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Analytical and Experimental analysis ofthermal characteristics throughTriangular microchannel heat sink

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ABSTRACT
Microscale heat transfer technique is widely intended for best cooling applications in electronic devices as high heat transfer coefficients are achieved in microscale convection. In present study, analysis of thermal characteristics has been carried out by analytical calculations along with experimental investigation for a straight microchannel heat sink of equilateral triangular cross section of 173.21 μm hydraulic diameter with distilled water as the working fluid. Designed Heater input watts and Reynolds number based on flow rate are varied for optimized microchannel geometry. Experimental analysis is carried out under constant heat flux condition. The microchannels are produced on highly accurate micro wire cut EDM. The Reynolds number is varied from 100 to 700. The major intension for this work is to enhance heat transfer coefficient and minimize pressure drop across microchannel. The Reynolds number, temperature distribution, pressure distribution, heat transfer coefficient, hydrodynamic entrance length, thermal entrance length, equivalent thermal resistances parameters are calculated for microchannel heat sink performance analysis. The results of analytical calculations are verified with experimental investigation. It is found that heat transfer coefficient and pressure drop increases with increase in Reynolds numbers and decrease in microchannel heat sink hydraulic diameter. Also channel length is directly proportional to temperature rise.

Keywords-Heat transfer coefficient, Laminar flow, Pressure drop,Reynolds number&Triangular Micro channel Heat sink

I. INTRODUCTION

Most of thermally operated equipments are designed for high heat transfer rates. The heat transfer enhancement with minimum pressure drop, minimum pumping power are goals of best heat transfer equipment design. The microchannel heat exchangers are used for heat recovery and energy interactions. The first innovation for microchannel is studied by Tuckerman and Pease [1]. They are considered as father of microchannel heat sink which is used for high heat transfer applications in electronics devices cooling.They have achieved high heat transfer coefficient in single and two phase flows field. Also they observed that heat transfer coefficient is inversely proportional to hydraulic diameter.

The microchannel heat sinks are capable for disposing high heat flux. It is become popular within fewer time frames for cooling applications for electronics devices. The high surface to volume ratio has proven the use for high heat transfer applications. The microchannel heat sink geometries which are widely used for research and applications are rectangular, circular, triangular and trapezoidal. Triangular microchannels are become popular because for equal heat transfer coefficient they require less volume corresponds to rectangular channel and they are easy to analysis than trapezoidal cross section. The geometrical parameters are affecting on performance of heat sink.

P. Wibulswas [2] has implemented numerical solution method for rectangular duct, right-angled isosceles and equilateral triangular geometry with thermally developed and developing boundary conditions. He has demonstrated method for various aspect ratio having constant wall temperature and constant heat flux conditions. He used 1*2 in^2straight rectangular duct with 3ft. length for analysis. Nusselt numbers which is obtained in this analysis was depends on channel aspect ratio and dimensionless axial position. The simultaneously developing velocity profile gives higher Nusselt number as compared with developed velocity profile. In order to design best microchannel heat exchanger increase number of channel of short length rather than few number of channels with more length .He has developed no of relations for Nusselt numbers which are good agreement with other equivalent researches.Kandlikar and Upadhye [3] has done investigation on optimization of heat sink geometry for constant heat flux and constant wall temperature conditions in order minimizes pressure drop across the channel. They have presented numerical calculations for single phase flow for laminar and turbulent boundary conditions. They have worked for optimization of cooling system for silicon microchannels with water. The plain rectangular microchannels with 300 μm width single pass arrangement which are engraved on 10 mm*10 mm silicon chip are used for analysis with high heat flux 3 MW/m^2 with maximum chip temperature 360 K. They have investigated that number of channels for optimized geometry are from 68 to 90. They have used split flow arrangement for analysis because the pressure drop which we get for loner channel is higher as compared to short length channels and large mass flow rate is required to maintain designed temperature rise across the microchannel Thus it is concluded that roadmap of microchannels heat sink investigation can be useful for high heat dissipation in short area in applicationsaircraft, automotive sector.Konstantinos, Yannis, Steryios, Dimitris [4] have done numerical investigation on triangular andtrapezoidal cross section geometry with long channels having acute angle 54.74° which is produced from chemical etching of silicon wafers. They have evaluated linearized shakhov model with impartment of Maxwell boundary conditions for combined gas flow. It is found out dimensionless flow rate due to pressure drop and temperature drop which is used for experimental analysis for validation.

Lee, Garimella and Liu [5] have conducted experimental analysis in single phase flow on rectangular microchannels. Straight parallel 10 no's of rectangular microchannels width 194 μm to 534 μm having depth 5 times for respective width are tested with deionized water for experimental investigation. The Reynolds numbers is varied from 300 to 3500 for carrying out experimentation. They have used predictive and fluid continuum approach for their analysis. Also they have collectively put conventional correlations from literature for microchannel heat transfer investigation. They compared their numerical predicted calculated results with experimental analysis results and it is within 5% limit. Jiann Cherng [6] has experimentally investigated pressure drop and heat transfer coefficient for silicon triangular microchannels in laminar flow with Reynolds number less than 100. As per experimental investigation Nusselt number is nearly directly proportional to Reynolds number and high temperature gradient is observed between input and output plenum. The empirical correlations obtained results are compared with experimental results and they are with 15%.

The major core about this research is to optimize number of microchannels for maximize heat transfer coefficient and minimize pressure drop across the channel. The laminar flow is best suitable for required results. The analytical calculations along with same designed experimental analysis which system is best useful for practical implementation.

II. THEROTICAL ANALYSIS

The Hydraulic diameter through microchannel will decide Nano and microchannel. The heattransfer coefficient is depends on Nusselt number.As microchannel are defined as per 10 to 200 μm hydraulic diameter. The microchannel chip having dimension 27.5*19.5 mm is used for analysis in this study. Since equilateral section is having maximum surface to volume ratio in comparison of triangular section so geometry is chosen as equilateral section. Standard manufacturing process capability Constrains will useful for sectional area determination. The best optimum tooling and heat transfer area constrain channel width is obtained as 300 μm. The hydraulic diameter for optimum width and cross section is 173.2 μm. The number of channels is varied from 0-50. The cross functional design is created as variation of number of channel and flow rate. The Reynolds number is varied from 0-2000 which is equivalent to laminar flow range. The best results for lowest pressure drop and maximum heat transfer is obtained from 100-700 Reynolds number. So it is taken as golden mean for optimum results. The effect of thermal resistance is decrease the convective heat transfer. The genetic algorithm is used with two objective functions as maximization of heat transfer coefficient and minimization of thermal resistance across the channel. The optimum numbers of channels are obtained as 21. This is optimum for heat transfer rate maximization along with minimization of pressure drop across the channel and minimization of thermal resistance for convective heat transfer. The same designed problem is experimentally investigated and results are compared and they are in good agreement with some reference study.

III. EXPERIMENTAL SET UP

The schematic of experimental facility used for analysis is shown in figure 1. The core section is microchannel heat sink test module. The data logger system consists of pressure transducer, thermocouple and input watts for accurate measurement. Peristaltic pump with different tubing will provide accurate flow rate along with sufficient pressure. The cartridge heater is used for uniform heating of copper microchannel heat test section.

Water tank at bottom Stores distilled water is used for microchannel experimental investigation. The micro filter removes contaminations and other particles from water through microporous membrane. The pore size of membrane used by us ranged from 1-10 µm. It is used prior to pump and microchannel system because it will saves pump tubing and system along with it will avoids clogging of flow in microchannel manifold due to contaminations

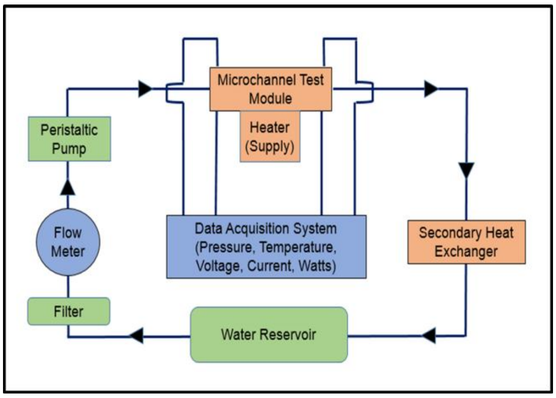

Figure1-Schematic of experimental facility

The pump provides require water as per required flow rate. The digital peristaltic pump provides different flow by adjusting speed and tubing sizes. We have used peristaltic digital variable speed provides flow rate from 0.06-3400 ml/min having speed control accuracy ± 0.25 %. The water flows through microchannel heat sink test module. The base core section of PTFE material will ensure leak proof and high temperature sustainability. The microchannels are engraved on chip 27.5*19.5 mm chip of electrolytic copper which is having maximum thermal conductivity. The optimized 21 number of microchannels are straight manufactured with highly accurate wire cut EDM with triangular micro wire with 0.3 mm length with equilateral section. Transparent acrylic cover at top will show water flow through manifold and microchannels.

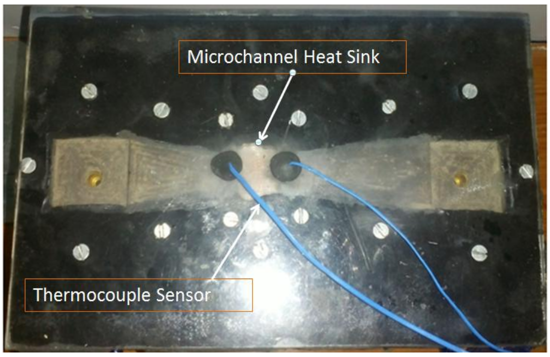

Figure 2 - Test section manifold

Micro plate heater is mounted at bottom of microchannel chip for uniform heating. The thermocouple sensors are used to measure the temperature at various locations at Inlet and outlet along with heater base. The accurate positioning and sensor length will decide accurate reading. The K type thermocouples are used for measurement of temperature 0.02resolution over -200 to 1200 ° C range. Pressure sensor measures 0-1000 Psi differential Pressure. The sensors get connected with data logger for accurate measurement. The logger system is USB portable and having digital display. The readings are taken when steady state is achieved. The heater thermocouple will create void, thermal grease can be used for perfect ensure of contacts. The voltage current supplied to heater can be recorded on same data logger. The readings are taken for constant heat flux also the Reynolds number is varied by equivalent varying flow rate. The theoretical designed conditions are taken for experimental analysis.

IV. RESULT AND DISCUSSION

The experimental analysis is conducted and graphs are plotted for variation of heat transfer coefficient with respect to variation of Reynolds number along with pressure difference across channel with respect to variations of same Reynolds number. The friction factor and thermal resistance across channel are theoretically calculated.

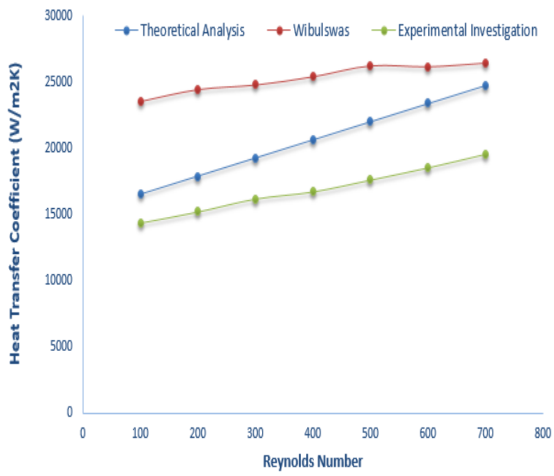

Figure 3 - Reynolds number versus Heat transfer coefficient.

It can be observed thatconvective heat transfer coefficient increases with increase in Reynolds numbers. The radioactive heat losses and conduction through grease surface will leads to difference in experimental investigation and theoretical calculations. We have compared theoretical results with Wibulswaswhich is draw by using correlation given in journal paper.

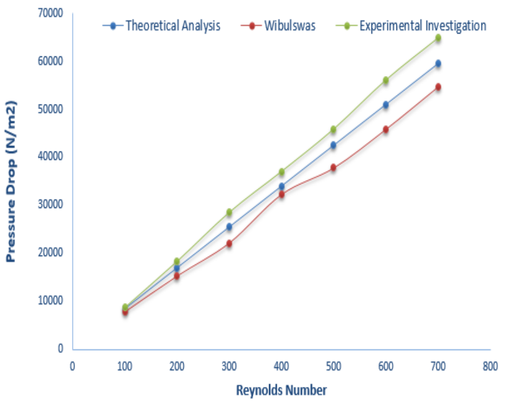

Figure 4 - Reynolds number versus Pressure Drop

Also it can be observed that with increase in Reynolds number,friction factor across the channel increases. It will affect cumulatively to increase the pressure drop across the channel. Since the entrance effect and other sudden expansion losses the effective pressure drop across channel increases as compared to theoretical pressure drop. We have compared theoretical results with Wibulswaswhich is draw by using correlation given in journal paper.

V. CONCLUSIONS

1. It is concluded that microchannel heat Sink are media which is best useful to dissipate large amount of heat within small surface area.
2. The optimum results for heat transfer enhancement with minimum pressure drop are observed in Reynolds number 300-650.
3. It is found that experimentally investigated pressure drop across microchannel is higher than theoretically predicted calculation
4. Heat transfer coefficient and Reynolds number which is investigated experimentally are slightly less than theoretically predicated analysis but they are in good agreement with correlations in Journal paper.
5. The flow rate and temperature drop across the microchannel are inversely proportional to each other for constant input watts.
6. In order to maximize heat transfer coefficient, minimize pumping power, minimize pressure drop, minimize friction factor, minimize entropy generation, there is a need to analyse simultaneous effects of geometry dimension, number of micro channels, aspect ratio, fluid properties, and hydrodynamic parameters along with thermal properties of sink material.

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