Heat transfer to Newtonian and non-Newtonian fluids in cross-corrugated chevron-type plate heat exchangers: Numerical approach

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Food fluids are frequently processed in plate heat exchangers (PHEs) and usually behave as non-Newtonian fluids, this behaviour being scarcely considered for PHEs design purposes (Rene et al., 1991). Moreover, many food fluids processed in PHEs have a high viscosity and, therefore, data obtained in laminar flow regime is useful to practical applications (Rene et al., 1991; Metwally and Manglik, 2002; Fernandes et al., 2005, 2006, 2007).

The thermal-hydraulic performance of PHEs is strongly dependent on the physical properties of the fluid and on the geometrical properties of the plates (Kumar, 1984; Kakaç and Liu, 2002; Ayub, 2003) namely, on the corrugation angle, β, and on the channel aspect ratio. The mostly widely used PHEs have corrugations of the chevron type (Palm and Claesson, 2006) with an area enlargement factor defined as the ratio between the effective plate area and projected plate area close to 1.17 (Kumar, 1984; García-Cascales et al., 2007).

In the present work non-isothermal laminar flows of Newtonian and power-law fluids through cross-corrugated chevron-type plate heat exchangers are studied numerically in terms of the geometry of the channels. The plates area enlargement factor was a typical one (1.17), the corrugation angle varied between 30° and 60° and the flow index behaviour, n, between 0.25 and 1.

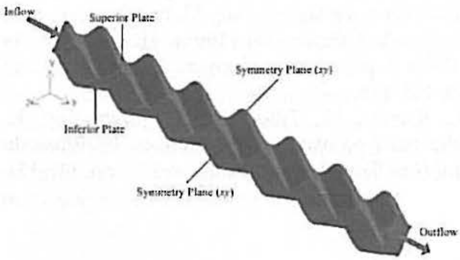

Fig. 1: Example of a channel used in the numerical calculations (Fernandes et al., 2007).

The numerical calculations were performed using the commercial finite element software package POLYFLOW®. The equations solved were the conservation of mass, momentum and energy equations for laminar incompressible flow of Newtonian and power-law fluids. The simulations were performed using channels containing seven consecutive unitary cells (Fig. 1), since thermal and hydraulic fully developed flows were achieved in the fifth or sixth consecutive cell, as described in previous works (Fernandes et al., 2007).

Coefficient K from the friction curves $f\mathrm{Re} = K$ compares very well with experimental (Kumar, 1984) and semi-theoretical data (Wanniarachchi et al., 1995) for all (seven) values of β. Nusselt number reaches a maximum in the interior of the studied β range, for a fixed Reynolds, Re, number. Shear thinning effects greatly affect the thermal-hydraulic performance of the plate heat exchangers

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