EXPERIMENTAL STUDY OF HEAT TRANSFER IN MICRO-CHANNEL HEAT- SINK WITH LEAF- LIKE PATTERN

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ABSTRACT

In this work, performance of microchannels having natural leaf like structure is studied experimentally. Previous studies shows that microchannel having leaf like structure have advantages over conventional rectangular microchannels.Also Previous studies of tree like branching networks have focused on symmetric structures although most natural tree like branching systems are asymmetric.Furthermore,leaf-lke branching networks have been rarely used. Microchannels of hydraulic diameter of 473 µm and 516 µm for Reynolds number between 169 to 2256 were studied. Experiments were conducted under a input heat of 5 W to 25 W and mass flow rates of 0.0000833 kg/sec to 0.000917 kg/sec with deionised water as the working fluid.Nusselt number tends to be linear as Reynolds number increases.High temperature difference observed between inlet and exit of microchannel.

Keywords: Natural leaf, Primary veins, Secondary veins, Symmetric, Unsymmetric

I. INTRODUCTION

Micro-channel heat sinks constitute an innovative cooling technology for the removal of a large amount of heat from a small area. The heat sink is usually made from a high thermal conductivity solid such as silicon or copper with the micro-channels fabricated into its surface by either precision machining or micro-fabrication technology. These micro-channels have characteristic dimensions ranging from 10 to 1000 µm, and serve as flow passages for the cooling liquid. Micro-channel heat sinks combine the features of very high surface area to volume ratio, large convective heat transfer coefficient, small mass and volume, and small coolant inventory. Microchannel are used in fluid control and heat transfer.The introduction of branching networks into micro-channel cooling technique has stimulated this field and attracted increased interest in branching micro-channels. A large part of studies had used traditional arrangements (Specific number of rectangular micro-channels placed parallel to each other). Micro-channel heat sinks with rectangular and constant cross-section area shows a non-uniform temperature profile.Temperature field could be made more uniform in a natural form micro-channel heat sink. In a theoretical way, the convective coefficient is inversely proportional to the channel hydraulic diameter. Based on this principle, if the channel hydraulic diameter is decreasing the convective coefficient is improved as a result.

Nomenclature

As	surface area
Acs	cross-section area
Dh	Hydraulic diameter
h	Heat transfer coefficient
Kf	Thermal conductivity of fluid
q	supplied heat,watt
q”	heat transfer per unit area
v	Average velocity of water
Ti	inlet temperature
To	outlet temperature
Tf avg	Average fluid temperature
Ts avg	Average Surface temperature
μ	Dynamic viscosity of water
Nu	Nusselt number
Re	Reynolds number
ρ	Density of fluid

II. LITERATURE REVIEW

Tuckerman and Pease [1] studied experimentally a rectangular micro-channel heat sink in a 1x1 cm^2 silicon wafer. The channels had a width of 50 μm and a depth of 302 μm, and were separated by 50 μm thick walls. The researcher concludes that the convective heat-transfer coefficient' h' between the substrate and the coolant was found to be the primary factor to achieving low thermal resistance. For laminar flow in confined channels, h scales inversely with channel width.

Kandlikar et al [2] studied numerically design of micro-channel heat Sinks with natural patterns. They considered two postulates that model natural forms in a mathematical way : the Allometric Law and the Biomimetic Tendency for the two cases. Using both theories, six models were analyzed. They observed that the largest heat dissipation in the heat sink is located at the zones where bifurcations are found. Also they have concluded that increasing the bifurcations, the heat dissipation improves.One important observation is that the fluid velocity can be increased only decreasing the hydraulic diameter.

Suhas S. Mohite and Vinayak P. Gaikwad (2013) [3] numerically studied flow and thermal characteristics of micro-channel having natural patterns. They studied physical models of three different leaf venation networks. Heat sink with asymmetric branching and two secondary veins having aspect ratio 5.0 and 2.5 were numerically analyzed. The aspect ratio is ratio of height of channel to its width. Also heat sink with symmetric branching of secondary veins of uniform aspect ratio was numerically analysed. They observed that micro-channel with secondary veins and symmetric branching results in a low temperature gradient of the order of 0.1 K/mm.

Wang et al [4] numerically studied three different networks (a) symmetric tree-like (b) symmetric network (c) Asymmetric leaf-like network for electronic component cooling. They formulated a three-dimensional model to compare the flow and heat transfer characteristics of symmetric/asymmetric tree-like branching networks and symmetric/asymmetric (offset) leaf-like branching networks. They observed that the influence of the asymmetry is very small for tree-like branching network at low branching number. Offset in leaf-like branching network can reduce pressure drop significantly while maintaining maximum temperature difference between the inlet and outlet of the flowing fluid.

Chen and cheng [5] experimentally investigated the thermal efficiency of fractal tree-like micro-channel nets. They used afractal tree-like micro-channel net heat sink having dimensions 20mm X 20mm X 1.4mm.The length, width and height of the entrance micro-channel were 10 mm,800 µm and 25µm respectively. They observed that the thermal efficiency of a fractal tree-like micro-channel heat sink is much higher than that of the traditional parallel micro-channel heat sink for the same heat transfer rate, the same temperature difference and the same velocity.

AmitAgrawal,V.S.Duryodhan,S.G.Singh,Abhimanyu Singh[6] experimentally studied heat transfer in converging and diverging microchannels.Also three-dimensional numerical study is performed on single phase liquid flow in two scenarios: heated diverging and heated converging microchannel.Microchannel with 8° angle of divergence and 156 µm of hydraulic diameter is used for experiments in both converging and diverging modes.They observed that thermo-hydraulic performance of converging and diverging microchannels is of significance in the developments of compact heat sinks.

III.CO-RELATIONS USED FOR CALCULATION OF MICROCHANNEL GEOMETRY

$$q'' = q / A_s \quad \text{------------} \quad (1)$$

$$T_{f\,avg} = (T_i + T_o)/2 \quad \text{-----------} \quad (2)$$

$$h = q'' / (T_{s\,avg} - T_{f\,avg}) \quad \text{------------} \quad (3)$$

$$Nu = (h \times D_h)/K_f \quad \text{------------} \quad (4)$$

$$Re = (\rho \times v \times D_h) / \mu \quad \text{------------} \quad (5)$$

IV. EXPERIMENTAL SET-UP

Flow loop of experimental setup is described in fig.The supplied heat to the microchannel wall was adjusted to achieve the the steady state using electric heater. Water from tank is pumped by the pump passes through the microchannel where it absorbs heat which causes its temperature to rise. This heated water exits the microchannel and is stored in another water tank.Thus inlet and outlet temperature of water is noted from the temperature indicator with the help of K type thermocouples.The test setup has microchannel with heater on back side of piece ,two tanks for storage of water ,one pump for circulation of water through microchannel.Water is used as a working fluid.Microchannel is heated by heater by supplying power through dimmerstat from 5 W to 25 W and measured by digital ammeter and voltmeter.

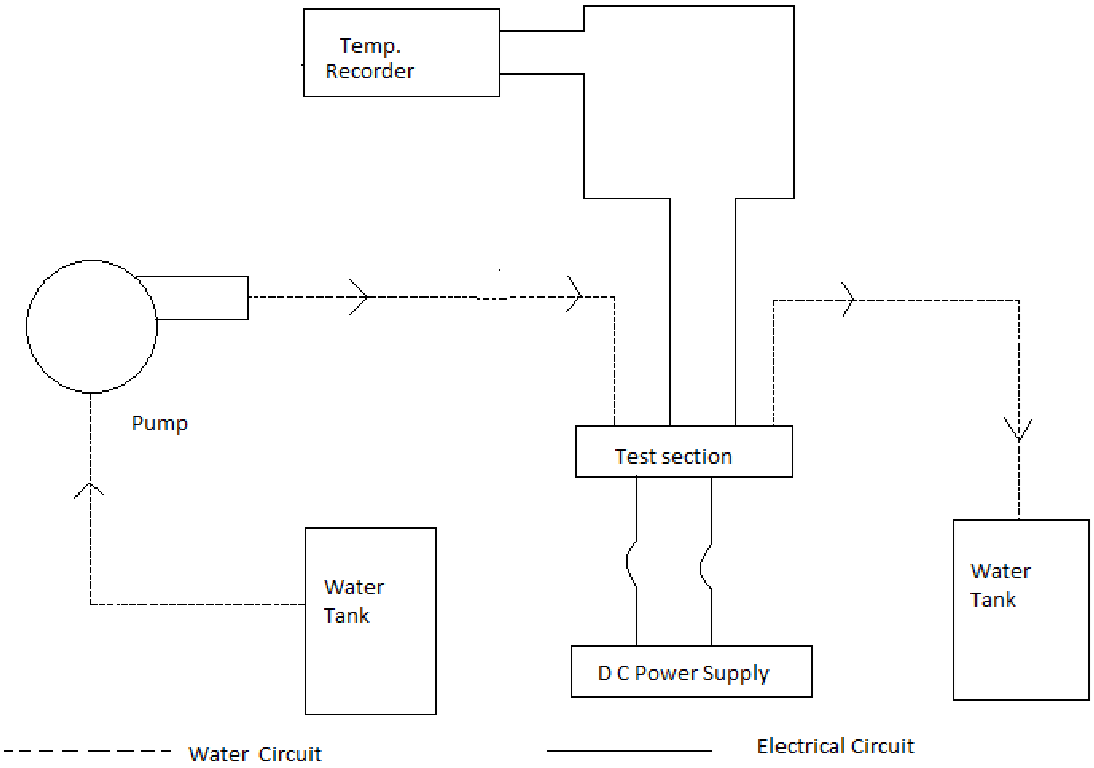

Fig.1 Experimental Setup

V. GEOMETRICAL SPECIFICATION

Type of pattern of microchanel	Hydraulic diameter (µm)
Symmetric	516
Unsymmetric	473

VI. EXPERIMENTAL RESULTS

For 5 W heat input and different flow rate conditions the Nu number is in the range of 3.21 to 9.18 for hydraulic diameter 516 µm . For hydraulic diameter 473 µm the Nu number is in the range of 6.56 to 14.84.Nusselt number with variation of heat input with Re number for both symmetric and unsymmetric network is described in fig. 2 and fig.4.

Experimental results of temperature variation with heat input 5 W to 25 W are described in fig.3 and fig.5

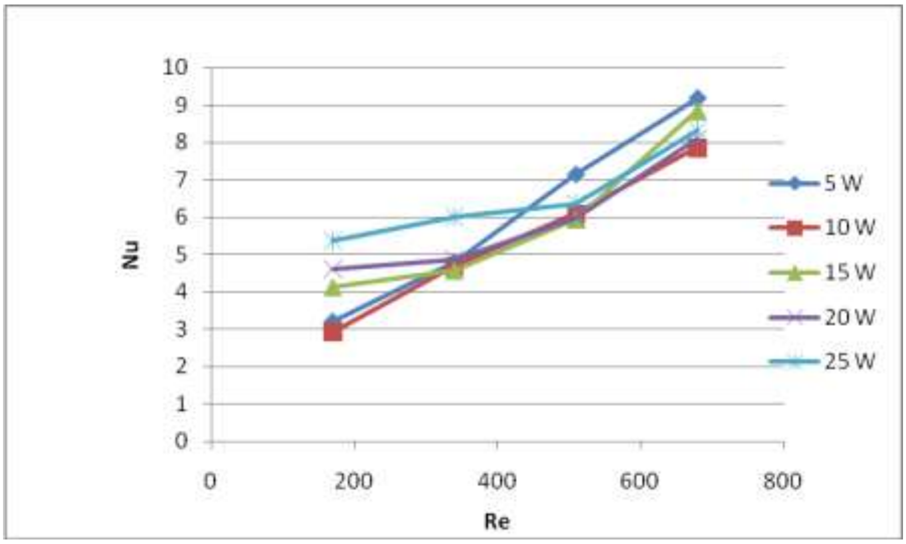

Fig.2 Variation of Nusselt number with Reynolds number for symmetric network

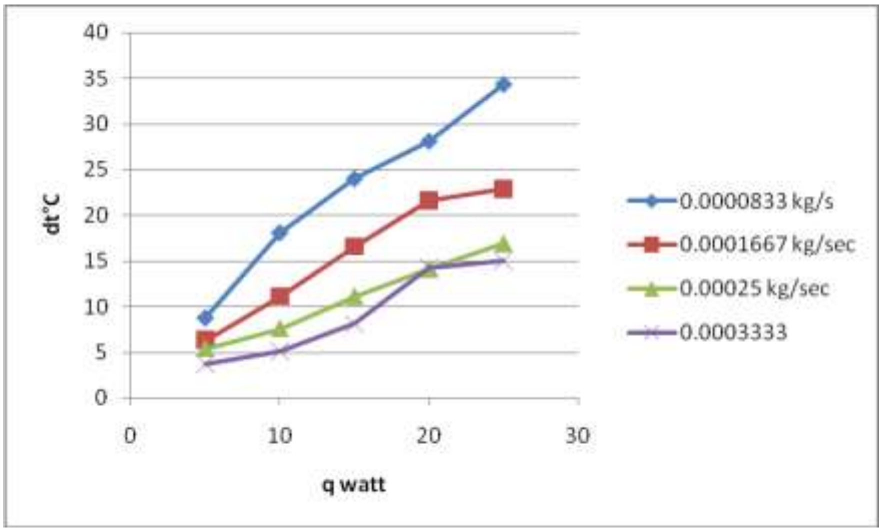

Fig.3 Temp. Diff.Vs HEAT INPUT for symmetric network

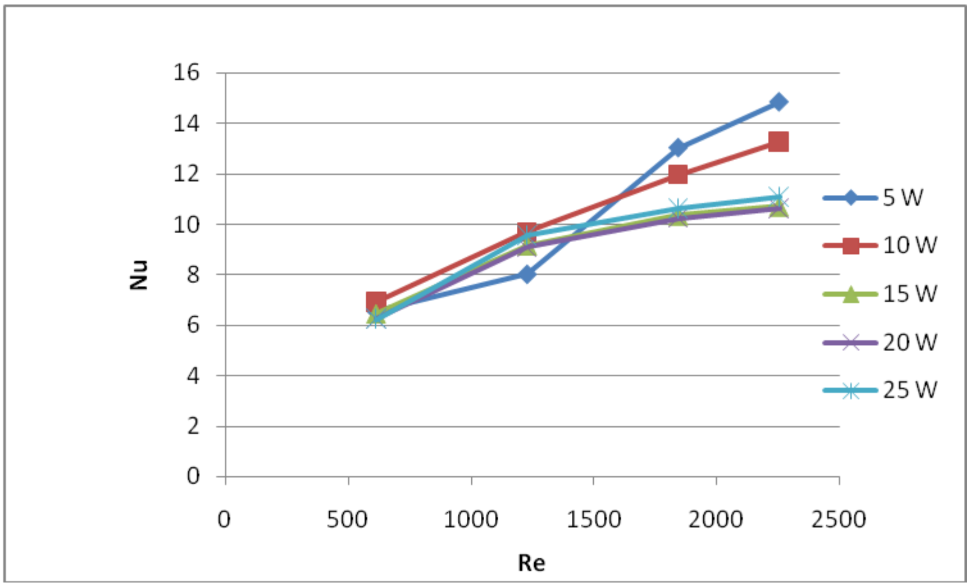

Fig.4 Variation of Nusselt number with Reynolds number for unsymmetric network

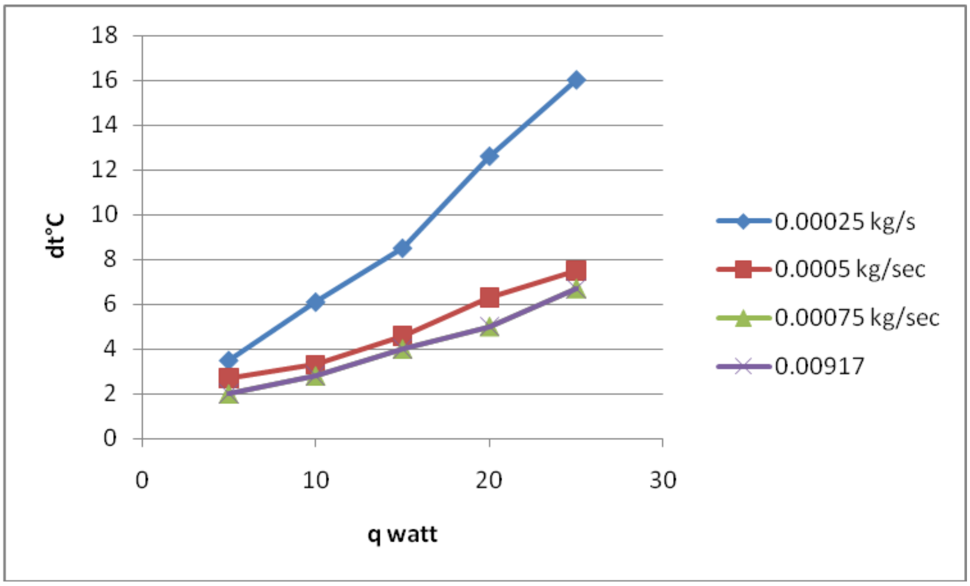

Fig.5 Temp. Diff.Vs HEAT INPUT for unsymmetric network

VII. CONCLUSION

Heat transfer coefficient varies from 3753 W/m² °K to 10482 W/m² ° for heat input of 5 W to 25 W and mass flow rates of 0.0000833 kg/sec to 0.000333 kg/sec for symmetric network. Heat transfer coefficient varies from 8291 W/m² °K to 18518 W/m² ° for heat input of 5 W to 25 W and mass flow rates of 0.00025 kg/sec to 0.000917 kg/sec for symmetric network. Nusselt number for Symmetric pattern is having in the range of 2.9 to 14.84 .Thus leaf like networks holds great promise in enhancing the heat dissipation of electronic components.

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