Transactions of the Korean Nuclear Society Virtual spring Meeting
May 13-14, 2021

CFD simulation on hydraulic performance of a rectangular mini channel with staggered mini pin fins

Armanto P. Simanjuntak [a] , Benrico Simamora [a] , Jae-Young Lee [a*]
[a]*Department of Mechanical Engineering Handong Global University, Pohang, Gyeongbuk, South Korea*
[*]*Corresponding author: jylee7@handong.edu*

1. Introduction

Researchers have been attempting to understand the characteristic of hydraulic performance by considering the pressure drop of various type of PCHE. Nikitin et al. investigated the performance of PCHE in supercritical CO2 loop. The study proposed an empirical correlation to predict the local heat transfer coefficient and pressure drop as a function of Reynolds number [1]. Kim et al. Investigated the hydraulic performance of a micro-channel PCHE. The hydraulic performance on longitudinal corrugation flow channel was predicted by computational fluid dynamics (CFD) simulation and validated by experiment data [2]. Sung and Lee conducted a study about a tangled channel heat PCHE for thermoelectric power generation [3].

Nowadays, mini channel has a big attention in the flow and heat transfer field. It has been used in many fields such as electronic cooling, power plant reactor, and micro engines. To obtain greater active area of heat sinks, mini/micro fins are installed inside the flow channel. The appearance of fins can raise the heat transfer ability of the system. This study is an effort to contribute to the develop new PCHE configuration with different shape of fin arrangement.

2. Methods and Results

A numerical simulation was carried out using three-dimensional commercial CFD software fluent 18.0 [3]. The governing equations of continuity and momentum were solved using a second order upwind scheme and semi- implicit method pressure linked equation (SIMPLE) was utilized to couple velocity to pressure.

Numerical simulation was conducted in the range of 30< Re < 100 which consists of 7 cases. For each case, a CPU powered by Intel® Core™i7-4930K 3.40 GHz CPU and 64 GB RAM.

Grid independence is investigated to ensure the accuracy and efficiency of the numerical data. To evaluate the influence of grid density on the calculated result, three sets of grid numbers were studied at Reynolds number 100. The calculated result is nearly identical to the increase in number of elements.

Table I: Pressure difference under 3 grid number conditions

Mesh #	Number of grid	ΔP
Mesh #1	1129507	34.8933
Mesh #2	5505618	33.7621
Mesh #3	2917991	33.5023

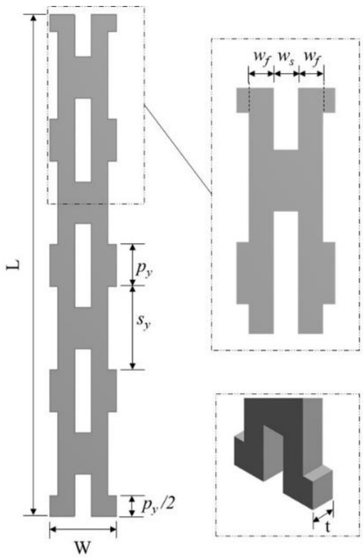

Fig. 1. Geometry design and dimension

Numerical simulation resulted pressure difference value which is measured as the difference between inlet and outlet surfaces. Total length 60 mm was simulated in this study. Friction factor was calculated by considering the pressure difference by using below equation:

$$f_L = \frac{2\Delta p_L D_h}{\rho_L v_L^2 L} \quad (1)$$

Reynolds number was obtained by considering below equation:

$$Re_L = \frac{\rho_L v_L D_h}{\mu_L} \quad (2)$$

Where Dh is calculated by using. This method was also used by [4].

$$D_h = \frac{4A}{P} = \frac{4AL}{PL} = \frac{4V}{A_{wetted}} \quad (3)$$

Where A is the area (m^2), P is the wetted perimeter (m); V is the volume (m^3) ; ρ_L is the density of liquid (kg/m^3); v_L is the liquid velocity (m/s) and μ_L is the liquid dynamic viscosity ($Pa.s$)

Qu and Siu-Ho [5] conducted both adiabatic and diabatic test for water flows across arrays of staggered rectangular micro pin fins in the range 37.9 < Re < 85.8. They proposed a power-law type correlation based on their data.

$$f = 20.09Re^{-0.547} \tag{4}$$

2.1 Friction factor

The friction factor resulted by simulation result was shown in Fig.2. It shows that the friction factor decreases as the Reynolds number increases. The simulation was performed under fully laminar region assumption. Friction factor resulted by simulation was compared with correlation proposed by Qu and Siu-Ho [5]. It is shown that the simulation result is averaged 14% lower compared to Qu and Siu-Ho's correlation.

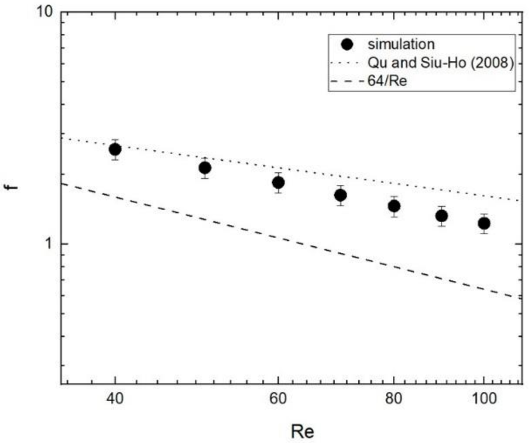

Fig. 2. Friction factor resulted by simulation result.

2.2 Effect of Height to Diameter (H/D) ratio

A unique geometry which consists of rectangular pin fins was used in this study. Effect of ratio between pin's height and diameter (H/D) was also observed. Fig. 3 shows the friction factor under 3 different H/D conditions. It is shown that the friction factor decreases with the increase of H/D ratio. In condition of H/D = 0.6, friction factor is 14% higher than H/D condition of 1.1 while H/D = 1.4 friction factor is higher averaged 18% compared to H/D = 1.1.

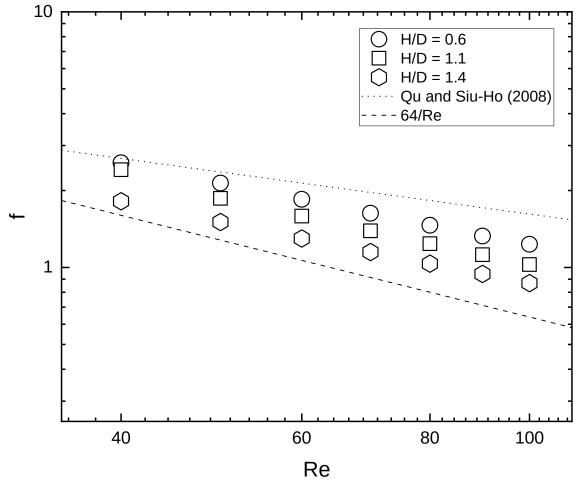

Fig. 3. Friction factor resulted by simulation result in 3 different H/D ratio conditions.

2.3 Effect of tip radius

Rectangular channel of PCHE has tip edge area. This tip edge area will cause uncertainty in numerical simulation calculation. In this study, effect of tip radius is also observed. 2 different tip radius condition which is 0 mm and 0.25 mm tip radius were simulated. Fig. 4 shows the friction factor result under different tip radius condition. The simulation result shows that there is no significant difference between two different tip radius conditions. An average of 4% deviation was resulted under two different tip radii.

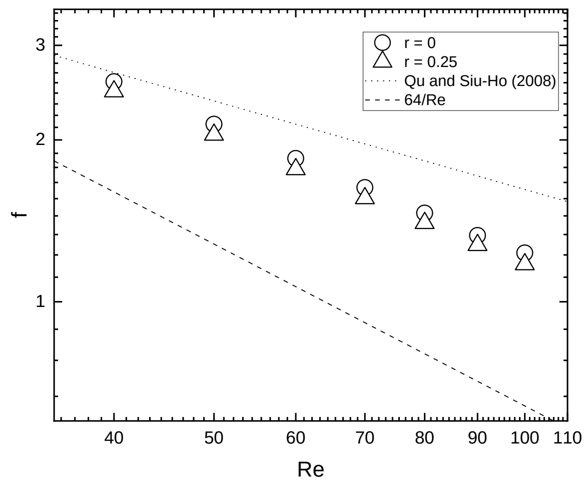

Fig. 4. Friction factor resulted by simulation under different tip radius conditions.

3. Conclusions

Numerical simulation to observe the hydraulic performance of a rectangular mini channel with rectangular shape fins has been conducted under condition of 30 < Re <100. The numerical simulation result was compared to a correlation which was proposed by Qu and Siu-Ho with around 14% deviation range. Besides that, effect of H/D ratio was also observed with around 14% deviation range.

3. Further work

This hydraulic performance study should be supported by experimental data. Meanwhile, experimental study will be conducted.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2017M2A8A4018624)

REFERENCES

[1] Nikitin, K., Kato, Y., Ngo, L., Printed circuit heat exchanger thermal-hydraulic performance in supercritical CO2 experimental loop. International Journal of Refrigeration 29 (2006) 807-814.
[2] Kim, J.H., Bae, S., Jeong, S., Jung, J., Hydraulic performance of a microchannel PCHE. Applied Thermal Engineering 30 (2010) 2157-2162
[3] ANSYS Inc. ANSYS Fluent User's Guide 18.0. 2017
[4] Sung, J., Lee, J.Y., Effect of tangled channels on the heat transfer in a printed circuit heat exchanger. International Journal Heat Mass Transfer 115 (2017) 647-656.
[5] W.Qu, A. Siu-Ho, Liquid single-phase flow in an array of micro-pin-fins-Part II: Pressure drop characteristics. J. Heat Transfer. Transaction ASME 130 (12) (2008) 124501. 1-4