The Analysis of Topology Optimized 3D Printing Heat Exchanger for the Small Nuclear Reactor

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1. Introduction

The PCHE (Printed Circuit Heat Exchanger) is known as a compact type heat exchanger with small volume and excellent heat exchange efficiency compared to its capacity. The possibility of PCHE application in small nuclear reactor was studied [1-3]. The chemical etching techniques used to produce PCHE have limitation to make complex design flow channel. As the 3D printing technology develops, complex shaped flow channel can be manufactured. The complex channel through topology optimization method is considered to increase heat transfer efficiency. The topology optimized flow channels for small nuclear reactor were analyzed to compare heat transfer ability with existing flow channels.

2. Methods and Results

The topology optimization of the flow channel was performed using COMSOL Multiphysics 5.6 code simulation. The analysis was performed on the single cold flow path (blue lines) in PCHE shown in Fig. 1 because the optimization task takes a long time [4]. The hot flow path (red lines) was replaced by external heat supply due to the limitation of the simulation time. The pseudo 3D model was adopted to calculate the heat transfer in the external heat supplying condition with reduced interpretation time shown as Fig. 2 [5]. The 2D conductive base plate transfer the heat at 2D flow channel. The thermal coupling was used to interpret the geometry of flow channel.

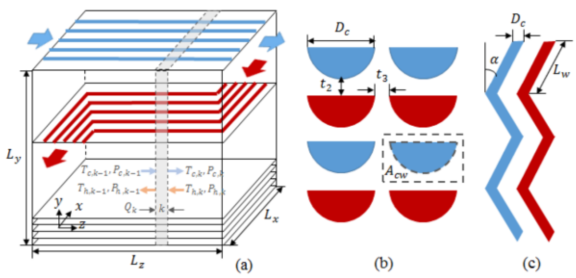

Fig. 1. Geometry of PCHE (a) plate arrangement, (b) cross-section, (c) channel design [4].

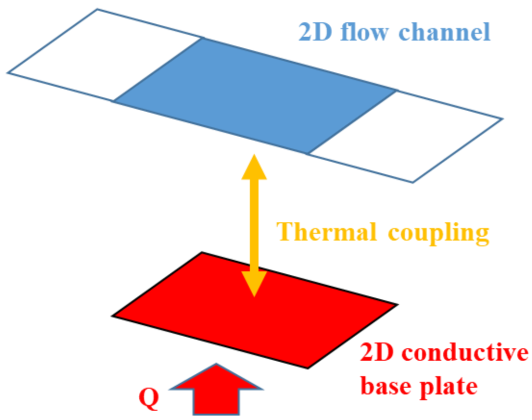

Fig. 2. Concept of pseudo 3D model consisting of 2D flow channel (design domain) and base plate.

The topology optimization was achieved with the aim of minimizing thermal resistance. The geometry was analyzed in the aspects of the number of flow channels. In the case of one-line flow channel, the optimized geometry was represented in Fig. 3. The white region represents fluid flowing path and black region represents the wall. The inlet flow condition was 15 Pa and outlet flow conditions was 0 Pa. The 5 W of heat was transferred to the flow channel with the insulated wall. The fish bone shaped wall was derived to increase heat transfer efficiency.

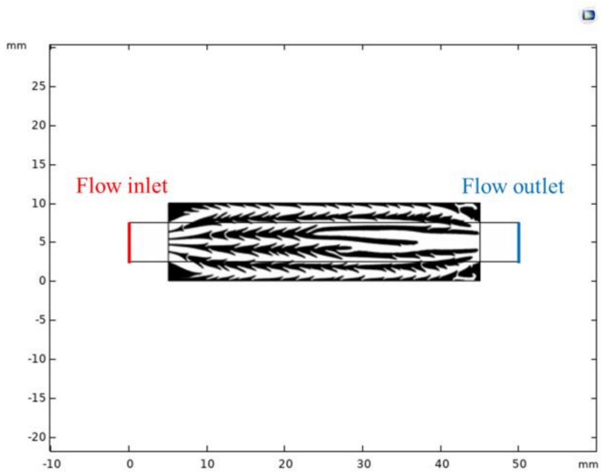

Fig. 3. One-line Topology optimized geometry of flow channel at inlet pressure condition of 15 Pa.

The four-lines topology optimized geometry was represented in Fig. 4. The inlet pressure flow condition was 20 Pa and outlet flow condition was 0 Pa. The same 5 W heat transfer was adopted. The flow channel was not straight geometry to increase heat transfer of fluid.

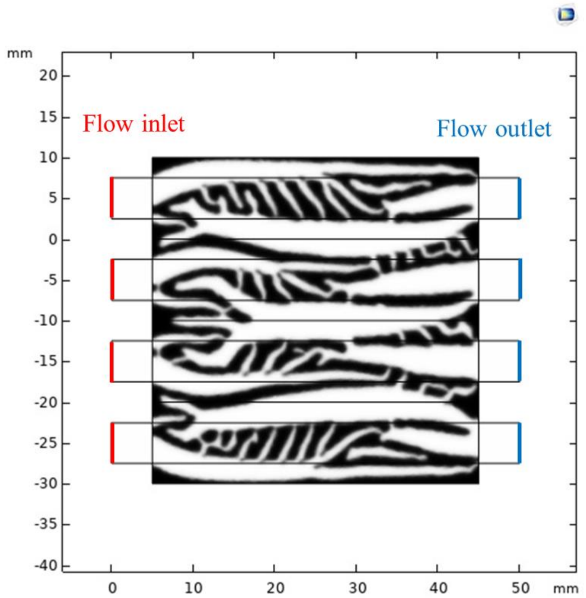

Fig. 4. Four-lines Topology optimized geometry of flow channel at inlet pressure condition of 20 Pa.

3. Conclusions

The topology optimized geometry of PCHE was presented. We thought that optimized geometry could increase the heat transfer rates which can remove heat from heat exchanger in small reactor. The comparative analysis with the existing PCHE will be studied in the future, and simple form of the 3D printed heat exchanger will be experimented.

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