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EFFECT OF HEAT TRANSFER CHARACTERISTICS AND PRESSURE DROP OF MICROCHANNEL HEAT SINK IN DIFFRENT SHAPES MANIFOLDS WITH SLOPE

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ABSTRACT

The geometrical parameters have a great effect on overall performance of microchannel. An experimental analysis is carried out in present study with reference to Heat transfer coefficient and Pressure drop for three types of arrangements of manifold. In the present study, three different manifolds arrangements are investigated i.e. Rectangular (R), Triangular (T) and Slanted (S) having 3 degree slope in manifolds towards the microchannels. On the basis of experimental results, it is concluded that T-type manifold arrangement has the highest heat transfer coefficient in comparison to R by 15-36% and in comparison to S by 40-69%. Result also shows that Pressure drop of T-type manifold is the highest among R-type and S-type manifold i.e. 80% more than R-type and 75% more than S-type manifold. Reynolds number for this MCHS is ranging from 705-1411.

KEYWORDS: Manifolds, Heat Transfer, Reynolds Number, Nusselt Number & MCHS

Original Article

1. INTRODUCTION

Heat generated by electronic devices and electronic circuits must be dissipated to environment for better efficiency and reliability of the device. Various techniques are used for this purpose. Convection is also a heat dissipation technique which can be seen in fluids and gases. When the gases or fluid flows over the heated surface, it transfers the heat to the region of lower temperature that may be atmosphere or some other material depending upon the temperature difference. In various engineering applications, the mechanism of microchannels is vastly utilized to increase the convective heat transfer rate. Heat dissipation through microchannels can also increase the life span of microchannels which gives good working conditions and more heat removal.

D.B. Tuckerman et al. (1981) stated the concept of microchannel heat sink for the first time. When studied the greater ability of thermal collection of heat in bigger integrated circuits with conventional transfer of heat they get lower pressure drop, lower coolant needs smaller geometric size and lower cost of operation with more heat transfer performance. Poh Seng lee et al. (2002) experimentally analyzed the MCHS with laminar heat transfer in it. In the rectangular micro channels the experimental results are obtained for laminar forced single-phased convection. The tests are undergone on MCHS with total number of channels 64 having width and height 54µm and 215µm respectively. The cooling fluid is taken as deionized water and the flow rate of fluid is taken from 0.5 cc/s–10 cc/s. The results are shown in term of total drop in pressure and resistance thermally. The result shows that the agreement between theoretical results and experimental results is good as the thermal resistance and Nusselt number are inversely related to each other. The greater the Nusselt number, the greater heat transfer rate and thermal resistance get lower. H.Y. Wu et al (2003) studied experimentally silicon microchannels with heat transfer through convection along with distinguished surface condition. In trapezoidal silicon microchannels investigation is carried out to find rate of heat transfer and pressure drop through covection. As the surface roughness and property of surface hydraullic increases the friction factor and nusselt number also increases. At higher Reynolds number these properties becomes more efficient. When the Reynolds number is less than 100 the nusselt number increases more faster with Reynolds number and when the Reynolds number is greater than 100 it increases slowly. At last, a result is stated on heat flux with the help of difference in temperature and pumping energy on the microchannels. Suresh V. Gerimella et al (2006) studeid at the inlet area of rectangular microchannel the laminar convective heat transfer is examined under constant temperature of wall and thermal boundary conditions of heat flux. Numerical simulations in 3-D is done in microchannels for thermally developing laminar flow of distinguished aspect ratios. Comparison is done on the used correlations with other conventional correlations. The results shows that H1 boundary condition represents the best microchannel heat sink. This shows that the arrangement is very satisfactory and states that the given correlations developed can be utilized in getting heat transfer coefficients in micro channel heat sink. Sr-Jia Jian et al (2006) investigated a smooth effect of microchannel cross-section shape on the friction factor. Necessary factor in performance of MEMS in microchannels is pressure drop. Friction factor and pressure drop mainly depends on the geometry of microchannels. Four different types of microchannels of different cross-section are taken into account and their effects are investigated. The area of cross-section and its shape greatly effects friction factor. The result shows that the triangular microchannel with greater diameter has greatly affected factor of friction and in rectangular microchannel friction factor is not significantly affected by hydraulic diameter. Also, as the Reynolds number increase the friction factor decreases non-linearly. Li Zhuo et al (2006) considered non-circular cross-section of silicon microchannels with laminar flow and heat transfer in water for 3-d numerical simulations. In this FVM is used for operations. They have compared the numerical data with experimental data in literature to get the results. From the field of synergy principle the changes in nusselt no. and Reynolds no. are discussed by taking into account the different shapes and sizes of microchannels. In the interaction between velocity and temperature coefficient there is an abrupt change in interaction angle around Re=100. Nusselt number and Reynolds number are proportional at lower Reynolds number region, but when reynolds number increases, the nusselt number becomes higher with greater Reynolds number. Lutfullah kuddusi et al (2007), aims to predict the distribution in temperature and nusselt number on rectangular micro channels at uniform heat flux. At constant heat flux slip-flow in rectangular microchannel is heated in H2 boundry condition. This shows effect on heat transfer in microchannel of different thermal versions. To determine the temperature difference in microchannel the heat conduction and convection problems are used simultaneously. Result shows that rarefraction has a lowering heat transfer effect on microchannels. Hee Sung Park et al (2008) aims on the future scope on the issues in microfluids for heat transfer in microchannels. Laminar flow ($69<Re<800$) is examined in between rectangular cross-section microchannel having hydraulic diameter 106μm-307μm for liquid flow. The manifold improves the efficiency of the microchannel for uniform flow and improves the accuracy. The result of the study shows that there are deviations in theoretical and experimental rate of heat transfer in microchannels. A correlation is given in term of $Nu(Re^{0.62}Pr^{0.33})$ and brinkman no. with experimental range confirmation. O. Barlay Egru et al (2009) considered a rectangular microchannel geometry having dimension of width 3.70mm, height 0.107mm and length of 35mm which shows the pressure drop and mass transfer. The Reynolds number ranged between 100-845, distilled water as working fluid are utilized for the measurement of pressure and at Reynolds number range of 18-552, chemical sol^n is used for the measurements of mass transfer and the technique used is electro chemical limiting diffusion current technique (ELDCT). At the end a point sharewood correlation is also obtained. P. Gunnasegeran et al. (2009) considered three distinguished shapes of MCHS i.e. in Triangular, Trapezoidal and Rectangular. Pressure drop and friction factor are examined in these microchannels. FVM is used for solving 3-d steady laminar flow and heat transfer governing equations for Reynolds number ranging from 100-1000. Geometrical parameters greatly effects Poiseuille no. and factor of friction.

At Reynolds number 1100 the transition is occurred from laminar flow to turbulent flow. Rieyu Chein et al. (2009), aims the study to numerically examine the flow rate of fluid and rate of heat transfer in microchannels. For solving the 3-D governing equations the finite volume method is used. For the inlet and outlet ports, inlet and outlet plenums and microchannels a computational domain is used for heat sink. This study mainly focuses on input/output arrangements and its effect on flow rate of fluid and rate of heat transfer in the heat sink. Only the input/output arrangements are changed and rest geometry remains the same. Due to this reason the drop in pressure is also different in each case. The result shows that when the coolant is supplied and collected vertically at inlet/outlet ports better uniformities are found in temperature and velocities. Vertical use of coolant is suggested over other means of supply for better results in heat dissipation of microchannels. Omar Mokrani et al. (2009) considered a rectangular microchannel with large aspect ratio is studied to investigate the design, construction and instrumentation which allow the flow and convective transfer of heat under some conditions to vary hydraulic diameter. Direct measurement of preesure drop inside the microchannels in a fully developed flow zone the flow friction coefficient is calculated. Inverse heat conduction method is used to measure the thermal conditions inside the microchannels. Continuum mechanics laws for conduction and fluid mechanics remains validated in microchannels of hydraulic dia. $\geq 100\mu m$ for smooth walls. Y. Sui et al. (2010), aims on numerical simulation of rectangular cross-section wavy microchannel with laminar liquid-water flow and rate of heat transfer in 3D. The field of flow is analyzed and for fluid mixing a dynamical system technique is taken into account. The wavy amplitude of microchannel with the flow of fluid can be varied for different microchannel purpose. The result shows that a secondry flow is generated when coolant is passed through wavy microchannel. It leads to chaotic advection ad the location of vortices is may differ from before, which enhaces the convective fluid mixing. Result shows that wavy microchannels are better than straight microchannels. H.A. Mohammed et al. (2011) considered the performance of microchannels thermally and hydraulically when the shape of microchannel is changed. In this numerical study and simulations are done to solve the three dimensional steady of microchwannel and FVM method is used to find the 3D governing equations. Curvy, zig-zag and step microchannels are studied and their effects are studied on MCHS performance. Result shows that there is least and greatest change in temperature and heat ransfer coefficient in all the microchannels heat sink. Pressure drop of all the microchannels is far better than conventional microchannels. For all the experiments done on MCHS the zig-zag arrangement of microchannel is best after that the curvy one comes.

2. METHODOLOGY

For the experiment, three types of microchannels heat sink designs are made having 3 degree slope in manifols towards microchannel as showed. Figure 1 shows the assembly of MCHS with three different types of manifolds arrangements which are of different shapes and sizes having equal area of cross-section. Figure 2 shows the assembly of microchannels with Acrelic coves fitted upon them. The base element used make the microchannels is Copper *(cu)* and a cover of Acrelic sheet is mounted on it so that no fluid leaks from the assembly. Two holes are made on the Acrelic sheet taking cente of manifolds for the inlet and outlet of fluid. In Table 1, the specifications taken for MCHS and Acrelic sheet cover is shown. In table 2, different parameters which are taken for consideration in study are shown. Basic working fluid for the experimental analysis of the study is taken as water. For result, these readings are taken for the calculations.

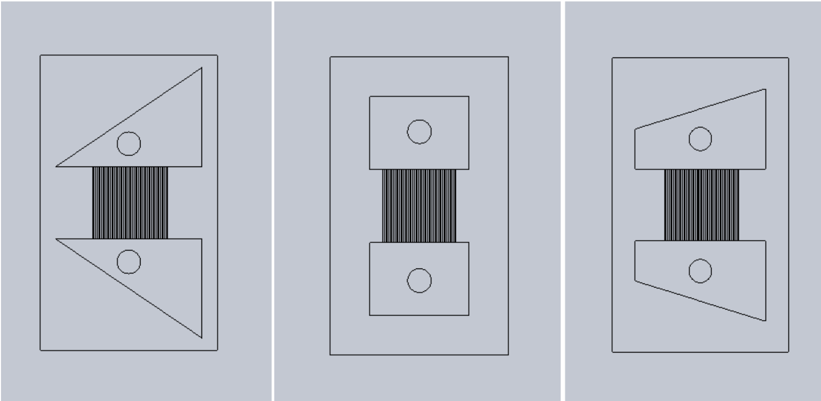

Figure 1: Assembly of Microchannels with Different Manifolds with Acrelic Covers.

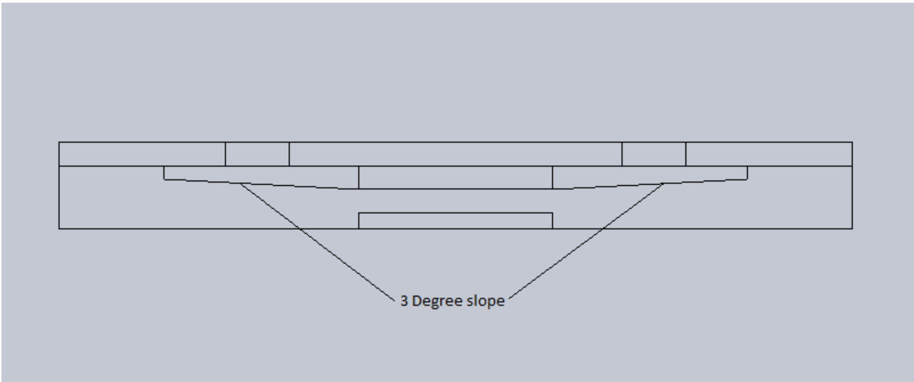

Figure 2: Front view of Microchannels with 3 Degree Slope in Manifolds.

Table 1: Microchannels Specifications

Width of the channel	500 µm
Channel spacing	500 µm
Thickness of base plate	5000 µm
Channel length	24500 µm
Channel depth	3000 µm
Cover thickness	5000 µm

Table 2: Considered Thermo-Hydraulic Parameters

Fluid Flow rate	4,6,8
Wattages	50,75,100
Taken base fluid	Water
Considered designs	Rectangular(R), Triangular(T), Slanted(S)
Type of flow	Perpendicular

Calculations steps are taken into account as follows:

Calculation of Reynolds Number

$$Re = \frac{\rho v d_h}{\mu}$$

Average Temperature

$$T_{avg} = \frac{T_1 + T_2}{2}$$

T_1 = Inlet Temperature

T_2 = 0utlet Temperature

Difference in Temperature

$$\Delta T = T_w - T_{avg}$$

Where,

Tw = Temperature of wall

Tavg = Average temperature

At the bottom of microchannel heat sink a constant heat is supplied and remaining three walls are taken to be adiabatic in nature. For wall temperature consideration a thermocouple is situated beneath the MCHS.

Discharge of Flow

$$q = mc_p \Delta t$$

The Coefficient of Heat Transfer

$$h = \frac{q}{A_s \Delta t}$$

The Nusselt Number

$$N_u = \frac{hd_h}{k}$$

3. RESULTS AND DISCUSSIONS

3.1 Variation of Heat Transfer Coefficient with Reynolds Number

Experimental analysis have been worked at three different wattages i.e. 50, 100 and 150W at three different flow rates i.e. 4, 6 and 8 LPH. Based on the experimental results, it is concluded that the heat transfer coefficient of the Triangular manifold arrangement having 3 degree slope towards microchannels from both sides is highest among the three followed by Rectangular and Slanted manifolds arrangement having Same 3 degree slope toward microchannels. Variation in the Heat transfer coefficient w.r.t. Reynolds number is shown in figure 3-5.

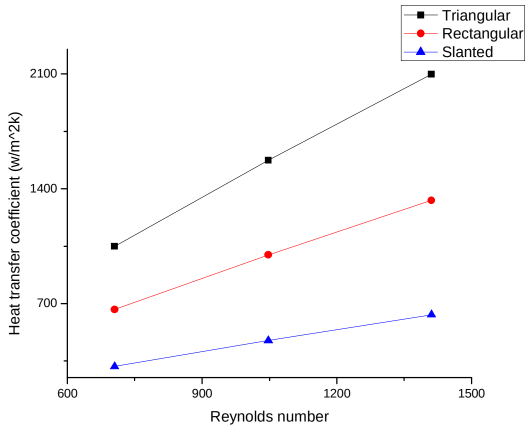

Figure 3: Reynolds Number vs. Heat Transfer Coefficient at 50W.

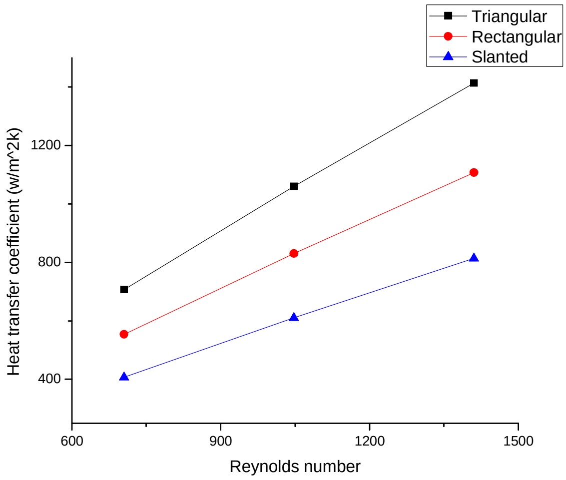

Figure 4: Reynolds Number vs. Heat Transfer Coefficient at 100W.

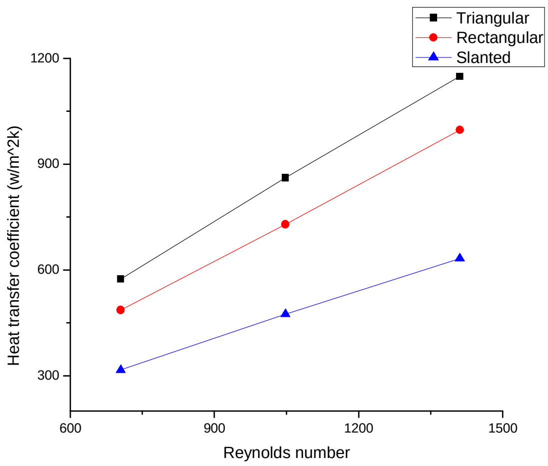

Figure 5: Reynolds Number vs. Heat Transfer Coefficient at 150W.

3.2 Variation of Nusselt Number with Reynolds Number

Experimental analysis have been worked at three different wattages i.e. 50, 100 and 150W at three different flow rates i.e. 4, 6 and 8 LPH. Based on the experimental results, it is concluded that Nusselt number of the Triangular manifold arrangement having 3 degree slope towards microchannels from both sides is highest among the three followed by Rectangular and Slanted manifolds arrangement having Same 3 degree slope toward microchannels. Variation in the Nusselt number w. r. t. Reynolds number is shown in figure 6-8.

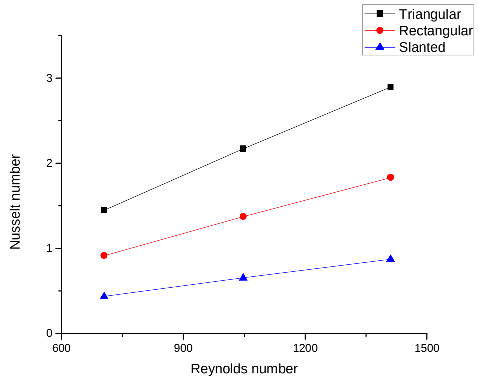

Figure 6: Reynolds Number vs. Nusselt Number at 50W.

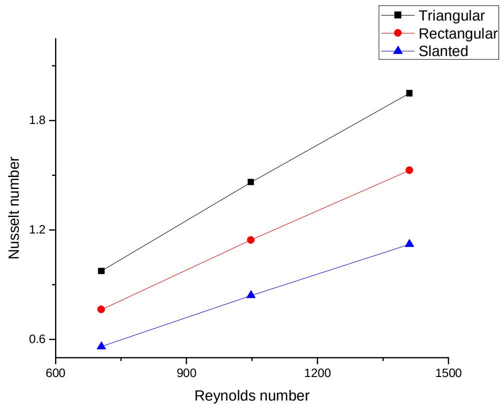

Figure 7: Reynolds Number vs. Nusselt Number at 100W.

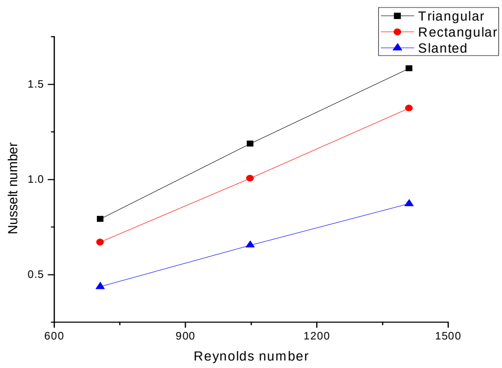

Figure 8: Reynolds Number vs. Nusselt Number at 150W.

3.3. Variation of Reynolds Number with Change in Pressure

Experimental analysis have been worked at three different wattages i.e. 50, 100 and 150W at three different flow rates i.e. 4, 6 and 8 LPH. Based on the experimental results, it is concluded that Pressure drop of the Triangular manifold arrangement having 3 degree slope towards microchannels from both sides is highest among the three followed by Rectangular and Slanted manifolds arrangement having Same 3 degree slope toward microchannels. Variation in the Pressure drop w.r.t. Reynolds number is shown in figure 9.

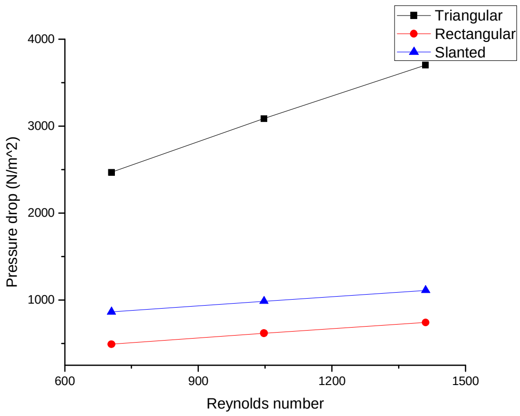

Figure 9: Reynolds Number vs. Pressure Drop.

4. CONCLUSIONS

Experimental analysis has been carried out in the present work to calculate the heat transfer characteristics using water as base fluid on Microchannels. From the analysis following conclusions can be drawn.

- It has been observed that heat transfer coefficient is increased in triangular manifold than that of rectangular and slanted manifold by 36.6 % at 50W, 21.6 % at 100W, 15.3% at 150W.
- Rectangle manifold have more heat transfer than that of slanted manifold by 52.3% at 50W, 26.5 % at 100W and 34.9 % at 150W but less than the triangular manifold at different Reynolds number for different heat inputs.
- It has been observed that Nusselt number is more in triangular manifold than that of rectangular and slanted manifold 36.6% at 50W, 21.9 % at 100W and 15.1% at 150W.
- Rectangular manifold have more Nusselt number than that of slanted manifold by 52.4% at 50W, 26.4 % at 100W and 34.9 % at 150W but less than the triangular manifold at different Reynolds number for different heat inputs.
- Pressure drop also plays a significant role in heat transfer characteristics of micro channels. Pressure drop of triangular manifold is highest among the rectangular and slanted manifold.
- Pressure drop of triangular manifold is 80% more than rectangular and 75% more than slanted manifold arrangements.

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