Generalised semi-empirical correlation for heat transfer in channels of plate heat exchanger

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The analogy of heat and momentum transfer in turbulent flow modified for channels of Plate Heat Exchanger (PHE) is proposed. The effects of channel geometry, flow velocity and fluid properties on heat transfer are accounted in the resulting equation, which permits the calculation of film heat transfer coefficients using the generalized correlation for friction factor at the main corrugated field of the inter-plate channel. The results of calculations are compared with data from experimental study. The good accuracy of film heat transfer coefficients prediction is shown. In the case when the corrugations direction is parallel to the flow direction, the calculations results are quite close to the predicted by the Equation published in the literature for straight pipes. The Prandtl number influence on heat transfer is discussed and semi-empirical Equation for its evaluation is proposed. The comparison with experimental data available in the literature confirmed the accuracy of the heat transfer prediction. The proposed Equation is recommended to be used for optimization of PHEs channels geometry for different conditions in the process industries. It can be employed also for optimizing PHEs heat exchange networks and also to determine PHEs heat transfer area targets when process integration methodology is employed.

In present paper the approach, which enables to account the influence of the Reynolds and the Prandtl numbers on heat transfer, is presented. The results of the solution are approximated with the use of heat and momentum transfer Reynolds analogy and the equation which account the influence of the Prandtl number on heat transfer. The obtained equation enables to predict the film heat transfer coefficients for turbulent flows inside PHE channels in a wide range of the Reynolds and Prandtl numbers using the data for friction factor at the main corrugated field of the channel.

The influence of the Reynolds and the Prandtl numbers on heat transfer in a wide range of their values cannot be accounted by simple power Equations with a constant as the Prandtl number exponent what is usually used in empirical correlations. The proposed semi-empirical model, which is based on a modification of Von Karman analogy for heat and momentum transfer, allows to predict the Prandtl number influence on heat transfer for flows in PHE channels . The expression for the Prandtl number exponent depending on the Prandtl and Reynolds numbers is obtained.

The proposed Equation can be used for determining the Prandtl number exponent in generalised correlation for calculation of film heat transfer coefficients. It enables to estimate the heat transfer intensity in PHE channels for friction factor at the main corrugated field in such channels. Such calculation procedure enables to obtain the film heat transfer coefficients with maximal error less than 15%, as was demonstrated by the comparisons with experimental data on heat transfer published by a number of different researchers. These comparisons are presented in the paper. The introduction of the proposed Equation allowed to widen the range of applications of the proposed calculation procedure compare to the fixed Prandtl number exponent in under the calculations. It is estimated as follows: the Prandtl number Pr is from 0.7 to 10^3; the Reynolds number Re is from 80 to 25,000; the corrugation inclination angle β is from 14° to 68°; the corrugation aspect ratio γ is from 0.5 to 1.5; the area enlargement factor F_x is from 1.14 to 1.5. This range covers the most of the possible conditions for PHE applications in process industries, as well as feasible options of corrugations on the PHE plates. Together with Equations for estimation of local pressure drop in channel distribution zones and ports the presented Equations allow to develop the thermo hydraulic mathematical model of PHE. Such model can be used for optimization of PHEs channels geometry for different conditions in the process industries. It can be employed for developing software for optimisation of individual PHEs, and for optimizing PHEs heat exchange networks.

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