

## Thermal hydraulic analysis of a plate heat exchanger

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In present study, for prescribed pressure drop in a reference stream and heat transfer rate, size of plate heat exchanger is calculated iteratively. Martin's correlations for chevron-type PHEs are employed through curve fitting.

**Keywords:** Plate heat exchangers (PHEs), Pressure drop, Thermal hydraulic model

### Introduction

Plate heat exchangers (PHEs) are widely used in dairy plants, food processing plants, chemical industries, power plants, pollution control systems etc. Traditional design method ( $\epsilon$ -NTU or logarithmic mean temperature difference method) for PHEs, involves many trials to meet pressure drop constraints, which can be avoided through optimal design method<sup>1</sup>. Gut & Pinto<sup>2</sup> presented a screening method for selecting optimal configurations for PHEs. Zhu & Zhang<sup>3</sup> discussed integrated optimal design of materials, placement, size and flow-rate of a PHE. Peng & Ling<sup>4</sup> demonstrated successful application of genetic algorithm (GA) combined with back propagation neural networks (BPNN) for optimal design of plate-fin heat exchangers (PFHE). Mathematical model of heat-transfer phenomenon in a double-pass laminar countercurrent heat exchanger with uniform heat fluxes has been developed<sup>5</sup>. Kanaris *et al*<sup>6</sup> suggested a general method for optimal design of a PHE with undulated surfaces that complies with sustainability principles. Mishra *et al*<sup>7</sup> developed a GA based optimization technique for crossflow PFHEs using offset-strip fins. Bobbili *et al*<sup>8</sup> carried out an experimental investigation to find flow and pressure difference across port to channel in PHEs for a wide range of Reynolds number (1000-17000).

This study presents thermo-hydraulic formulation, which represents relationship between stream heat transfer coefficient (HTC), pressure drop and exchanger area.

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### Thermal Hydraulic Formulation for Plate Heat Exchanger (PHE)

In order to design PHEs with full utilization of allowable pressure drop, thermal-hydraulic model<sup>1</sup> is employed in present study. Martin's correlations for chevron-type PHEs (Fig. 1) valid for corrugation angles (10-80°) are used. Computational predictions were compared with reported data<sup>9</sup>.

### Results and Discussion

#### Solution Methodology

Under solution methodology (Fig. 2), various input parameters are supplied at the beginning for reference stream 1 (chilled water). After calculating fanning friction factor ( $f$ ), coefficients  $c$  and  $d$  are calculated by curve fitting. In a similar manner, after calculating Nusselt Number, coefficients  $a$  and  $b$  are calculated by using these coefficients; pressure drop ( $\Delta P$ ) for reference stream 1 is calculated. If  $\Delta P$  is different from design value, procedure is repeated till convergence criteria is satisfied. Using this value of  $\Delta P$ , HTC  $h_1$  for reference stream 1 is calculated. Complete

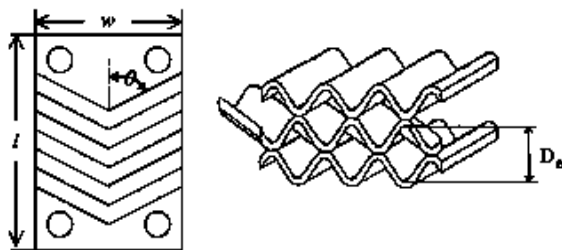


Fig. 1— A schematic of a chevron- type plate heat exchanger

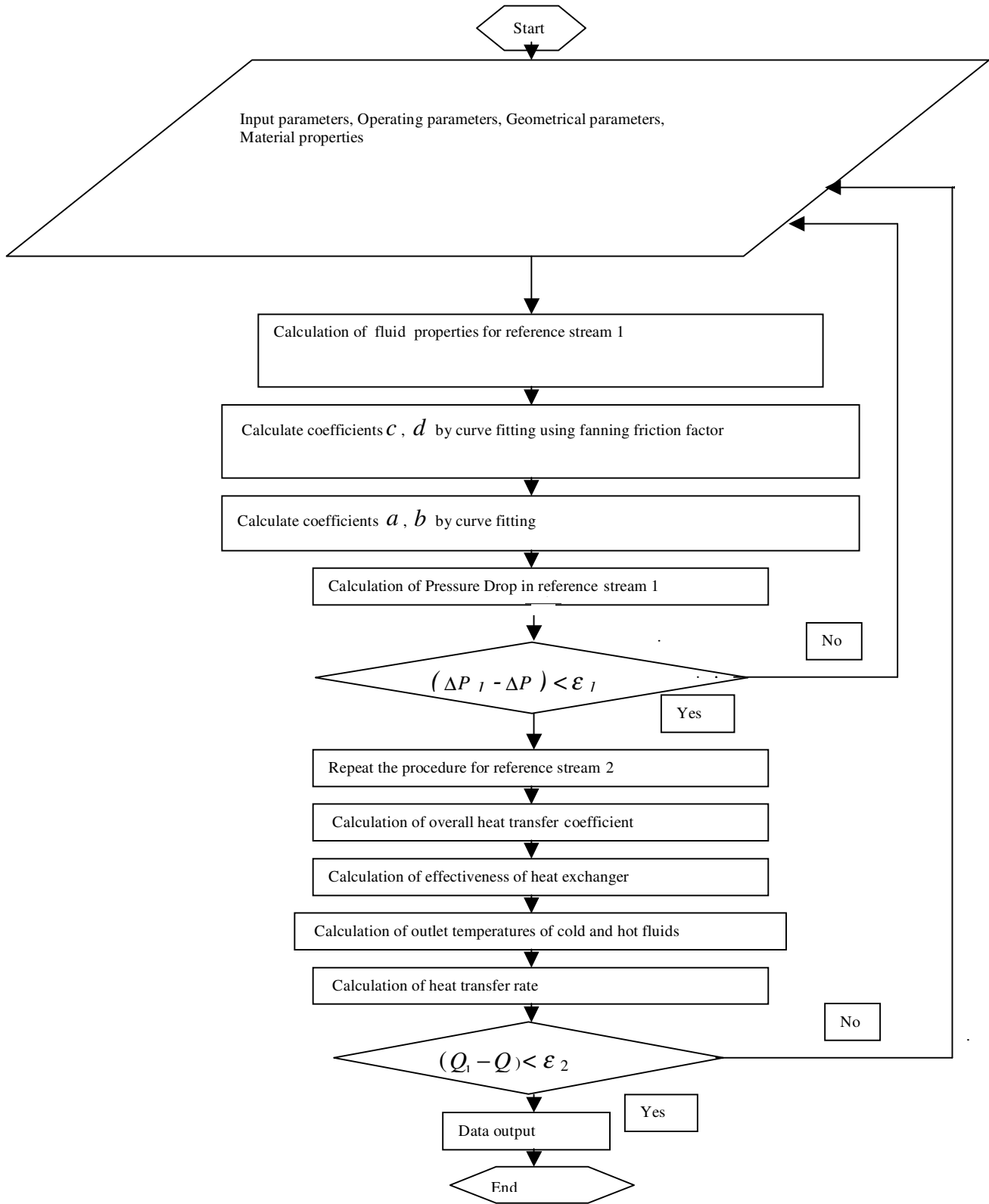


Fig. 2— Flow chart for thermal-hydraulic formulation

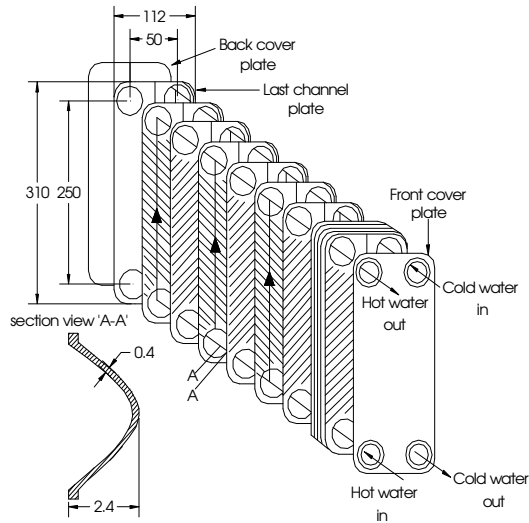
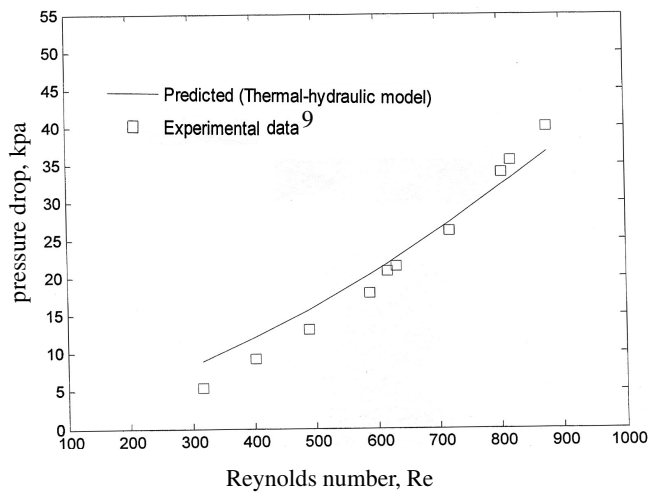
Fig. 3— Schematic of plate heat exchanger<sup>9</sup>

Fig. 5— Pressure drop versus Reynolds number

procedure is repeated to calculate HTC  $h_2$  for reference stream 2 (hot water). Overall HTC of PHE is calculated. In above procedure, stream with higher pressure drop is selected as reference stream. Effectiveness is calculated by NTU method and corresponding outlet temperatures of both fluids are calculated. Once outlet temperatures are known, total heat transfer rate is calculated by energy equation. If calculated heat transfer rate is different from design value, procedure is repeated till convergence criteria is satisfied.

#### Input Conditions

Operating parameters were as follows: chilled (cold) water inlet temperature ( $T_{ci}$ ), 4 °C; hot water inlet temperature ( $T_{hi}$ ), 22 °C; mass flow rate of chilled water

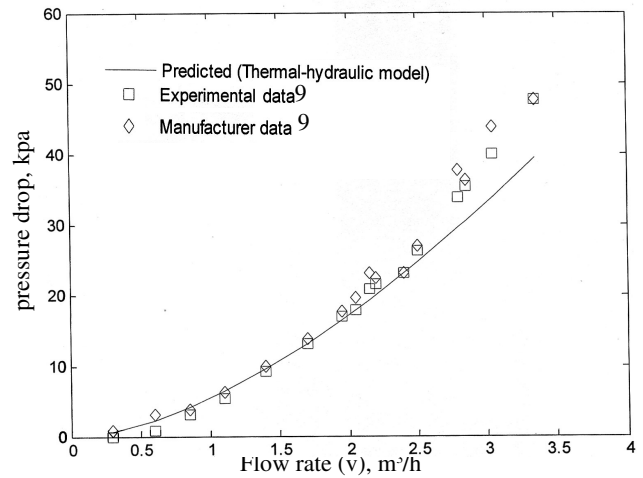


Fig. 4— Variation of pressure drop with flow rate

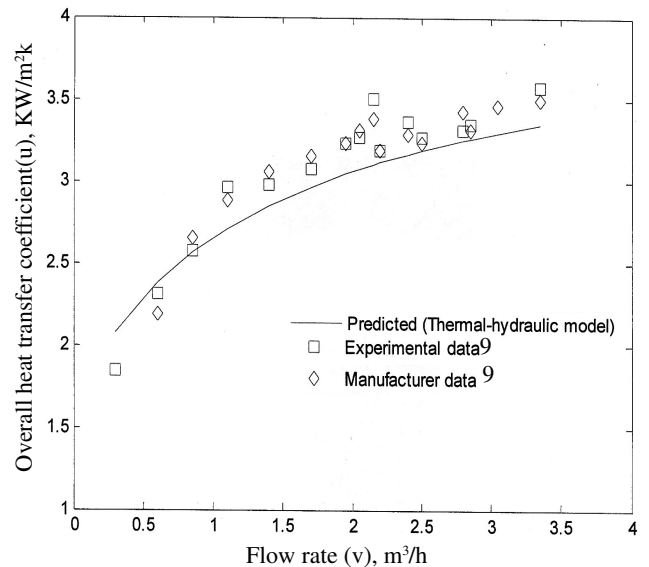


Fig. 6— Variation of overall heat transfer coefficient with flow rate

( $M_1$ ), 0.083333-0.9305 kg/s; mass flow rate of hot water ( $M_2$ ), 0.1944 kg/s; volumetric flow rate of chilled water ( $V_1$ ), 0.000083333-0.0009305 m<sup>3</sup>/s; volumetric flow rate of hot water ( $V_2$ ), 0.0001944 m<sup>3</sup>/s; and thermal conductivity of plate material ( $\lambda$ ), 13.56 W/mK. Geometrical parameters (Fig. 3) used were as follows: number of plates ( $N$ ), 24; equivalent diameter ( $D_e$ ), 0.004 m; port diameter ( $d_p$ ), 0.050 m; pass number ( $n$ ), 1; projected plate length ( $l$ ), 0.250 m; path number of chilled water ( $m_1$ ), 11; path number of hot water ( $m_2$ ), 11; plate width ( $w$ ), 0.100 m; corrugation angle ( $\theta$ ), 60°; and plate thickness ( $\delta$ ), 0.0005 m.

#### Pressure Drop

Experimental and manufacturer data<sup>9</sup> are compared with predictions of present formulation on

variation of pressure drop with flow rate of chilled water (Fig. 4). Predicted chilled water matches reasonably well with experimental and manufacturer data for a flow rate up to  $2.5 \text{ m}^3/\text{h}$ , beyond which experimental and manufacturer data shows higher as compared to predictions. Under variation of pressure drop vs Reynolds Number (Fig. 5), predicted and experimental data matches satisfactorily. Up to Reynolds Number less than 700, model slightly overestimates, whereas model underestimates for values above 700.

#### Heat Transfer

Overall HTC is found slightly overestimated up to flow rate of  $\text{m}^2/\text{h}$  (Fig. 6), whereas it is underestimated beyond higher values of flow rates.

#### Conclusions

Thermal hydraulic model provides relationship to predict heat transfer based on allowable pressure drops are reasonably matching with experimental data. Therefore, thermo-hydraulic model is useful for design of individual PHEs. Model can be extended for optimization of PHE networks.

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