Seeking the optimal design of a typical plate heat exchanger (*PHE*)

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The need for designing process equipment that complies with the principles of economic and ecological sustainability acted as a driving force towards the evolution in the design of plate heat exchangers (***PHE***). Because of their compactness, close temperature approach and ease on inspection and cleaning (Shah & Wanniarachchi, 1991), *PHEs* are used in process and power industries for a wide range of temperatures. The plates of these *PHE* comprise some form of near-sinusoidal corrugations in a herringbone pattern (***Fig. 1***). When two of these plates are arranged and placed abutting, a channel with complicated passages is formed. As expected, the fluid flow inside a passage of this channel undergoes a series of periodic changes in flow direction, a kind of flow that augments heat transfer, while on the other hand it induces a significant resistance to the flow.

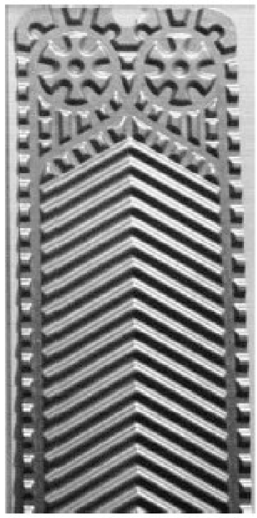

Fig. 1. A typical plate of a PHE.

Previous work conducted in this Laboratory (Kanaris et al., 2006) has proved that *CFD* is a reliable tool for simulating the operation of a commercial *PHE*. Thus, in place of expensive and time consuming laboratory experiments, *CFD* simulations can be effectively used for predicting the performance of this type of equipment, which is strongly affected by the geometry of the conduit. Thus, the geometrical parameters of the conduit (***Fig. 2***) are used for creating a series of computational domains, based on a design-of-experiments (*DOE*) method, to ***optimize*** the *PHE* performance.

These conceptual *PHEs* have been numerically studied (in terms of heat transfer and fluid flow analysis), using a previously validated commercial *CFD* code (*ANSYS CFX® 10*) (Kanaris et al., 2006). To quest for the optimal design of the corrugated surface, an *objective function* is formulated, as a trade-off between heat transfer and pressure drop, using a weighting factor to account for the relative significance of friction losses to heat recovery (i.e., electric energy vs. thermal energy). Five dimensionless groups are selected as design variables for the simulations, namely:

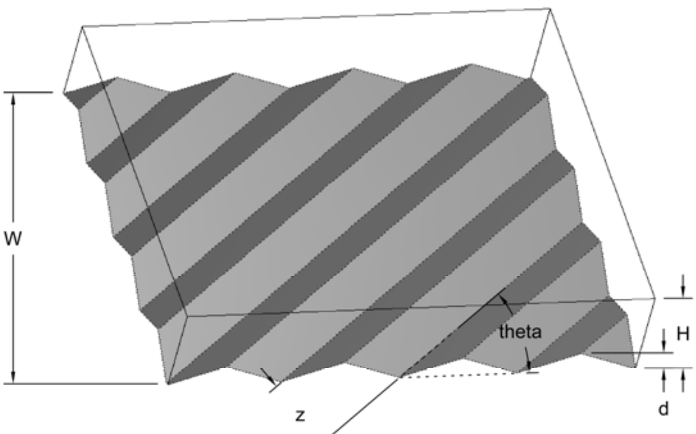

Fig. 2. Geometric parameters on a part of the computational domain.

- the blockage ratio (*BR=d/H*) that expresses the percentage of the entrance of the channel ‘blocked’ with corrugations,

- the channel aspect ratio (*ChanAR=H/W*); a measure of how narrow the channel is,
- the corrugation aspect ratio (*CorAR=d/z*); a measure of the obtuseness of the corrugation,
- the sine of twice the angle of attack ($sin2\theta$) and
- the Reynolds number, *Re*, defined as: $Re = {uD_h\rho}/{\mu}$, where D_h the hydraulic diameter of the conduit and u is the mean entrance velocity.

Box-Behnken design was selected for the design variables in order to construct the response surface. The calculated values of the objective function are used to create a quadratic model to be optimized using response surface methodology (*RSM*) (Myers & Montgomery, 2002).

A typical plot with results, covering a *Re* number range from 500 to 6000, is presented in ***Fig. 3***, for a typical weighting factor. Apparently, the objective is to construct flow passages that enhance secondary flow inside the furrows, which in turn augments heat transfer rates. For low values of the weighting factor (i.e. when pumping cost is low), the optimal performance of the *PHE* is achieved for the shortest distance between the plates and for less obtuse corrugations. As *Re* increases, the *PHE* performance can be improved for lower channel aspect ratios (i.e., wider channels) and for higher values of the angle of attack. Nevertheless, if the weighting factor is high, i.e., the pumping cost is high, the optimal design of a *PHE*, as shown in ***Fig. 3***, dictates greater distances between the plates and less sharp corrugations, as *Re* increases.

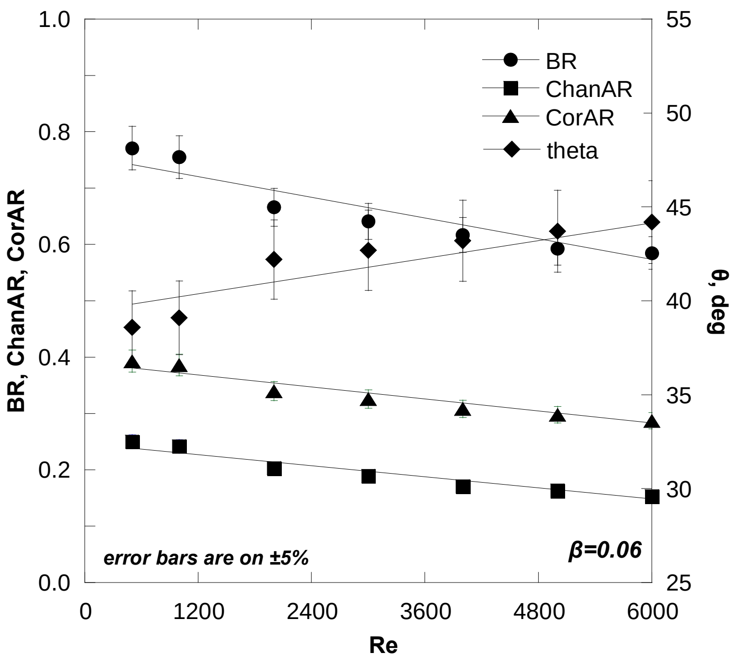

Fig. 3. Typical optimal values of various design parameters vs. *Re* number.

References

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