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Effect of inlet location in flow maldistribution in microchannel- An Experimental study

C. Anbumeenakshi1, R. Wasim Akram[2], G. Guruvendren[3], S. Muthu Kumar[4]
[1]*Associate Professor, Dept of Mechanical Eng, K.L.N. College of Engineering, Madurai, Tamil Nadu, India*
[2,3,4]*Student, Dept of Mechanical Eng, K.L.N. College of Engineering, Madurai, Tamil Nadu, India*

***Abstract* - The microchannel cooling technique appears to be a viable solution to high heat rejection requirements of today's high-power electronic devices. The thermal design of the small electronics cooling devices is a key issue that needs to be optimized in order to keep the system temperatures at certain levels. Thus, the need of microchannel became vital. This present work investigates the experimental work conducted in a rectangular microchannel heat sink of hydraulic diameter of 0.763 mm for a flow rate of 24 to 42 kg/hr with water to study the flow maldistribution with a rectangular header of three inlet condition viz. side inlet, centre inlet and double inlet condition. The header plays a significant role in distributing the water into the channels. The uniform distribution of water leads to uniform heat transfer in microchannels. From the experimental results carried with a rectangular header of three inlet condition arrangements, it was found that rectangular microchannel with double inlet condition gives better uniform flow distribution than to other inlet conditions.**

***Index Terms* - Rectangular header, flow maldistribution, side inlet condition, centre inlet condition, double inlet condition.**

I.INTRODUCTION

Due to the evolution in the latest technology it leads to globalization and miniaturization of large electronic devices into an integrated compact device. When the system or devices becomes too smaller, heat flux increases in general. The thermal management in this device is a major problem and suitable cooling methodologies has to be incorporated to prevent the failure of the components. The microchannel cooling technique using liquid as a cooling medium is the most promising technique to enhance the life of the electronic components. Recently, a large number of studies were explored in microchannel to better understand the flow, pressure, and temperature distribution in microchannel. From the three parametric study i.e flow, temperature, and pressure, one of the most prominent which has to be studied in detail is the flow distribution in microchannel. To remove the heat generated from the electronic device liquid is circulated inside the microchannel. The distribution of liquid in microchannel should be uniform. If the distribution of liquid in microchannel is not uniform, then the uniform cooling in the electronic device is not possible which leads to hotspots.

In the beginning of 1980s, Tuckerman and pease [1] conducted initial experiments on water flow and heat transfer characteristics in microchannel heat sinks that demonstrate the cooling of electronic components by the use of forced convective flow of fluid through microchannels. This opened a wide area in the field of electronics cooling and heat transfer in micro scale geometries.

Dharaiya et al. [2] carried out a simulation study using CFD for two different header combinations namely circular header cross section and tapered header cross section and identified that tapered header configuration gives uniform flow distribution than circular header cross section.

Cho et al. [3] carried out experiment in microchannel heat sink and found that diverging channel with trapezoidal header is the best choice for considering the temperature distribution and pressure drop. Pan et al. [4] carried out a study numerically in the velocity distribution of rectangular microchannels and identified that to achieve a uniform flow distribution, microchannel length and depth should be large and microchannel width and pitch should be made as small as possible. Reiyu et al. [5] carried out numerical simulation on the fluid flow and heat transfer in microchannel heat sinks. According to the inlet / outlet arrangements, performance of heat sink was studied. From the study, it is suggested that better heat sink performance can be achieved when the coolant is supplied and collected vertically.

Manikanda Kumaran et al. [6] studied the effects of header design on flow maldistribution in a micro-channel heat sink. Anbumeenakshi and Thansekhar[7] performed an experimental study in microchannel with three different types of headers and two inlet conditions and identified that rectangular header with vertical inlet flow condition at higher flow rates.

Omidbakhsh Amiri and Ghasemi Ahmad chali [8] performed a numerical study in a microchannel to investigate the flow and temperature distribution in a microchannel and it was identified that rectangular manifold with horizontal inlet flow provides better uniformity of flow and temperature.

Several studies were performed in numerically and analytically in microchannel and few experimental studies were performed in microchannel. There is a lack in the experimental work in microchannel and there exists a lot of discrepancy It needs a systematic experimental investigation. This is the motivation for taking an experimental work. Thus, in this paper a detailed experimental investigation is carried out with three different inlet location.

II. EXPERIMENTAL SETUP AND MEASUREMENT PROCEDURE

The microchannel setup consists of 25 number of rectangular microchannels, machined by WEDM machining process. Figure 1 shows the microchannel. The header is the part of the microchannel from where the inlet fluid is distributed to the channels. In the present work, rectangular shaped headers of 10 mm width with two inlet location were used Figure 1 show the rectangular headers of 10 mm with two inlet Locations

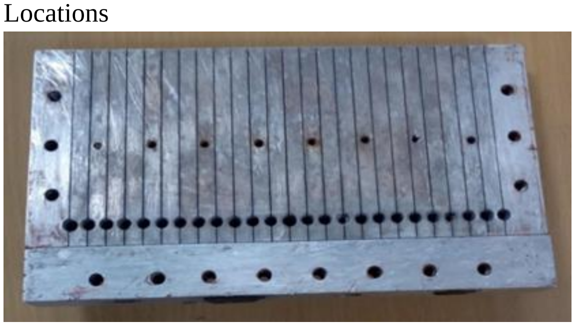

Fig 1: Photographic view of microchannel with blank header

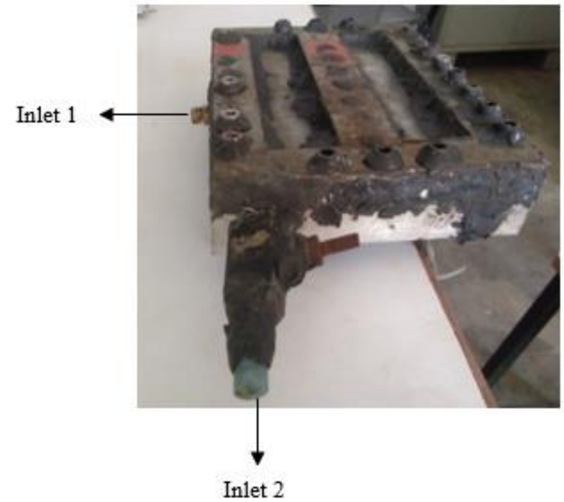

Fig 2: Photographic view of microchannel with two inlet location

For each channel of this set up, the width and depth have been measured using machine vision at five different locations. Deionized water is used as working fluid. To visualize the flow arrangement, the top of the surface is covered with an acrylic sheet and to maintain a proper balancing force, a mild steel cover is placed on the sheet. The mild steel cover and acrylic sheet and the channel were bolted together.

A peristaltic pump is used to supply the water to the channel with proper filtration to remove the impurities in the water before it is sent to the channel, as shown in fig 3. Prior to the start of experiments, preliminary inspection was carried on the set up to ensure that there is no air leak and fluid flows only into the channels. After the inspection, the pump is switched on and when the flow gets stabilized, the water from each channel is collected with the measuring jar for 5 min, and the mass of the water is measured by a digital electronic balance.

Fig. 3 Photographic view of Experimental set up

Experiments were carried out with rectangular header with two different inlet locations with various flow rates. If the fluid enters through the side, then it is known as side inlet. If the fluid enters through the centre it is known as centre inlet and if the fluid enters through the side and the centre then it is known as double inlet condition. The reading taken from each channel shows some variations and comparison was made by plotting graphs for channel number to the normalized flow rate for rectangular header of side inlet arrangement. The normalized flow rate is the ratio of channel flow rate to the average flow rate in each channel. If the value of normalized flow rate is one then that channel flow rate is equal to the average flow rate. It is inferred that channel does not has any maldistribution. If the value lies less than 1 or greater than 1 then there exists some mal distribution.

III. RESULTS AND DISCUSSIONS

Experiments were carried out with a rectangular header of three different inlet locations and graphs were plotted with channel number and normalised flow rate. Figure 5 show the channel wise flow rate for rectangular header of side inlet.

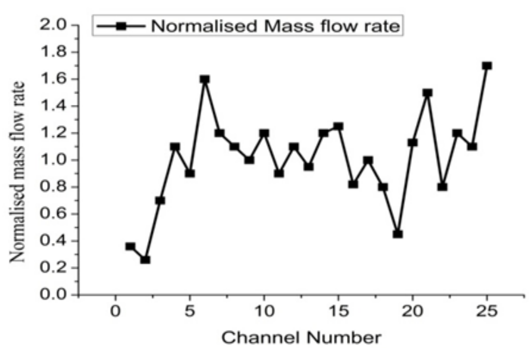

Fig:5 Channel wise flow rate for rectangular header of double inlet condition

Experiments were carried with rectangular header of three different inlet location of side inlet, double inlet and centre inlet for various flow rates of 24 kg/.hr to 42 kg/hr and maldistribution in percentage was found with percentage absolute mean deviation or flow non uniformity factor ϕ Figure 6 shows the graph drawn for flow rate (kg/hr) with percentage absolute mean deviation. From the graph it was found that as the flow rate increases percentage absolute mean deviation decreases [2]

Percentage absolute mean deviation

$$[MAD] = \sqrt{\frac{C_1{}^2+C_2{}^2+C_3{}^2+ \ldots\ldots\ldots\ldots + C_n{}^2}{n}} \times 100\%$$

where,

$$C_1, C_2, \ldots, C_n = \frac{(\text{Average flow rate} - \text{Channel flow rate})}{\text{Average flow rate}}$$

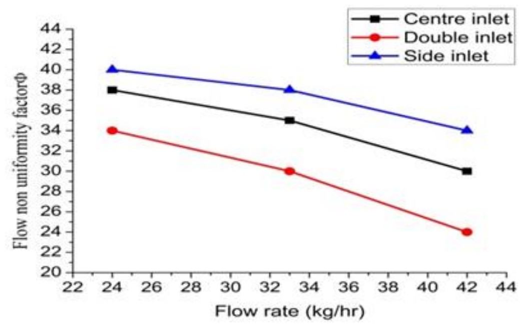

Fig: 6 Effect of flowrate on flow maldistribution

It was also inferred that rectangular header with double inlet flow configuration gives less maldistribution than other two flow inlet configuration. This is due to the reason increasing mass flow rate in double inlet configuration as the fluid enters through two directions simultaneously and it also prevents the phenomenon of jet impingement, and it reduces the reverse flow and recirculation inside a header.

IV. CONCLUSIONS

An experimental study has been carried out to investigate the effect of inlet location on maldistribution in microchannel. Experiments were carried out with 25 numbers of rectangular microchannels with a rectangular header of three different inlet location for a flow rate of 24 kg/hr to 42 kg/hr with deionized water as working fluid. The inlet location of the header plays a significant role in flow maldistribution. Severe maldistribution was found for the rectangular header with side inlet than to centre inlet and double inlet location. The experiment also indicates that as the flow rate increases the maldistribution decreases inspite of the location of the headers.

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