PERFORMANCE COMPARISION BETWEEN RECTANGULAR PARALLEL FLOW AND COUNTER FLOW MICROCHANNEL HEAT EXCHNAGER

Avinash Yadav[1], Satyendra Singh[2]
1: Department of Mechanical Engineering, B.T.K.I.T Dwarahat Almora, Uttarakhand, India.
2: Associate Professor, Department of Mechanical Engineering, B.T.K.I.T Dwarahat Almora, Uttarakhand, India.

Abstract:
The study of heat transfer rate, effectiveness, performance index and effectiveness are calculated between counter flow and parallel flow microchannel heat exchanger with varying thickness of separating wall were calculated. The rectangular type 3D isosceles right triangular microchannel is taken for the study. The water is taken as working fluid for both hot and cold fluid. By using the single phase liquid flow the thermal performance of microchannel heat exchanger is analyze. By solving the energy, continuity, and momentum equations the results are achieved, all the equations are solved in FLUENT 16.0. The heat transfer rate, effectiveness, and the hydraulic and thermal performance of the channel are calculated for Reynolds numbers between 100 to 400. The consequences show the good arrangement between both channels. Comparatively Parallel flow passage the superior consequences are obtained in the counter flow channel. The hydraulic and thermal enactments are very fine in counter flow channel. Hence the accuracy of the counter flow channel is more than parallel flow channel.

Key Words: Microchannel, Heat transfer, Parallel flow, Counter flow, Performance Index

Introduction:

The advancement of technology in computational speed, requirement of power supply, diagnostic and biological advancement depended on the reduction of the size of thermal fluids systems in micro scales. In modern centuries there is speedy growth of applications which generate high heat transfer rate in relatively small channels. Tuckerman and Pease (1981) first introduce the concept of microchannel with the hydraulic diameter from 86μm to 95μm calculated the pressure drop and required pumping power. Aggarwal et al. (2012) analyze the pressure drop in diverging microchannel heat exchanger with sweltering in dissimilar divergence angle and recommended that at the existence of critical angle which can decrease the mean pressure drop. Hernando et al. (2009) experimentally examined heat transfer and pressure drop with in two different cross-sectional microchannels using deionized water as a working fluid. The result displayed the no heat transfer incremental seemed as an outcome of small channel sizes, and result showed moral contract with the common theory. Park and Punch (2008) experimentally premeditated heat transfer

Nomenclature

Notation		Meaning
x	:	horizontal coordinate, m
y	:	vertical coordinate, m
z	:	axial coordinate, m
h	:	channel height, m
b	:	channel width, m
l	:	channel length, m
v	:	velocity of fluid, m/s
v_{in}	:	average velocity, m/s
c_h	:	heat capacity of hot fluid, w/k
c_c	:	heat capacity of cold fluid, w/k
D_h	:	hydraulic diameter, m
Q	:	heat transfer rate, w
m	:	mass flow rate, kg/s
P	:	pressure, Pa
q_{max}	:	maximum possible heat transfer rate, w
q_{actual}	:	actual heat transfer rate, w

Greek Symbol

f	:	friction factor
η	:	performance index
ε	:	effectiveness
ρ	:	density
μ	:	dynamic viscosity

Subscript

h	:	hot fluid
c	:	cold fluid
i	:	inlet
o	:	outlet
max	:	maximum

Dimensionless group

Reynolds number, Re : $\frac{D_h}{\mu}$

and friction factor in rectangular microchannel under laminar flow (69 < Re < 800) condition with varying hydraulic diameter between 106-307µm. It was initiate that, while predictable hydrodynamic principle for fully-developed flow is significant for this range of flow Re, unconventionalities were observed in heat transfer calculations.

Choi et al. (1991) distinguished the friction factor in silica micro pipes using nitrogen as a functioning fluid with diverse hydraulic diameter (3, 7, 10, 53, 81µm). They concluded that Poiseuille numbers are lower than the conventional value for different values of Reynolds.

Numerical calculations:

The figure shows the arrangement of the channel using as counter flow and parallel flow.

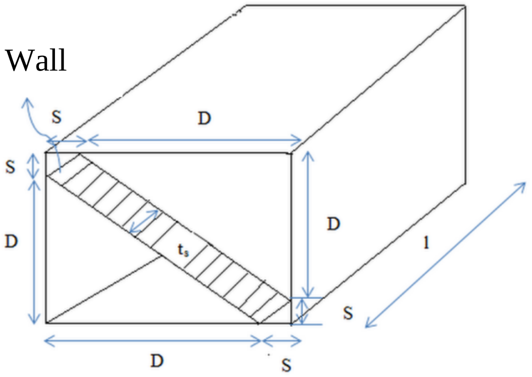

Fig.2 Schematic of rectangular microchannel heat exchnager

The effectiveness of the heat exchanger can be described taken as the ratio of actual heat transfer to the maximum possible heat transfer.

$$\varepsilon = \frac{Q_{actual}}{Q_{max}} \quad (1)$$

And the performance index of microchannel are calculated as

$$\eta = \frac{\epsilon}{\Delta P} \quad (2)$$

Where,

$$\Delta P = \Delta P_h + \Delta P_c \quad (3)$$

To check the accuracy of the present model the comparison of the temperature profiles is shown in [6, 7]. From the agreement the percentage error is very low. The comparison is accounted for parallel flow channel.

Results and Discussions:

The result shows the comparative study between parallel flow and counter flow rectangular microchannel.

Figure 2 show the variation in effectiveness with varying Reynolds numbers.

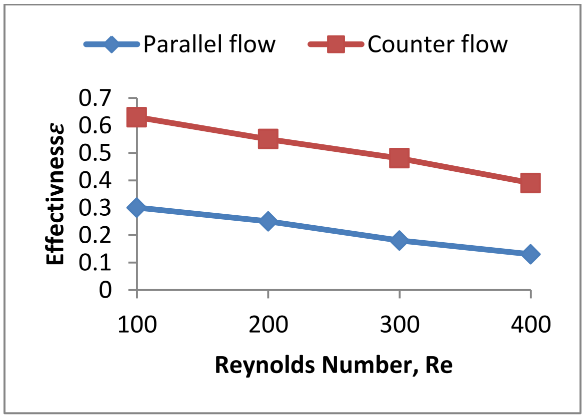

Fig.2 Variation in effectiveness

Form the figure 2 it can be accomplishing that as increase in value of Reynolds number the effectiveness of both flow type channels are decreasing.

Figure 3 demonstrate that the variation heat transfer with Reynolds number 100 to 400.

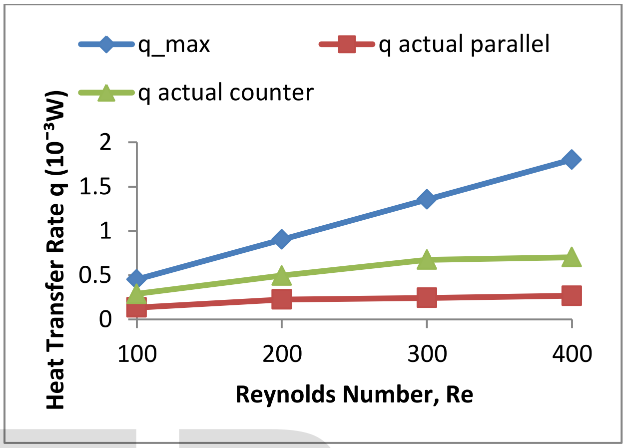

Fig.3 Variation in heat transfer rate

The heat transfer rate variation trend is same for counter and parallel flow. Re = 100 has minimum heat transfer rate and Re = 400 has maximum heat transfer rate for both flows. The counter flow has more heat transfer rate than the parallel flow for all values of Reynolds number.

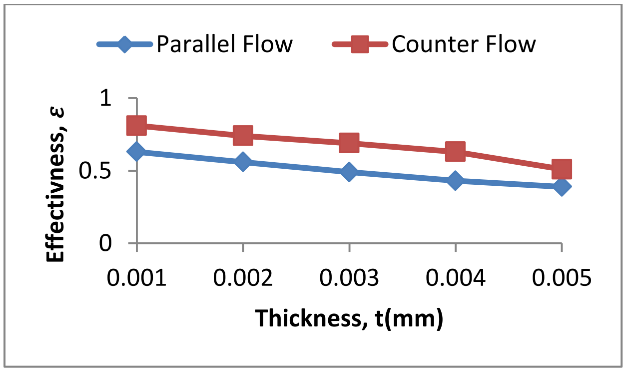

Fig. 4 Effectiveness variation with thickness of the wall

From figure 4 it can be seen that with increasing separating wall thickness the effectiveness is decreasing. The counter flow has more effectiveness than the parallel flow irrespective of increasing separating wall thickness.

Performance index gives the relation between the thermal and hydrodynamic performance. The different values of Reynolds number taken are 100, 200, 300, and 400. From the Figure 5 it can be seen that the performance index is decreasing with increased value of Reynolds number.

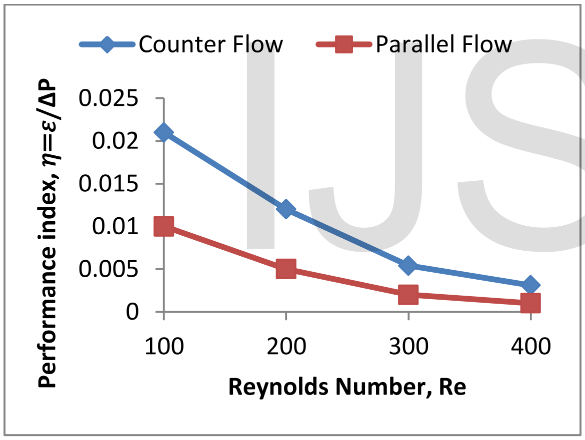

Fig. 5 Variation in performance index with Reynolds numbers

The value of performance index is higher for counter flow than the parallel flow. The difference of performance index is maximum at Re = 100 and decreasing with higher Reynolds number. The variation trends of performance index for counter and parallel flow are same.

Conclusions:

The following conclusions are made during the study between parallel flow and counter flow microchannel heat exchanger.

1. With No-slip flow the effectiveness of counter flow channel has much greater then parallel flow channel and the effectiveness of the channel is dependent on Reynolds number as well as type of flow.
2. The effectiveness is decreasing with increase in Reynolds number due to higher inlet velocity. The aluminum channel gives better effectiveness as compared with available literature.
3. For both counter flow and parallel flow, the performance index decreases with increased value of Reynolds number. Performance index represents the overall performance (thermal and hydrodynamic) of microchannel heat exchanger unit.

The overall performance of the counter flow heat exchanger is much high as compared with parallel flow heat exchanger.

References:

1. Agrawal, A., Duryodhan, V.S., Singh, S.G., (2012) Pressure drop measurements with boiling in

diverging microchannel, Front. Heat Mass Transfer 3, 013005.

2. Choi, S.B., Barron, R.F., Warrington, R.O., (1991) Fluid flow and heat transfer in microtubes, in: Micromechanical Sensors, Actuators and Systems, ASME DSC, vol. 32, Atlanta, GA, pp. 123–134.
3. Hernando, G.N., Iborra, A.A., Rivas, R.U., Izquierdo, M., (2009) Experimental investigation of fluid flow and heat transfer in a single-phase liquid flow micro-heat exchanger, Int. J. Heat Mass Transf. 52, 5433-5446.
4. Park, H.S., Punch, J., (2008) Friction factor and heat transfer in multiple microchannels with uniform flow distribution, Int. J. Heat Mass Transf. 51, 4535-4543.
5. Tuckerman, D.B., and Pease, R.F., (1981) “High performance heat sinking for VLSI”, IEEE electron device letter 2, 126–129.
6. Yadav, A., Singh, S., Kumar, R., Heat Transfer Analysis in Isosceles Right Triangular Microchannel Heat Exchanger Using ANSYS International Journal of Engineering Science and Computing, Vol. 6, Issue 6 (2016), 7064-7068.
7. Yadav, A., Singh, S., Joshi,C., L., “ Numerical Investigation of Counter Flow Isosceles Right Triangular Microchannel Heat Exchanger” International Journal of Mechanical Engineering & Technology, Volume 8, Issue 1 January 2017, pp. 81-87;