

Heat Transport in High Heat Dissipating Electronic Devices

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ABSTRACT: With the decrease in the dimensions of electronic components and increase level of heat generation by the equipments, the problem of removing heat has become a bottleneck problem in the electronic chip industry. This paper reports, an experimental investigation of heat transfer and pressure drop characteristics of Trapezoidal Minichannel arrays cooled with Radiator coolant Veedol rapid kool. Steady, forced convection, turbulent flow conditions were maintained in this experiment. Flow rate was varied and heat flux was kept constant. For all the investigated flow rates, it was observed that with increase in Reynolds number, both the Nusselt number and pressure drop increases which further lead to increase in the pumping power.

KEYWORDS: Trapezoidal Minichannel, Forced convection, Radiator coolant, turbulent flow.

I. INTRODUCTION

Recent advances in electronic industry have resulted in high heat flux operating devices (for example, the heat flux in IC chips which was chilled using air as a coolant has almost reached its limit to about 100 W/cm²). There are also applications which require heat fluxes more than these devices. The heat dissipation problem of these electronic equipments is a major issue and many investigations have been made regarding this. This high heat dissipation can be achieved either by better geometry through increasing surface area to volume ratio for heat transfer or using better coolant. There are also many other ways to enhance heat transfer. Micro channel liquid cooling can be considered important among these methods [1]. This geometry offers large surface area so heat transfer coefficient will be high but the problem associated with these devices is the pressure loss. So mini channel has to be used where the heat flux is high and pressure loss is less [1].

II. RELATED WORK

The novel technology of Micro channel cooling was first proposed by Tuckerman and Pease [2] in 1981, where they used water as a coolant on micro channels fabricated in silicon chips. They were able to achieve a high temperature drop between substrate and inlet but the pressure drop obtained was very high. Later, Philips [3] studied the micro channels in more detail and provided fabrication techniques of micro channels. Recently, Kandlikar et al. carried a number of experimental studies on to the use of micro channels for direct cooling [4–5]. Lee J and Mudawar I [6] carried out an experiment to investigate micro channel cooling benefits using Al₂O₃Nanofluids. They found an

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increment in heat transfer in single phase and mostly in laminar region. They also found that heat transfer coefficients were higher at the entrance region and lower at fully developed region.

From the literature it is very much clear that most of the work is carried out using ordinary water as a coolant in Minichannel. So the present work aims at analysing the heat transfer performance of Minichannel using radiator coolant Veedol oil. The coolant Veedol oil is expected to decrease the thermal resistance and improve the heat transfer performance compared to ordinary water. In this work, an experimental study which comprises the heat transfer analysis of trapezoidal Minichannel cooled with water based coolants is carried out. The study was conducted under turbulent, steady and forced flow condition. The important parameters of interest like Reynolds number, Nusselt number, friction factor, and pressure drop will be calculated. These parameters will be compared using graphical representation.

III. EXPERIMENTAL SETUP

The test section [7] comprises of Minichannel array (10 in number) as per the required geometry (Trapezoidal). It was fitted to strip heater at its bottom. The heat input to the Minichannel can be varied by using dimmer start but in this experiment it was kept constant. The Minichannel was further connected to inlet header for inflow flow of coolant and outlet header/plenum to discharge the coolant out of the Minichannel. A pump along with control valve was used for continuous supply of coolant and for controlling the flow rate of coolant. The upper surface temperature of Minichannel was measured using K-type thermocouples which were fixed at equal distance throughout the length of channel. While T-type thermocouples were attached to inlet and outlet of the Minichannel to measure inlet & outlet temperature of the coolant. Also pressure transducers were used at inlet and outlet section to measure pressure drop.



Fig. 1 Experimental set up

The whole assembly was mounted on an iron frame which holds the pump and reservoir at the lower sections of the framed table, Minichannel test section was placed on the table. Coolant was first pumped from the reservoir tank to the test section. Inlet temperature and pressure were measured as soon as it gets into the inlet. Then the coolant flows in to the Minichannel tubes with defined cross sections and gets heated up. After that it is passed through the heat

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exchanger to retain its inlet temperature value. Again it is transported to the reservoir and the procedure is repeated for different flow rates. Minichannel of 2mm hydraulic diameter was used for the study. The analysis was carried out for various discharges, keeping heat flux as constant. Steady state, forced convection, turbulent flow conditions were maintained throughout the experiment. For each flow rates, steady state temperature readings were recorded.

IV. RESULTS AND DISCUSSION

In this work, an experimental study which comprises the heat transfer analysis of trapezoidal Minichannel cooled with water based coolants is carried out. The study was conducted under turbulent, steady and forced flow condition. The important parameters of interest like Reynolds number, Nusselt number, friction factor, and pressure drop were calculated and compared using graphical representation.

1. Effect of length to diameter ratio(X/D) on local Nusselt number

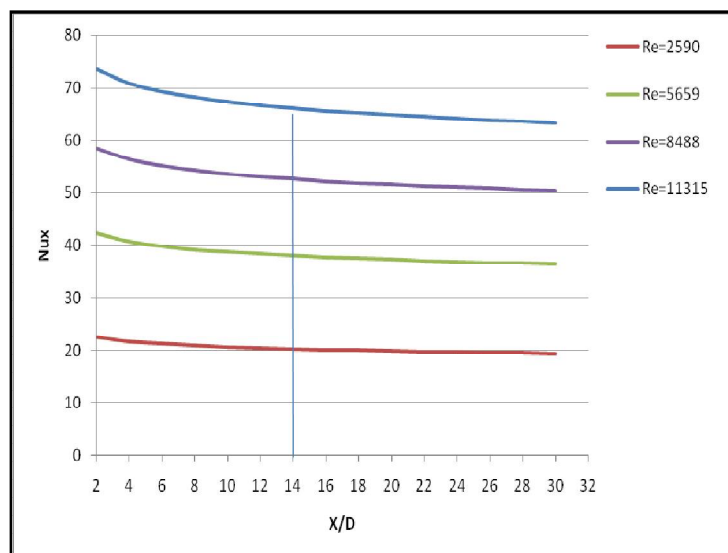


Fig. 2 Effect of length to diameter ratio(X/D) on local Nusselt number

Figure 2 shows variation of local Nusselt number with length to diameter ratio(X/D) of the channel. It can be seen that, the Nusselt number and hence the heat transfer coefficient were much higher at the entrance [8], the Brownian motion, interaction of nanoparticles and the resulting disturbance in the boundary layer can be the possible reasons for the observed increments. It is also seen that after certain length to diameter ratio, the value decreased and remains constant, proving that nanoparticles have an appreciable effect on thermal boundary layer development [6]. So a faster transition to fully developed flow can be observed in these channels.

2. Effect of length to diameter ratio(X/D) on local heat transfer coefficient

Figure 3 below shows variation of local heat transfer coefficient with length to diameter ratio(X/D) of the channel. As discussed earlier, the local heat transfer coefficient is much higher at the entrance [8] and after certain length to diameter ratio(X/D), it decreased and becomes constant. So a fully developed flow was obtained for an X/D=14. So a faster transition to fully developed flow was observed in these channels.

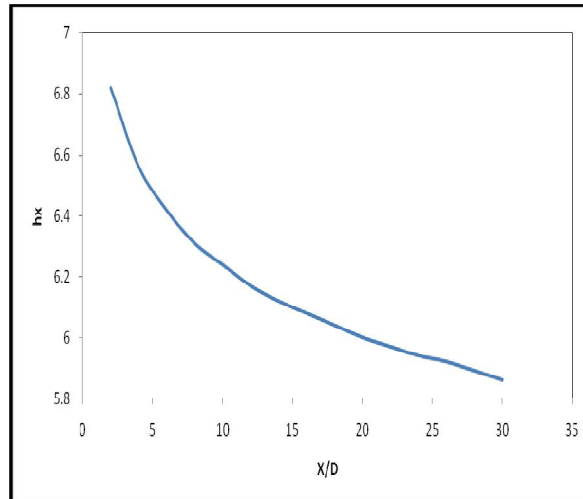


Fig. 3 Effect of length to diameter ratio (X/D) on local heat transfer coefficient

3. Effect of Reynolds Number on Nusselt Number

The below figure 4 shows the impact of Reynolds number on Nusselt number in the channel. It is very much clear, from this figure that as Reynolds number increases, the Nusselt number also increases which is quite obvious. The reason being increase in velocity of flowing fluid, which causes turbulence & increases the heat transfer coefficient. Hence the overall Nusselt number increases.

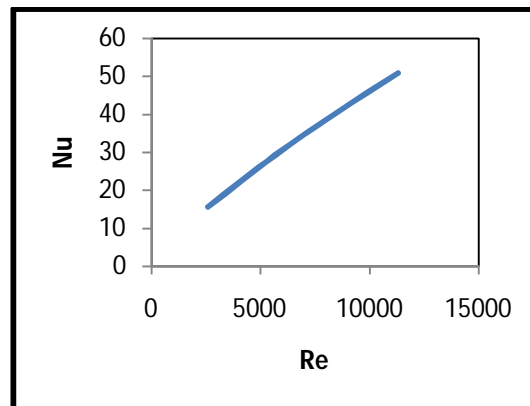


Fig. 4 Effect of Reynolds Number on Nusselt Number

4. Effect of Reynolds number on pressure drop

The pumping power is very important parameter which gets affected by pressure drop. The figure 5 below shows the effect of Reynolds Number on Pressure drop along the length of the channel. It can be seen that as Reynolds number increases, the drop in pressure also increases because velocity and pressure are inversely proportional to each other. So increase in velocity causes the pressure to drop in the channel. This increase in pressure drop causes an increase the pumping work. So it can be concluded that augmentation in heat transfer does occurs in Minichannel but at the cost of pumping power.

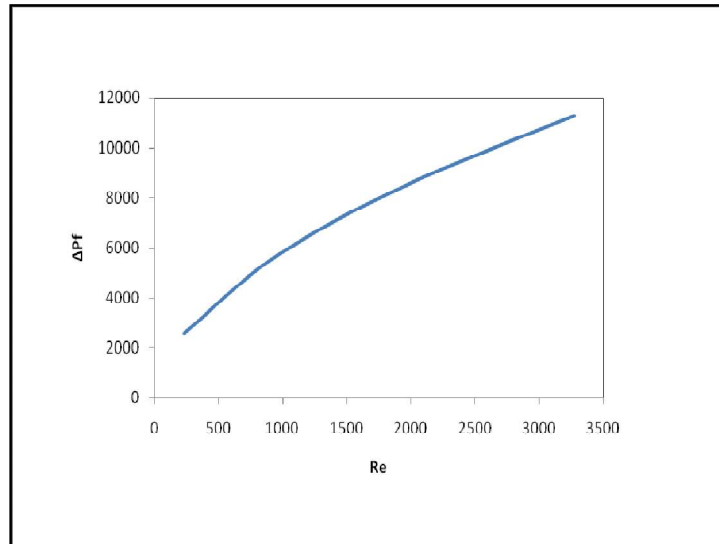


Fig. 5 Effect of Reynolds Number on Pressure drop

5. Effect of length to diameter ratio (X/D) on friction factor

Figure 6 below shows variation of friction factor with length to diameter ratio (X/D) of the channel. It is clearly observed that, when length to diameter ratio increases, the friction factor diminishes and after certain ratio of length to diameter, it remains constant. The ratio where it remains constant was found to be at X/D = 14. The reason being the dominance of momentum diffusivity over thermal diffusivity, which further decreases the heat transfer rate.

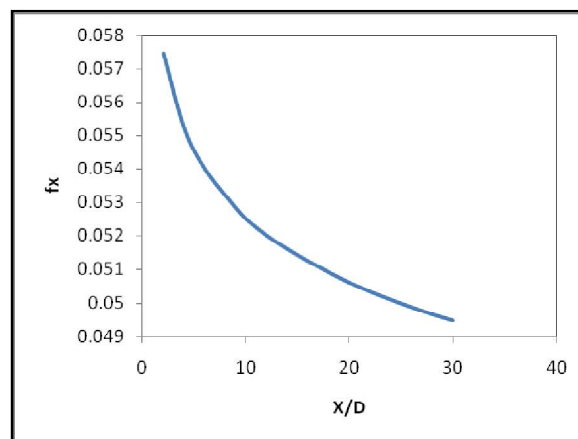


Fig. 6 Effect of length to diameter ratio (X/D) on friction factor

V. CONCLUSION

An analysis was carried out in Trapezoidal Minichannel using Radiator oil as a coolant. Heat flux was kept constant flow rate was varied. The experiment was conducted under steady state forced convection, turbulent flow conditions.

The following conclusion were drawn from the analysis

1. Nusselt number, heat transfer coefficient and friction factor varies very significantly and has a higher value at the entrance region. But reaches a constant value after a short distance from the entrance. So a faster

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transition towards the fully developed flow condition was possible using these channels.

2. It was observed that, the Nusselt number and heat transfer coefficient increases, with increase in Reynolds number. Hence heat transfer rate also increases in the mini channels considered.

3. With increase in Reynolds number, pressure drop also increases. Hence enhancement does occurs but at the penalty of pumping.

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