Numerical analysis of non-isothermal Newtonian flows on plate heat exchangers

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Plate heat exchangers (PHE's) are widely used in chemical, pharmaceutical, biochemical processing, food, and dairy industries, offering this type of equipments several advantages like the low space requirement, high efficiency, easy cleaning and maintenance, low fouling tendency and high flexibility (Reppich, 1999). Heat transfer in a PHE is strongly dependent on geometrical properties of the chevron plates, namely on corrugation angle, area enlargement factor and channel aspect ratio. Besides these factors, heat transfer is also influenced by the local variation of temperature dependent physical properties and especially the variable viscosity effects (Kakaç and Liu, 2002; Manglik and Ding, 1997). The design of this heat exchange equipment involve the determination of optimum pressure drops being referenced in the literature several studies directed to this subject (Bassiouny and Martin, 1984; Leuliet et al., 1990; Stasiek et al., 1996; Mehrabian and Poulter, 2000).

Computational fluid dynamics calculations are useful in order to understand the local properties of the flows in the complex geometries of PHE's being the geometries and flows more accurate described by implementing 3D channels (Kho and Müller-Steinhagen, 1999). Resorting to a 3D geometry of a PHE with corrugation angle, β, of 30° Fernandes et al. (2005) made a non-isothermal, non-Newtonian analysis of stirred yoghurt cooling in a PHE, based on experimental data of Afonso et al. (2003), and a good agreement was found between numerical and experimental results.

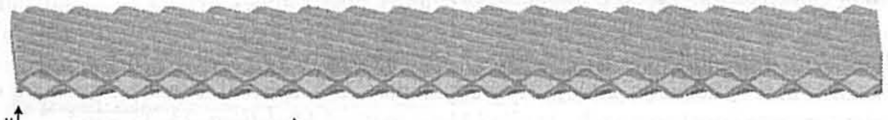

Fig. 1: Geometrical domain for PHE with $\beta = 60°$.

On the present work non-isothermal Newtonian flows are analysed, being proposed relations between fanning friction factors and Reynolds numbers for PHE's with the same plate distance but different corrugation angles and area enlargement factors. Velocity field, radial and axial variations of shear rate and viscosity are studied as well as the variations of Nusselt number on x and z directions, Fig. 1, of the different plate heat exchangers. Local Nusselt numbers were determined on x and z directions by:

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$$\mathrm{Nu} = \frac{hD_H}{k}$$

where k is the fluid thermal conductivity, D_H the hydraulic diameter and h the convective heat transfer coefficient:

$$h = \frac{q}{T_f - T_w}$$

being q the heat flux imposed on the plates as thermal boundary condition, T_f the bulk fluid temperature on the channel and T_w the plates temperature. The temperatures T_f and T_w can be calculated by the numerical results, Fig 2.

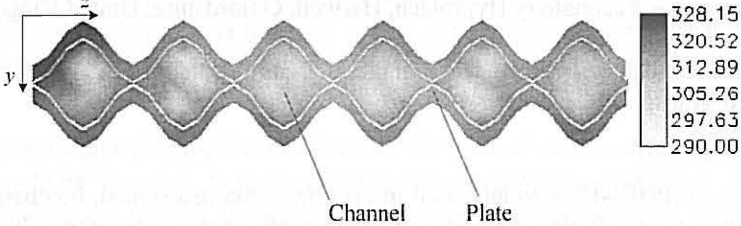

Fig. 2: Temperature distribution in a plane of equation $x = const.$ and $\beta = 60^o$.

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