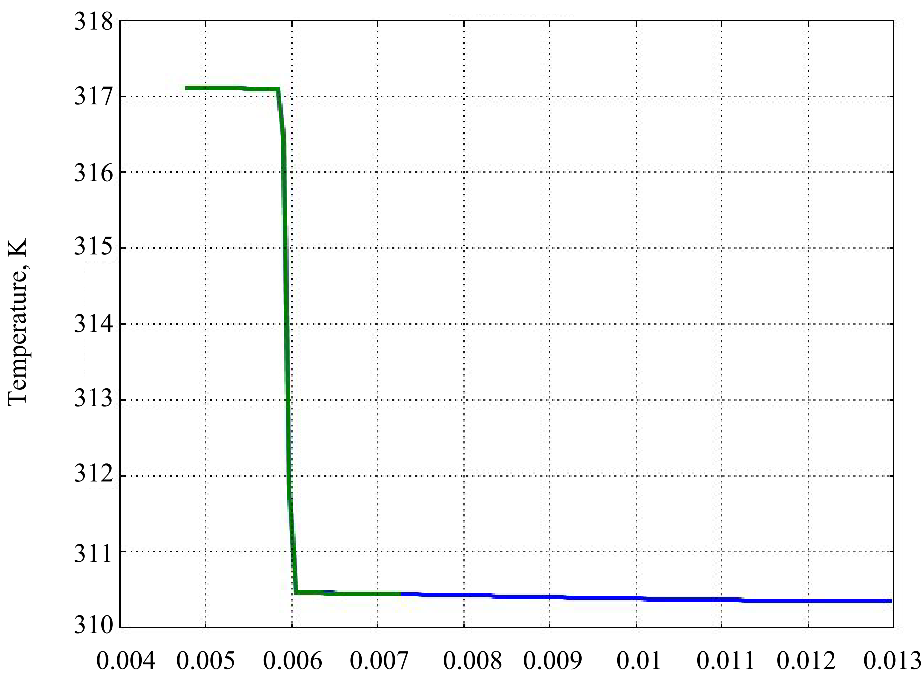


*b*

Fig. 4. Elements of a modeling computational template of the multilayered contact surface of heat exchange with ribbing:
*a* – three-dimensional model of a bimetallic pipe;
*b* – final-element splitting of computational area




*a*




*b*

Fig. 5. Elements of the interface of a computational template of a multilayered contact surface of heat exchanger:
*a* – an element of the interface of the user for the task of initial data;
*b* – an example of graphic representation of results of temperature distribution in cross-section (on the rib center) of the modeling

Practical implementation of computational templates finite element method involves partitioning the computational domain into finite elements of various sizes and various shapes. Example adopted under verification software finite element is shown in Fig. 4, *b* (axisymmetric task).

In Fig. 5 examples of elements of the interface and graphic representation of results of computing experiment are given.

The numerical solution of this problem was carried out in relation to the problem of asymmetric exchange.

Subsequently, results of computing experiment will be coordinated with results of an experimental research on natural model of a bimetallic surface of heat exchange within the limits of the decision of a return problem of heat exchange.

**Conclusion.** As follows from the results of given research, application of the presented computing template of a bimetallic contact surface of heat exchange of the industrial sample shows its physical consistency and stability at the definition of boundary conditions of various kinds.

Practical use of similar modeling computing templates will allow raising reliability of integrated methods of results generalization of tests of industrial heat-exchange devices and by the reduction of expenses and time of their introduction to the power market of Belarus.

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