

# Thermal Analysis of Heat Dissipating Electronic Devices

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**ABSTRACT:** The rapid increase in the growth and advancement of electronic technology leads to the miniaturization of the devices. As the compactness of the device increases the problem of heat transfer also increases. There is a limitation for the cooling with air in the devices with high heat dissipation. The compactness and limitation in air cooling forces the use of Minichannel and use of liquid coolants. The main aim of this work is to carryout experimentally, the heat transfer analysis of Square Minichannel (used as a heat sink) cooled with RO treated water. The study was conducted under turbulent, steady and forced flow condition. The important parameters of interest like Reynolds's number, Nusselt number, friction factor, and pressure drop were calculated. From the obtained results, it was clearly observed that within the entry region, both local heat transfers coefficient and friction factor increases and after a short distance it becomes constant. Also with increase in Reynolds number, pressure drop increases. Hence enhancement does occurat the cost of pumping power.

**KEYWORDS:** Electronic devices, Square Minichannel, Turbulent flow, RO treated water.

## I. INTRODUCTION

With the increase level of miniaturization in the electronic devices, the cooling requirement of these devices has increased considerably. And as the temperature increases, the stability and efficiency deteriorate. Hence the problem of heat dissipation has become a bottleneck for the development of chips in the electronic industry. Also there is a rapid increase in applications of devices requiring very high heat transfer rates and fluid flows in relatively small passages. For example-electronics cooling, space thermal management, MEMS devices for biological and chemical analyses etc. Due to the development of these devices which require cooling of high degree in small passages, the researchers are focussing their attention towards the prediction of thermal performance in these mini and micro channels like devices. Channels having dimensions of the order of mm can be defined as minichannels [1].

## II. RELATED WORK

The novel technology of Micro channel cooling was first projected by Tuckerman and Pease [2] in the year 1981, where they used water as a coolant on micro channels made in silicon chips. A very high temperature drop between substrate and inlet was achieved in these channels but at the cost of pressure drop. Later, Philips [3] studied the micro channels in more detail and provided fabrication techniques of micro channels. Saad Ayub Jajja et al. [4] analyzed five different Minichannel heat sink to study the impact of fin spacing. They found that the base temperature and resistance decreased as fin spacing was decreased and discharge of water was increased. They also achieved an increment in the

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overall heat transfer coefficient. Hai Trieu Phan et al [5] carried out an experiment to study the impact of surface wet ability on two-phase pressure drop of water at a pressure of 1 atm. They observed that as surface contact angle increases the two phase pressure drop also increases. They also proposed a model to find the pressure drop caused by the change in static contact angle. Xie et al. [6] numerically analyzed a Minichannel heat sink using water as a coolant. The analysis was carried out for single phase, laminar flow conditions and the heat flux was kept constant. They found that a narrow deep channel with thin bottom thickness improves the heat transfer even though the pressure drop is high. They also found an optimal configuration of mini channel to cool the chip.

From the literature it is abundantly 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 RO treated water. The RO treated water is expected to decrease the thermal resistance and improve the heat transfer performance compared to ordinary water. In this project, an experimental study which comprises the heat transfer analysis of square Minichannel cooled with RO treated water as a coolant is carried out. The study was conducted under turbulent, forced flow condition. Steady state readings were noted. The important parameters of interest like, Nusselt number, friction factor, Reynolds number and pressure drop were calculated and compared using graphs.

### III. EXPERIMENTAL SETUP

The test section [7] is made of Minichannel array (10 in number) as per the required geometry (Square in this case). It was fixed to strip heater at its base. The heat input to the Minichannel can be varied by using dimmer start but in this experiment it was kept constant. The Minichannel was connected to inlet header for inflow flow of coolant and outlet header for outflow of the coolant. A pump was used for continuous supply of coolant and for controlling the discharge. The upper face temperature of Minichannel was calculated using K-type thermocouples set at equal distance throughout the channel length..



Fig. 1 Experimental set up

While T-type thermocouples were attached at entrance and exit of the Minichannel to measure entrance and exit temperature of the coolant Also pressure transducers were used at entrance and exit section to measure pressure drop.

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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 was passed through the heat exchanger to retain its inlet temperature value. Again it is transported to the reservoir and the cycle is repeated for different flow rates.

## IV. RESULTS AND DISCUSSION

In this project, an experimental study which comprises the heat transfer analysis of Square Minichannel cooled with Ro treated water as a coolant 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 graphs.

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

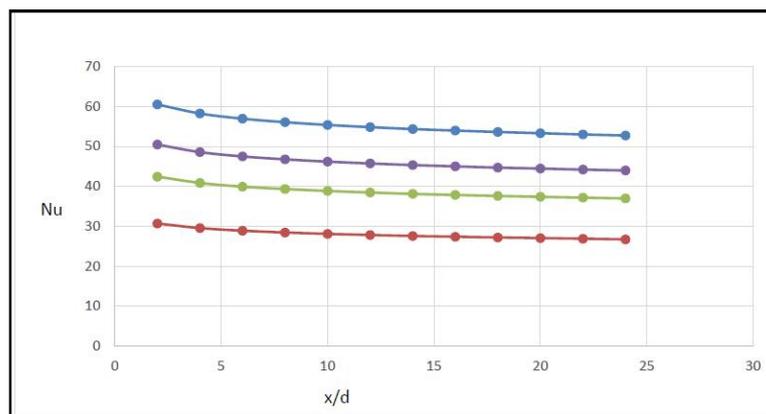


Fig. 2 Effect of length to diameter ratio(X/D) on local Nusselt number

Figure 2 shows the variation of local Nusselt number with length to diameter ratio(X/D) of the channel. It can be seen that the Nusselt number and heat transfer coefficient are 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 [9]. And it can also be seen that after certain length to diameter ratio(X/D) the variation is small and as the flow advances, the value becomes constant. So this region may be called as fully developed region and can be seen that the X/D ratio required to attain a fully developed flow is much shorter in mini channels. So a faster transition towards a fully developed flow can be achieved in mini 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). Again it can be observed that, the local heat transfer coefficient is much higher at the entrance [8] and after certain length to diameter ratio(X/D); the variation diminishes and becomes constant. So a fully developed region was found for an X/D =12.

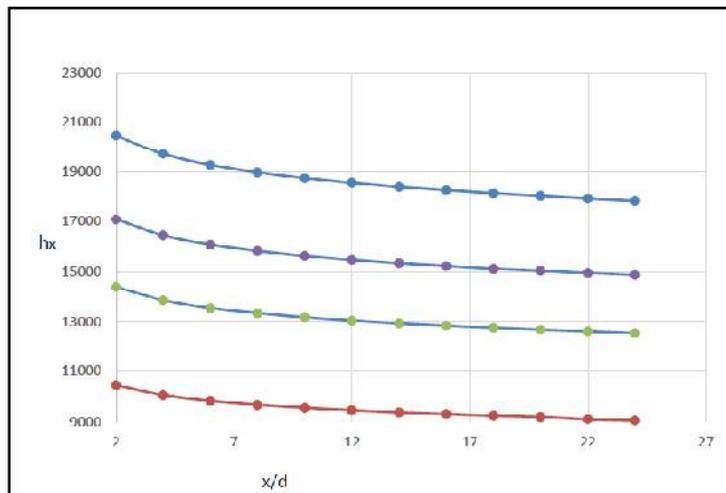


Fig 3. Effect of length to diameter ratio(X/D) on heat transfer coefficient

**3. Effect of Reynolds Number on Nusselt Number**

Figure 4 below depicts the variation of Reynolds number on average Nusselt number. It can be seen that as Reynolds number increases, obviously the Nusselt number increases because with increase in Reynolds number, velocity of flowing fluid increases, this causes turbulence & increases the heat transfer coefficient. Hence the overall Nusselt number increases.

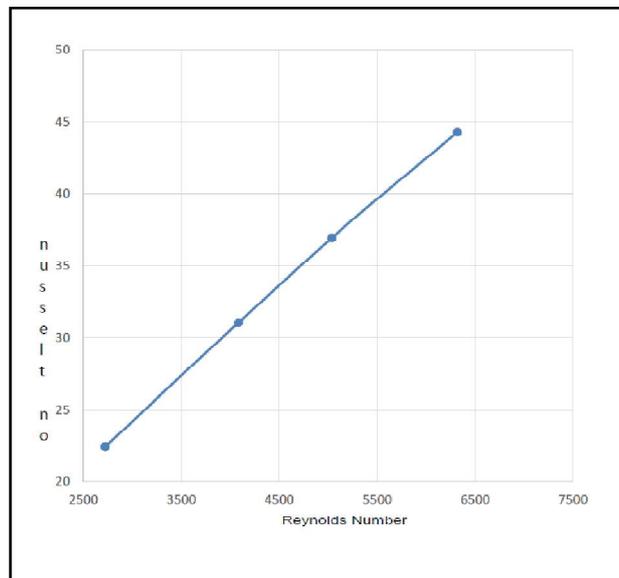


Fig. 4Effect of Reynolds Number on Nusselt Number

**4. Effect of Reynolds number on pressure drop**

Figure 5 shows the effect of Reynolds number on Pressure drops. It is abundantly clear from this figure that, with increase in Reynolds number, the pressure drop increases, as velocity and pressure are inversely proportional to each other. And as the velocity of the fluid increases, the pressure decreases, this leads to overall drop of pressure along the length of the channel. This increase in pressure drop causes an increase in pumping power. So it can be concluded that, heat transfer enhancement does occur in Minichannel but at the cost of pumping power.

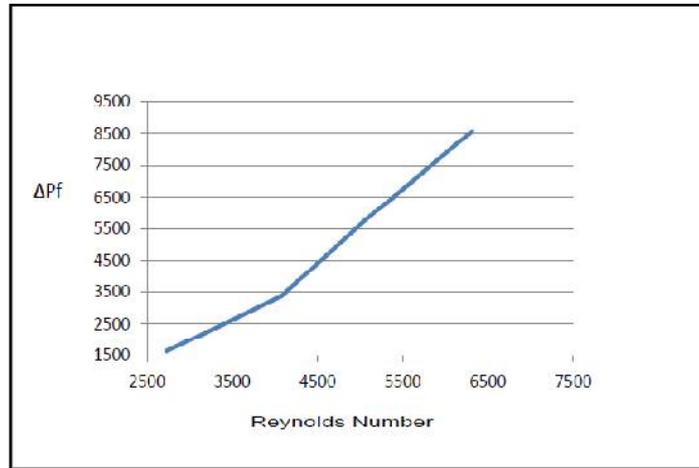


Fig. 5 Effect of Reynolds Number on Pressure drop

**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 can be seen that when length to diameter ratio(X/D) increases the variation in friction factor decreases and finally reaches a constant value, indicating a fully developed flow region. The ratio where it remain constant was found to be at  $x/d = 12$ .

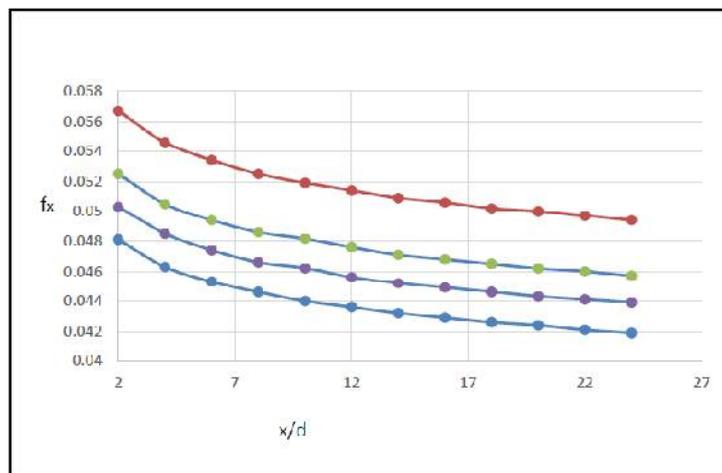


Fig. 6 Effect of length to diameter ratio(X/D) on friction factor

**V. CONCLUSION**

An analysis was carried out using Square Minichannel with RO treated water as a coolant. The readings were taken by varying the discharge and maintaining heat flux as constant. Steady state, forced convection, turbulent flow conditions were also maintained throughout the experiment.

The following conclusion were drawn from the analysis

1. Nusselt number, heat transfer coefficient and friction factor varies very significantly at the inlet region but reaches a constant value after a very short distance from the inlet. So a faster transition towards the fully developed flow condition can be observed in 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.

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3. With increase in friction factor, a decrease in heat transfer coefficient was observed for the mini channel considered at different Reynolds numbers. This indicates that the pumping requirement to pump the fluid increases with Reynolds number.

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