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CFD Analysis on the Periodic Element of a Printed Circuit Heat Exchanger

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1. Introduction

A typical printed circuit heat exchanger (PCHE) is composed of a large number of flow channels with lateral corrugations [1]. In an effort to investigate fundamental thermo-fluid characteristics of a PCHE with corrugated channels, computational fluid dynamics (CFD) analyses were previously made in [2,3]. One pair of flow channels (i.e., cold and hot channels) with the entire flow path was considered for the computational domain in the previous studies. Although only one pair of flow channels with coarse meshes was used, computational loads were found to be very high to simulate the entire flow path of the PCHE.

Fortunately a recent study [4] has shown that a simplified CFD methodology with a streamwise periodic assumption (called periodic CFD analysis) is feasible for a CFD evaluation of the thermo-fluid performance of compact heat exchangers. Since the periodic CFD analysis focuses on the periodic element of a flow channel, the required computing resources are dramatically reduced.

In the present paper, the periodic CFD analysis has been applied to the periodic element of the PCHE. The results are compared with those of the full elements which have an entire flow path. Based on the periodic approach the effects of the corrugation parameters on the thermo-fluid performance of the PCHE are investigated.

2. Physical Model

Fig. 1 shows the geometry of the periodic element of the PCHE with corrugated channels. The hot and cold fluids flow in a counterflow direction at the separated channels.

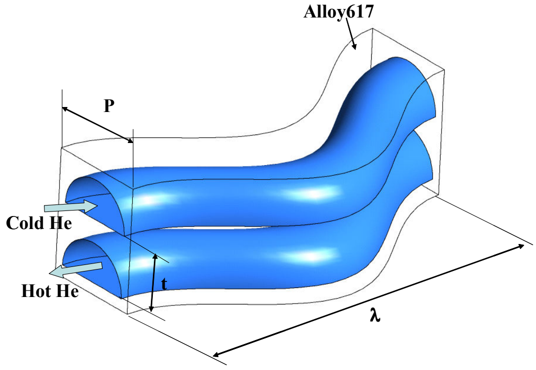

Fig. 1. Geometry of periodic element of PCHE.

The adopted geometric data are summarized in Table 1. The same geometric data and mesh structures in a previous work [2] are used for a fair comparison in this work. Only the laminar case (Re ≈ 800) is considered. Periodic boundaries are imposed on the outside surfaces including the fluid domains and the same methodology introduced in [4] is applied. The calculation is performed by using a commercial code CFX 10 [5].

Table 1. Reference geometric data of periodic element

Channel diameter (d_{ave})	1.7976 mm
Channel pitch (P)	2.44 mm
Plate thickness (t)	1.6 mm
Wavelength (λ)	9.3333 mm
Wave amplitude (H)	2.3333 mm

3. Numerical Results

Fig. 2 shows the calculated u-velocity contour on the x-planes with every λ/4 step. The same contours of both side planes confirm that the periodic boundary conditions are adequately imposed.

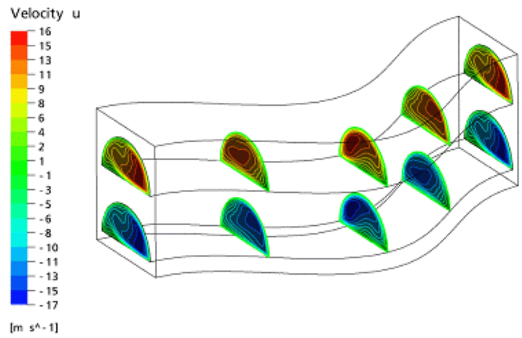

Fig. 2. Calculated u-velocity contour.

The second column of Table 2 shows the summarized CFD results on the periodic element of the PCHE. The results of the full elements (having 89 periodic elements) are also presented in the third column for a comparison. It is shown that the periodic CFD analysis with one periodic element can reasonably predict the thermo-fluid performance of the PCHE. The small differences seem to be mainly from the linear assumption of the temperature profiles and the developing effects.

Table 2. The CFD results of the periodic element and the comparison with those of the full elements

	Periodic element (λ)	Full elements (89 λ)
Hot channel pressure drop per element (Pa)	449	456
Hot channel temperature rise per element (K)	5.34	5.37
Ave. temperature difference bet. hot and cold channels (K)	13.7	14.8
Overall heat transfer coeffi. (W/m^2/K)	2034.3	1888.3
LMTD (K)	13.8	17.9
Calculation time (CPU time, sec)	4,235	286,177

Owing to the largely reduced computational load, parametric studies, which require a large number of computations, can be made with reasonable efforts. Based on the periodic CFD analysis, the effects of the corrugation parameters on the thermo-fluid performance of the PCHE are investigated. The flow in a corrugated wall channel is very interesting since a variety of flow phenomena can be considered by changing the corrugation parameters. Series of CFD calculations are made with various combinations of the corrugation parameters. Figs. 3 & 4 show the summarized results. Figs. 3 & 4 clearly show that the corrugation parameters largely affect the thermo-fluid performance of the PCHE. A compromise is required in a practical design between the pressure drop and the heat transfer coefficient.

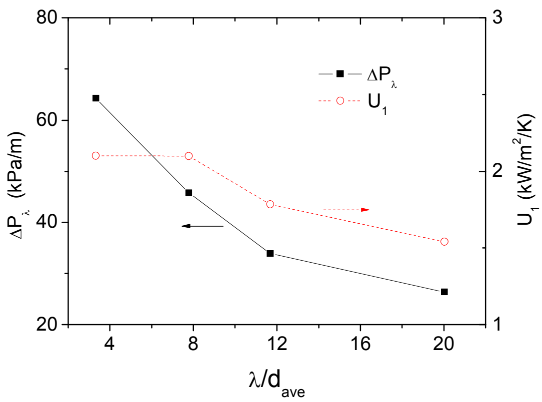

Fig. 3. Effects of wavelength-to-width ratio on pressure drop and overall heat transfer coefficient.

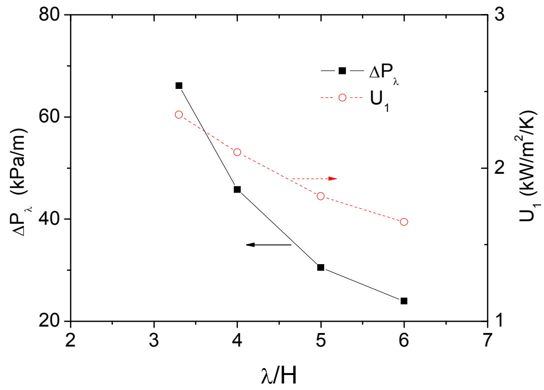

Fig. 4. Effects of wavelength-to-amplitude ratio on pressure drop and overall heat transfer coefficient.

4. Conclusions

The periodic CFD analysis was applied to the periodic element of the PCHE and the results are compared with those of the full elements. It is found that the periodic CFD analysis can produce reasonably good results with largely reduced computational resources. In addition, the parametric studies on the corrugation parameters of the PCHE show that the corrugation parameters considerably affect the thermo-fluid performance of the PCHE. Detailed optimization studies are required to obtain the best design.

ACKNOWLEDGMENTS

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