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Heat transfer and fluid flow in a plate heat exchanger. Part II: Assessment of laminar and two-equation turbulent models

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ABSTRACT

This paper presents a comparison of experimental data and numerical predictions for the hydrodynamic and thermal fields in a two-channel plate heat exchanger. The temperature distributions on the first and the last of the three plates, the friction factor and the Nusselt number for each channel as well as the outlet temperatures of the two streams are compared. The laminar model has satisfactorily been validated for Reynolds numbers less than 400. For the turbulent flow regime, several two-equation models were tested and the Realizable $\kappa-\varepsilon$ model with non-equilibrium wall functions has been found to give the closest results to the experimental data. The flow distribution in cross-sections of the channels was studied numerically. Streams of higher velocities on the channels' sides, where two narrow vertical smooth passages are located, were observed.

1. Introduction

Plate heat exchangers (PHE) are widely used in many applications (food, oil, chemical and paper industries, HVAC, heat recovery, refrigeration, etc.) because of their small size and weight, the ease of cleaning as well as their superior thermal performance compared to other types of heat exchangers. Several experimental and numerical studies have therefore been recently conducted in order to predict the flow and temperature distribution in PHEs. Many of the latter use simplifying assumptions.

By considering the periodicity of the flow and heat transfer in a corrugated channel, Mehrabian and Poulter [1] as well as Croce and D'Agaro [2] modeled a representative computational cell. This cell is the smallest possible segment of the undulated channel and is considered to be the section bounded by four adjacent contact points.

Bigoin et al. [3] studied the applicability of different turbulence models for describing the flow inside a PHE; they considered a 2D approach – the flow between two sinusoidal walls.

Lozano et al. [4] analyzed the flow distribution inside one channel of a PHE for the automotive industry, without considering the heat transfer. They created and validated a 3D model which consists of a single channel. Their analysis concluded that the flow was not uniform and preferentially moved along the lateral extremes of the plates.

Kanaris et al. [5] studied the flow and heat transfer in a PHE. They used a 3D model which includes two complete channels and validated it against experimental and literature data. A similar model was used by Tsai et al. [6] in order to investigate the hydrodynamic characteristics and distribution of flow inside a PHE, with no heat transfer involved. Their CFD models use the real geometry of the plates, including the entire entrance and distribution zones.

Jain et al. [7] considered a 3D turbulent model with a complete cold channel and two halves of the adjacent hot channels. This model uses more realistic hydrodynamic and thermal boundary conditions, the two halves of the hot channels on either side having flat periodic boundaries. As a consequence, they were able to validate their model on a PHE with 13 channels.

Hur et al. [8] created a similar model in order to study the heat transfer in a PHE. Although the chevron angle is the same as the one in the present study ($\varphi = 60^\circ$) and the Reynolds number varied between 249 and 1018, they used only the laminar model for all the simulations.

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