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Experimental Investigation of Micro-Channel Heat Sink With And Without Water Cooling

V. P. Joseph Arun Prasath[1], P.Mohan[2], M.Rajesh[3], P.Mathavan[4]
[1]*(Asst. Prof, Dept of Mech. Engg, Dhanalakshmi Srinivasan Institute of Technology, Trichy, India)*
[2,3, 4]*(Final Year Students, Dept of Mech. Engg, Dhanalakshmi Srinivasan Institute of Technology, Trichy, India)*

Abstract: Significant improvements in the performance of electronic system result, in high heat generation. It requires quick heat transfer because electronic components are strongly affected by high temperature. Considering high heat load and dimensional constraints, heat sinks are considered as best solution for cooling electronic components. Our project work focuses on thermal performance of micro-channel heat sinks. The research objective is to develop simple experimental model to study heat transfer by conduction through the solid heat sink, forced convection of air and liquid cooling by circulating water. A heat sink of 10 ×10 cm made of aluminium through which 0.5cm diameter copper tube is placed. Experimental investigation is concentrated on temperature rise along the fin and temperature distribution from the base to the tip. Heat Transfer Rate and Fin Temperatures are plotted and their variation is studied. This thermal performance is compared with simulation results of ANSYS and efficiency of micro-channel heat sink is validated.
Keywords: Micro-Channel Heat Sink, Fin Temperature, Cooling Systems

I. INTRODUCTION

With the emergence of latest electronic application, the need for high heat dissipation is growing exponentially. This leads to an increasing demand for highly efficient electronic cooling technology. Even though fins and heat sinks provide good heat transfer, usage of micro channel heat sinks coupled with liquid cooling are under study.

Micro channel heat sinks increase the component surface area significantly while also increasing heat transfer coefficient. However, a careful review of the literature reveals that no experimental study exists which compares cooling of micro channel heat sinks with and without liquid cooling.

The objective of this paper is to prepare an experimental setup that can be used to analyze heat transfer rate of micro channel heat sinks in pure conduction mode, forced convection using air and liquid cooling by circulating water. Experimental readings are validated by numerical analysis based on formulae derived from basic fin equation and forced convection equations.

II. LITERATURE SURVEY

Comprehensive reviews of the different heat transfer techniques employed in electronic cooling were provided by Mudawar and Yeh . (2000). [1] Weilin Qu, Issam Mudawar (2002) have analyzed 3D heat transfer in heat sink and discussed effects of flow Reynolds number and thermal conductivity of solid. They have concluded that temperature rise along the flow direction in solid and fluid region of micro channel heat sink can be approximated at linear. [1]

Pawar S.P et al. (2015) have concluded that heat transfer enhancement in thermal management systems of electronic cooling application can be achieved by using various cooling fluids, varying fin thickness, changing the orientation of the fan. They have tried Fan on Top (FOT) and Fan on Side (FOS) and concluded that FOS is better. [2]

Sharad D. Patil, Sagar C. Wangdare (2008) have listed out the advantage of micro channel heat sink.

- Very high surface area to volume ratio.
- Large convective heat transfer coefficient.
- It has small mass, small volume and small coolant inventory.
- Bring fluid into intimate contact with the channel walls.
- To bring fresh fluid to the walls and remove fluid away from the wall. [3]

Kays A. Al-Tae'y et al. (2017) have done experimental research using copper metal heat sink with air and water. The water cooling system has proved to be successful in reducing the CPU temperature from 42˚C to 33˚C at 0.0044 kg/s. The values of heat transfer rate at load operation condition are 907.88 W/hr which is higher than at no-load operation conditions that reached to 670.51 W/hr at 0.0177 kg/s of mass flow rate for one hour of period time.[4]

Dong-Kwon Kimet al. (2009) compared the thermal performances of two types of heat sinks i.e.: plate-fin and the second is pin-fin. By their investigation results propose, a volume averaging approach based model for envisaging the pressure drop and the thermal resistance.

Fahiminia et al. (2011) investigated the laminar natural convection on vertical surfaces computationally. The CFD simulations are carried out using fluent software. Governing equations are solved using a finite volume approach. Relation between the velocity and pressure is made with SIMPLE algorithm. [5]

Tuckerman and Pease (1983) were the first to perform micro channel heat sink experiments. Since then the potential of micro channel heat sinks as heat transfer devices has been motivating many researchers to analyze micro cooling phenomena and conduct parametric studies.

Kawano et al. (1998) performed both experimental and numerical studies for pressure drop and heat transfer in the micro channel heat sink. They found pressure drop in good agreement with the fully developed laminar flow theory for $0 \leq Re \leq 200$.

Rahman and Gui (1993) experimented with water flow through trapezoidal micro channels of different depths. They found that measured friction factor and Nusselt number are in agreement with the conventional theory. [6]

Ambeprasad.S.Kushwaha, Prof. Ravindra Kirar (2013) have listed out various governing equations to mathematically solve for fluid flow and heat transfer based on the principle of conservation of mass, momentum and energy. They have discussed comparison of three heat sink profiles using CFD analysis. The profiles are namely rectangular, trapezoidal and parabolic heat sink. [7]

A.Shanmuga Sundaram, Anirudh Bhaskaran (2011) have done the thermal modeling of Thermosyphon Heat Sink Integrated system for CPU cooling. An experimental setup has been constructed and tested at steady state condition from which the experimental values have been used to determine the effectiveness of the system.[8]

III. EXPERIMENTAL SETUP

3.1 HEAT SINK:

A heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device.. A Heat sink of 10cm length and 10cm width and 0.74mm thickness of a heat sink is placed over the heating element. Heat sink base thickness is 0.5cm. Rectangular fin heat sink is used. The heat sink is made of aluminium.

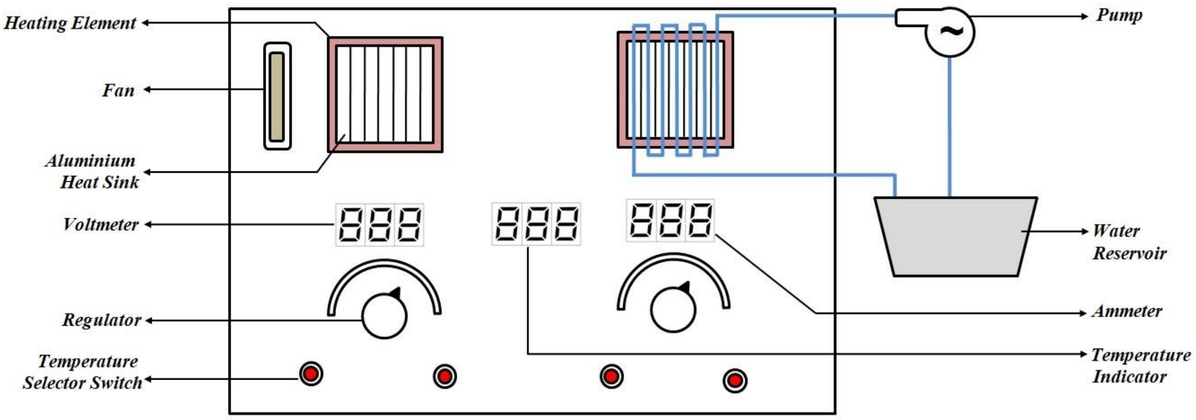


Fig 1: Experimental Setup

3.2 COPPER TUBING:

Copper tubing is joined using flare connection and brazing. The diameter of the copper tube 0.5 cm. This copper tube is placed in between the fin rows of the heat sink. One end of the copper tube is connected to the water inlet hose and another end is connected to the water storage tank. The copper tube is bent to required shape. The water is pumped through the coper tube for convection cooling.

3.3 FAN:

Fan is used to draw cooler air into the heat sink area. Square framed fan is placed in front of the heat sink, whose dimensions are 10cm width and 10cm length. Electrical specifications of the fan are 0.08A and 230V AC.

3.4 AMMETER & VOLTMETER:

An ammeter and voltmeter are provided to give heat input through the heating element. Specification for ammeter is 0 – 6 A and for voltmeter is 0 – 300 V.

IV. EXPERIMENTAL READINGS

The experiments are conducted for the heat sink with maximum base temperature of 115℃ and corresponding tip temperatures are compared. Heat supplied to the heating elements by varying voltage by regulator. Readings are taken at regular interval and at room temperature of 25℃.

The experiments are conducted and tabulated for

1. Natural convection mode
2. Forced convection using air as medium
3. Forced convection using water as medium

The tables are given below

TABLE 1: NATURAL CONVECTION MODE

S.No	VOLTAGE	CURRENT	HEAT SUPPLIED	BASE TEMPERATURE	TIP TEMPERATURE
	V (In Volts)	I (In Amps)	Q (In Watts)	T_b (In °C)	T_{Fin} (In °C)
1	212	1.2	254.4	85	60
2	212	1.2	254.4	95	72
3	212	1.2	254.4	105	82
4	212	1.2	254.4	115	95

TABLE 2: FORCED CONVECTION MODE USING AIR AS MEDIUM

S.No	VOLTAGE	CURRENT	HEAT SUPPLIED	BASE TEMPERATURE	TIP TEMPERATURE
	V (In Volts)	I (In Amps)	Q (In Watts)	T_b (In °C)	T_{Fin} (In °C)
1	212	1.2	254.4	85	49
2	212	1.2	254.4	95	55
3	212	1.2	254.4	105	57
4	212	1.2	254.4	115	60

TABLE 3: FORCED CONVECTION MODE USING WATER AS MEDIUM

S. No	VOLTAGE	CURRENT	HEAT SUPPLIED	BASE TEMP	TIP TEMP	WATER INLET TEMP	WATER OUTLET TEMP
	V (In Volts)	I (In Amps)	Q (In Watts)	T_b (In °C)	T_{Fin} (In °C)	T_{W1} (In °C)	T_{W2} (In °C)
1	212	1.2	254.4	85	43	33	41
2	212	1.2	254.4	95	44	33	41
3	212	1.2	254.4	105	45	33	43
4	212	1.2	254.4	115	47	33	43

V. GOVERNING EQUATIONS

Heat Transfer from Heat sink fins is calculated from

$$Q = \sqrt{\hbar PkA}\,(T_b - T_\infty) \tan \hbar\ \ (mL) \qquad -(1)$$

Where,

h	-	Heat Transfer Co-efficient
P	-	Perimeter of the fin
k	-	Thermal conductivity of the fin
A	-	Area of the fin
T_b	-	Base temperature
T_∞	-	Atmospheric temperature
m	-	Heat Transfer Module
L	-	Length

Temperature at the tip of the fin is calculated from Temperature distribution formula,

$$\frac{\mathrm{T} - \mathrm{T}_\infty}{\mathrm{T_b} - \mathrm{T}_\infty} = \frac{\mathrm{Cosh\ m(L - x)}}{\mathrm{Cosh\ (mL)}} \qquad -\ (2)$$

Heat Transfer Coefficient for forced convection using air and water are calculated from,

Reynolds Number:

$$Re = \frac{u \times D_h}{\square} \qquad -\ (3)$$

Nusselt Number:

$$For\ Air \quad \rightarrow N_u = 0.332 \times Re^{0.5} \times Pr^{0.333} \qquad -\ (4)$$

$$For\ Water \quad \rightarrow N_{u=} 0.023 \times (R_e)^{0.8} \times (P_r)^n \qquad -\ (5)$$

Heat Transfer Co-efficient :

$$h = \frac{N_u \times K}{D_h} \qquad -\ (6)$$

VI. RESULTS & CONCLUSIONS

An experimental and numerical model of multichannel heat sink is designed and presented in this paper. This setup is utilized for cooling of electronic and computer equipments such as CPU's and servers. An experimental setup is constructed and tested at steady state condition. Results are tabulated and presented graphically to determine the effectiveness of this system.

Numerical analysis of the heat transfer is done in three methods such as natural convection, forced convection using air and forced convection using water. Standard extended surface formulae are used to determine the heat transfer in aluminium fins. Reynolds number and Nusselt number relations are derived from the standard HMT data book.

Experiments are conducted by varying base temperature and flow characteristics of air and water.
The key findings of the experiment and numerical analysis are as discussed below.

1. For peak base temperature, fin tip temperature is observed to the more in natural convection. Fin tip temperature reduces drastically for air convection and water convection.

$$\boldsymbol{T_{Tip}(N.C) > T_{Tip}(A.C) > T_{Tip}(W.C)}$$

$$\mathbf{95℃ > 60℃ > \ 46℃}$$

2. Heat removed from the heat source found to be improving in water Convection than in air convection.

$$\boldsymbol{Q_{WATER} > Q_{AIR}} > \mathbf{Q_{Natural}}$$

$$\mathbf{50\ \ > 19 > 7\ \ (In\ Watts)}$$

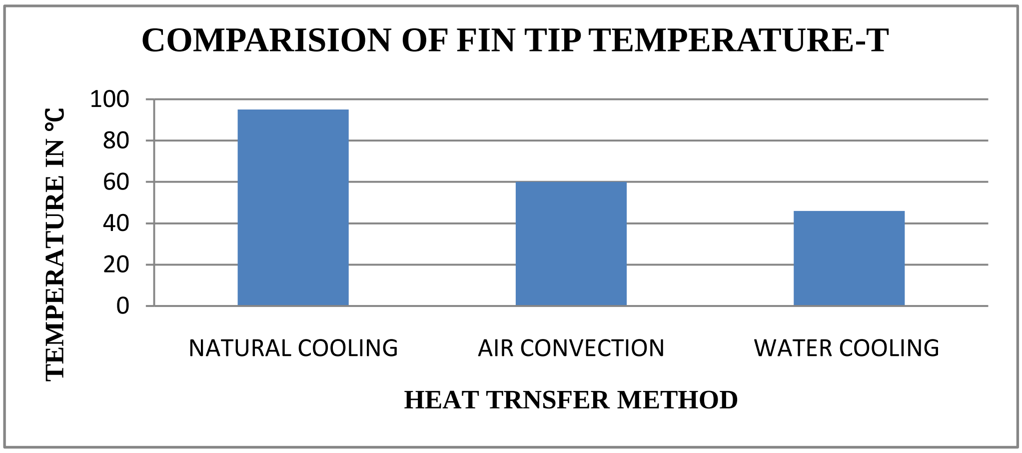


Fig 2: Comparison of Fin Tip Temperature

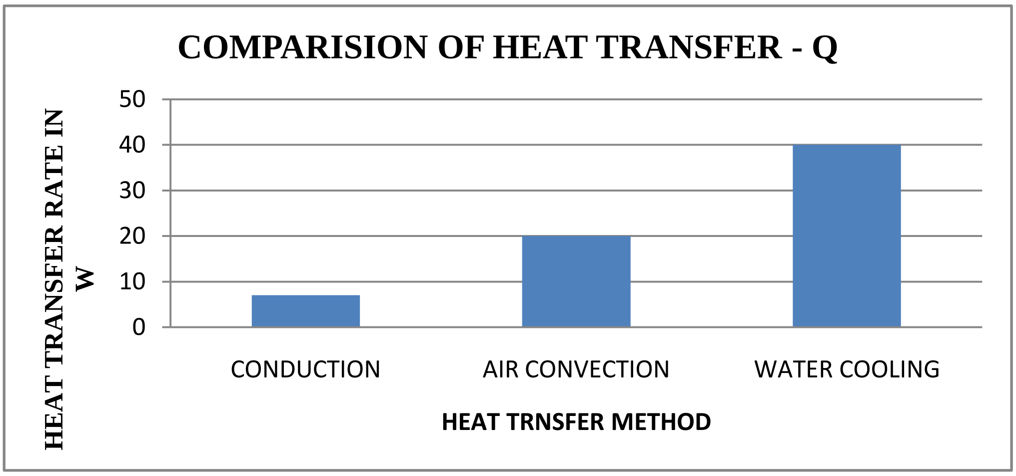
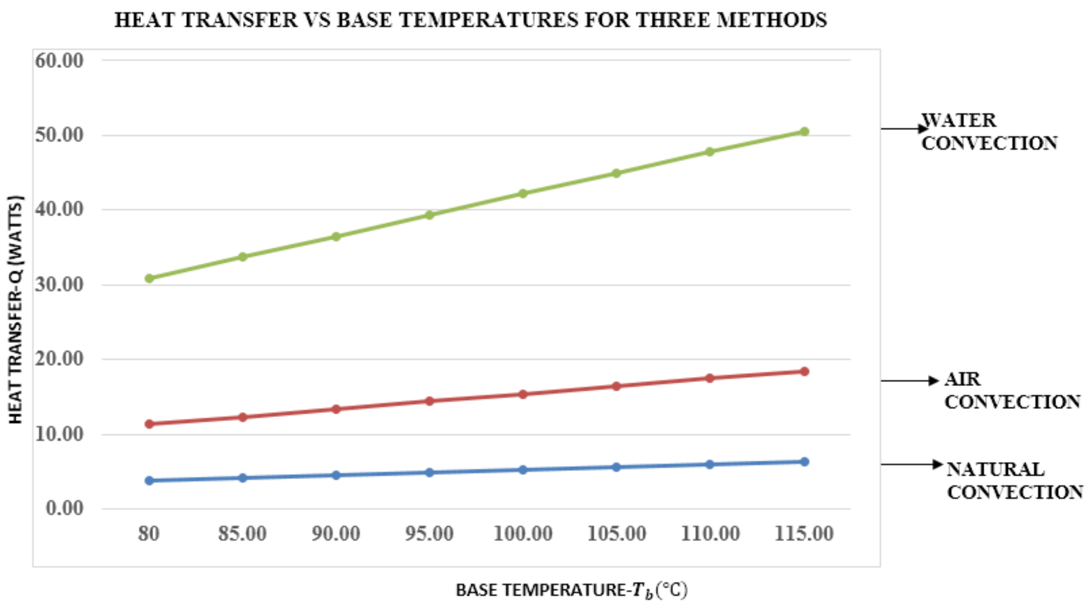
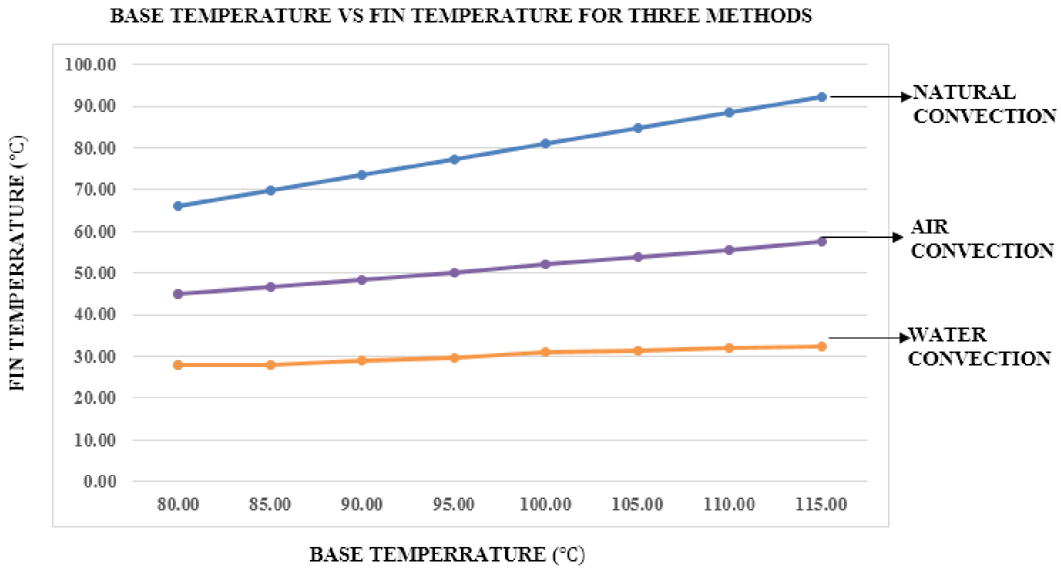


Fig 3: Comparison of Heat Transfer

3. Variation of fin temperature and heat transfer for base temperature is plotted from 80 ℃ to 115 ℃ Based on this graph heat transfer rate for the given temperature range can we derived easily for future work.





4. Finally here by we are concluding that liquid cooling more efficient for electronic equipment than forced convection of air.
5.

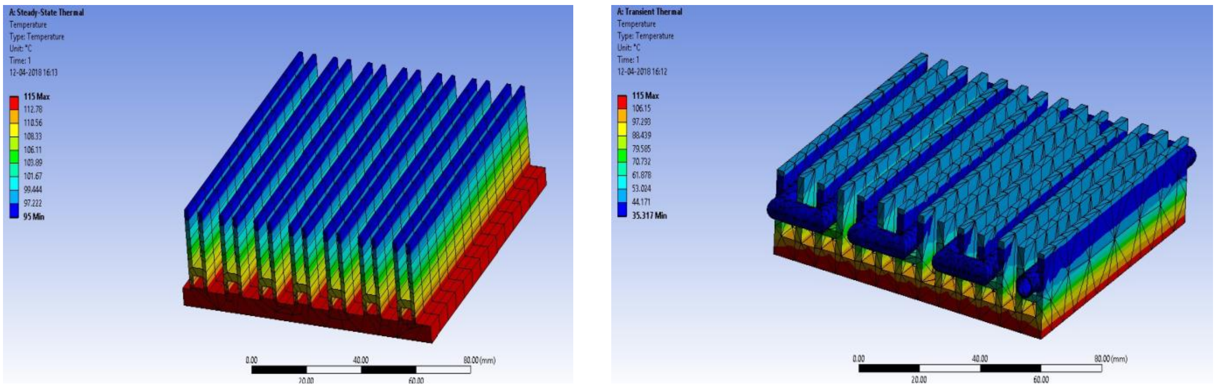


Fig 4: ANSYS Comparison

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