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Editorial

Modeling of heat transfer and Hydraulic Resistance of an intensified Turbu-lent flow of liquid or gas in pipes with annular Turbulators

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Abstract.

The theoretical model for calculation of heat transfer is developed at turbulent flow in channels in conditions of heat transfer enhancement distinguished from known models by higher accuracy, absence of additional assumptions, account of the greater number of parameters rendering influence to processes of heat transfer. The computation data on isothermal heat transfer largely appropriate to experimental data are obtained. For the first time theoretical model for calculation of nonisothermal heat transfer and hy-draulic resistance is developed at turbulent flow in tubes in conditions of heat transfer enhancement for var-ious kinds of heat-carriers (gas, dropping liquid) with variable thermophysical properties changed by a monotone image. The computation data for a broad band of turbulizers parameters and regime parameters are obtained. For the first time theoretical model for calculation of nonisothermal heat transfer and hy-draulic resistance is developed at turbulent flow of jet fuel of supercritical pressure (JFSCP) in tubes in condition of heat transfer enhancement on the base of four-layer scheme of turbulent flow.

Key words: tubular heat exchangers, heat transfer, enchancement, single-phase flow, boiling, fouling.

The problem of reducing the mass and size heat exchangers is urgent. Enhancement of convective heat transfer processes is a promising means for solving this problem. At present, different methods of heat transfer enhancement in channels have been proposed and studied.

Heat transfer in tubes at flow of heat-carries with constant thermal properties in conditions of heat transfer enhancement is simulated on the basis of a four-layer scheme of turbulent flow. From numerous results of the previous researches it is known, that at the definite depth of cavities roughness (smaller than 20 thicknesses of a viscous sublayer), i.e. at regime of a developed roughness, the fixed vortical flow with regular vortexes is observed. The number and arrangement of these vortexes depend on a relative pitch between protrusions. The roughness in considered as a system of protrusions and cavities; in last the steady regular vortex generations are formed. At streamlining of the closely located cavities the role of stagnation points is insignificant (for example, there are no brightly expressed stagnation points), therefore the modified Reynolds analogy is approximately correct. The analysis shows, that in rough pipes the thermal resistance of turbulent core makes of the order (10÷13)% from common thermal resistance, there-fore total error at calculation of heat transfer will not exceed 5% . Therefore, the violation of the Reynolds analogy will be in this case unsignificantly reflected in results of heat transfer calculation. The good coin-cidence of results of calculations with experimental data testifies also to it. In a rough tube the boundary layer contains four sublayers: a viscous sublayer, intermediate area, vortical core in a cavity, turbulent core with the stabilized velocity profile. For each sublayer the temperature drops are determined, on which it is rather easy to define dimensionless heat transfer coefficient — Nusselt number. Within the framework of the given research the above-stated four-layer scheme of turbulent flow was applied without additional assumptions connected to an error of approximations, and in view of all members in final computational equations, that is expedient distinguishes the given research from all more early.

Heat transfer and hydraulic resistance for nonisothermal flow in tubes in conditions of heat transfer enhancement is simulated on the basis of the four-layer scheme for turbulent flow, which was successfully applied within the framework of the given research at calculation of isothermal heat transfer enhancement at turbulent flow. The legitimacy of modelling of nonisothermal heat transfer and resistance at turbulent flow in tubes in conditions of heat transfer enhancement with this scheme is stipulated by that the as-sumptions used at a conclusion of equations, circumscribing nonisothermal heat transfer in conditions of turbulent flows in smooth tubes (uniformity and isotropy of the heat-carrier, the energy of deformation is small on a comparison with change of internal energy, the diffusion is absent, the mass forces are small on a comparison with forces of inertia and of internal friction), in a sufficient measure are correct and for conditions of heat transfer enhancement. By the major factor stipulating legitimacy of the given approach bases on use of properties of generalized coordinates.

The modelling of heat transfer at flow hydrocarbon fuels

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(JFSCP) is made on the base of four-layer scheme for turbulent flow at variable properties of heat-carrier, characteristic for JF in pseudocritical re-gion, with boundary conditions of constant heat flux density on the wall, as well as for heat-carriers, which properties are changed by a monotone image.

For a boundary layer in a rough tube we shall consider the four-layer scheme: viscous sublayer; in-termediate area; vortical core in a cavity; turbulent core with the stabilized velocity profile in a main flow.

Within the framework of the given model we shall consider , that the height of a roughness h << D.

As district from this research has not defect connected to a considerable error of approximation of an integral on the dimensionless thickness of a viscous sublayer. A divergence of this integral value with the precision solution is especial considerably at large Prandtl numbers. The precision solution also allows to make the conclusion that the values of integrals are much more conservative in relation to parameters of heat transfer: to Reynolds and Prandtl numbers and to the constant β than adduced. Also there was re-ceived that smaller divergence of values of the above mentioned integrals at replacement of the law "of the third degree" on the law "of the fourth degree", than stated in the same researches. The above men-tioned conservatism of integrals allows to make conclusion that the results concerning dependence of Nusselt number from Prandtl number, are obviously overstated. For heat-carrier in round tube with turbu-lizers there will correct following simplifications.1. The quasi-stationarity of the heat-carrier flow and heat transfer far from the inlet are considered. 2. The physical properties of the heat-carrier arbitrary de-pend on temperature. 3. It is supposed, that the physical properties of the heat-carrier within the limits of a pulsation of temperature are changed unsufficiently, therefore their values in the given point can be ac-cepted by constants and equal to values of physical properties at mean value of temperature in the given point.4. Change of heat flux density along axis stipulated by heat conductivity and turbulent transfer is small on a comparison with the change along a radius. 5. Change viscous and turbulent tangential stresses along azimuth and lengths is small on a comparison with change, along a tube radius. 6. Axial mass ve-locity component changes a little along an axis of a tube: $\left[\partial\left(\rho w_x\right)/\partial x\right] \approx 0$

The analysis of Nu/Nusm(d/D) dependence shows, that the theoretical calculation well coincides ex-periment. The given model has allowed to calculate heat transfer at various supercritical pressures. The computational data on heat transfer for a smooth tube at p=3÷5 MPa show, that the value of supercritical pressure does not render of large influence on heat transfer, there is only rather minor deformation of Nusm/NuT fields. Conducted for supercritical pressure of heat-carrier the calculation has shown, that the character of heat transfer qualitatively practically does not vary, the quantitative parameters differ no more than on 10%, but the greater Nusm/NuT values are in region of small supercritical pressure.

The theoretical computational model developed in the given research, is expedient differs from known modern models: higher accuracy of results, absence of additional assumptions, account of the greater number of parameters rending influence to heat transfer processes, obtained theoretical data of rather isothermal heat transfer, including a limiting case, well correspond to experimental data .

Theoretical model for nonisothermal heat transfer and resistance calculation for the first time is de-veloped at turbulent flow in tubes in conditions of heat transfer enhancement for various kinds of heat-carriers (gas, dropped liquid) with variable thermal properties changed monotonically, based on four-layer model of turbulent flow. The theoretical computational data on nonisothermal heat transfer and resistance for the data of conditions for gas practically appropriate to experimental data are obtained. The model allows to receive the computational data for more broad, than in experiment, range of geometric parame-ters of turbulizers and flow regimes: to relative diameter of diaphragms d/D=0.85/0.95; to relative pitch of turbulizers t/D=0.75/2.0; to Reynolds number Re=4000÷200000; dimensionless wall temperature θw=0.3/3.0. Theoretical model for calculation of nonisothermal heat transfer and resistance for the first time is developed at turbulent flow of jet fuel of supercritical pressures in conditions of heat transfer en-hancement based on four-layer model of turbulent boundary layer. The offered model has allowed to re-ceive the computational data for more broad band of parameters and flow regimes.