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# Experimental Study on Horizontal Rectangular Fin Arrays under Natural Convection

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*Abstract*— The operation of electronic devices results in generation of heat. Increase in operating temperature causes overheating problems and leads to failure of the component. The heat generated within the system must be dissipated to the surroundings. This is done by heat sink. In the present work electrical heater is placed in between two halves of heat sink with rectangular fins so that heat generated can be distributed equally. Heat transfer coefficient values are calculated from the measured data. Experiments have been conducted to determine the heat transfer coefficients under natural convection by placing fins in horizontal orientation in open air. From the experimental results it could be seen that, heat transfer coefficient h increases with heat input and also with temperature difference.

***Key words:*** Natural Convection, Heat Transfer Coefficient, Horizontal Rectangular Fin Arrays, Heat Sink

## I. INTRODUCTION

Heat sinks are the devices that enhance the heat dissipation from a component to a cooler ambient usually by air. Heat sinks consisting of rectangular fins are extensively used for cooling electronic devices. Dissipating heat will improve the performance and hence it increases the reliability and life of the component. Natural convection method is widely used for cooling electronic devices. In the present experimental study, the heat sink is mounted in such a way that the geometry is symmetric and heat flow around the heat sink is also symmetric. The main objective of this experimental work is to determine the heat transfer coefficient by placing fins in horizontal orientation in open air.

## II. LITERATURE REVIEW

Literature relevant to the present study is reviewed briefly and is given below.

Starner and McManus [1] studied four fin arrays positioned with base vertical, horizontal and inclined configurations. From the experimental data it was observed that heat transfer coefficient is maximum in vertical base configuration compared to other two positions.

Charles and Smith [2] conducted an experiment for finding out the optimum spacing of rectangular fins on horizontal surface by free convection. Result shows that fin spacing, S had a significant effect on the heat transfer coefficients.

Yuncu and Anbar [3] studied rectangular fins on horizontal base with 15 set of fin arrays with height of the fin varying from 6 – 26 mm, fin spacing from 6.2 – 83 mm, wattage from 8 – 50 W, number of fins from 4 – 41 and keeping fin length and fin thickness 100 mm and 3 mm respectively as constant. It was observed that heat transfer increases with the temperature difference. It should be mentioned that Welling and Wooldridge [4], Toshio and Aihara [5], Filtzroy [6], Van de Pol and Tierney [7], Leung and Probert, [8], Leung and Shilston [9], Yuncu [10], Yazıcıoğlu [11] have studied heat transfer from rectangular heat sinks with fins in vertical orientation.

Similarly, Seri Lee [12], Dayan, Kushnir, Mittelman and Ullmann [13], Yüncü and Mobedi [14], V. Dharma Rao [15], Mobedi and Sunden [16], have studied heat transfer from rectangular heat sinks numerically.

In the present study experimental investigation of heat sinks was carried out with fins horizontally orientation in open air. Since the geometry and flow are symmetric, the configuration is equivalent to study of one half of the heat sink with the base thermally insulated.

## III. EXPERIMENTAL SET UP AND INSTRUMENTATION

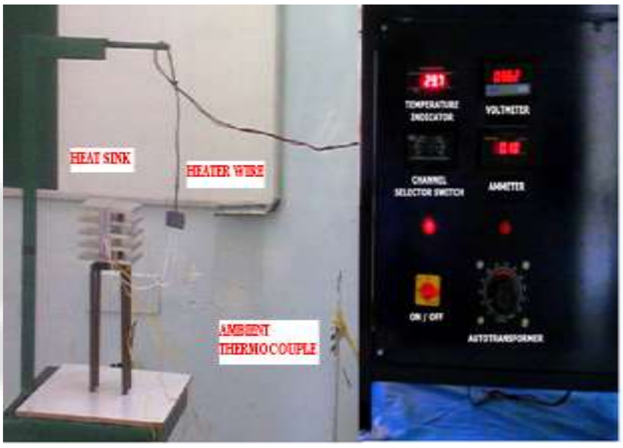


Fig. 1: Photograph of experimental set - up and instrumentation.

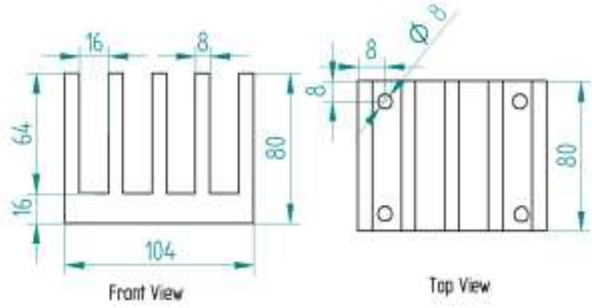


Fig. 2: Geometrical details of Heat sink.

Experimental set up (Fig. 1) is made for measuring the temperature of rectangular heat sinks. The finned heat sink geometry was fabricated by CNC milling machine from the longitudinal faces of a rectangular bar of Aluminium alloy 6082 (HE-30). The fin arrays were produced from rectangular bars with dimensions 80mmx104mmx80mm. Fins were the integral part of the base-plate, fins increase the surface area and hence enhance heat transfer. K- type Thermocouples are attached to the base plate of heat sink with fasteners. It should be noted that the heat sinks employed in the present experiments are symmetric in geometry. Electrical heater is placed in between the two halves of heat sinks. Four thermocouples $Tc_1$, $Tc_2$, $Tc_3$ and $Tc_4$ are fixed by means of fasteners at the drilled hole locations as shown in Fig. 2. The average of four thermocouple readings are taken as the base plate temperature. The ambient temperature value is also measured by using thermocouples.

## IV. EXPERIMENTAL PROCEDURE

Supply from the mains is given through UPS as input of the variac or auto transformer. The output of the auto transformer is given to the heating coil, the resulting current passing through ammeter. Voltmeter is connected across the heater to measure the voltage. The voltage V and current I are set at the required values and the temperature readings of all the thermocouples $Tc_1$, $Tc_2$, $Tc_3$, $Tc_4$ attached to the heat sink, and $T_{amb}$ the ambient temperature thermocouple are noted. It should be noted that in the formulas we consider only one half of the heat sink geometry. The following formulas have been used for calculation of h (Base Area) and h (Total Area).

$$Q = \frac{V*I}{2} \quad (1.1)$$

$$T_{avg} = \frac{Tc_1+Tc_2+Tc_3+Tc_4}{4} \quad (1.2)$$

$$\Delta T = T_{avg} - T_{amb} \quad (1.3)$$

$$A_{base} = (L * W) \quad (1.4)$$

$$A_{total} = L*W + 2n*H\,(L + t_f) + 2t_b\,(L + W) \quad (1.5)$$

$$h\ (\text{Base Area}) = \frac{Q}{A_{base}*\Delta T} \quad (1.6)$$

$$h\ (\text{Total Area}) = \frac{Q}{A_{total}*\Delta T} \quad (1.7)$$

## V. EXPERIMENTAL RESULTS AND DISCUSSION

Here results of the experiments conducted are presented and discussed. The steady state temperature difference values of ΔT are used in calculating the heat transfer coefficient values. Table 1 shows values of Q, ΔT, h (Base Area) and h (Total Area).

| Q (W) | ΔT (°C) | h (Base Area) ($W/m^2°C$) | h (Total Area) ($W/m^2°C$) |
|---|---|---|---|
| 5.071 | 16.15 | 37.211 | 4.3897 |
| 9.889 | 27.5 | 43.706 | 5.1591 |
| 14.877 | 37.72 | 47.7901 | 5.6376 |
| 20.16 | 49.47 | 48.587 | 5.7316 |
| 25.025 | 59.35 | 50.628 | 5.9725 |
| 30.305 | 71.15 | 50.678 | 5.9739 |

Table 1: Steady state temperature difference ΔT and heat transfer coefficient h values for finned Heat sink

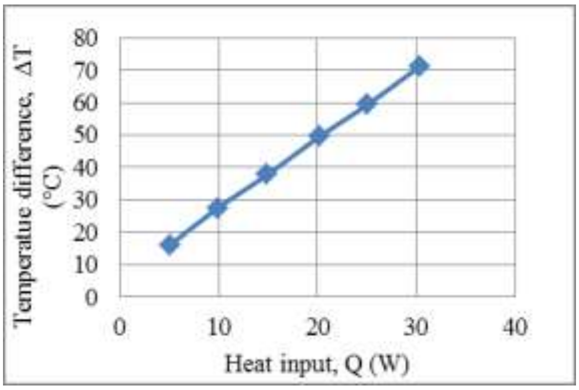


Fig. 3: Temperature difference of the heat sink plotted against the corresponding heat input values.

It can be seen from the graph that the Temperature difference ΔT values are higher for higher heat input values.

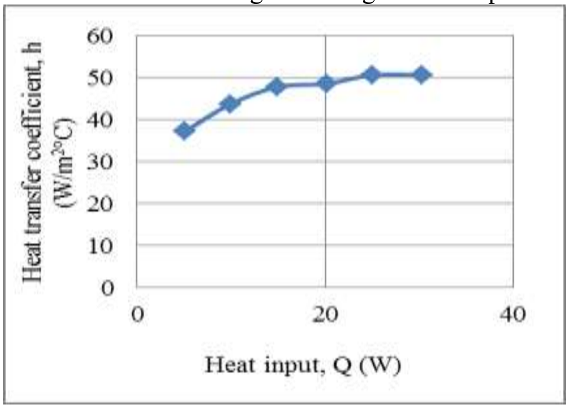


Fig. 4: Heat transfer coefficient h (Base Area) values plotted against the corresponding heat input values.

It can be seen from the graph that the heat transfer coefficient h values increase with heat input.

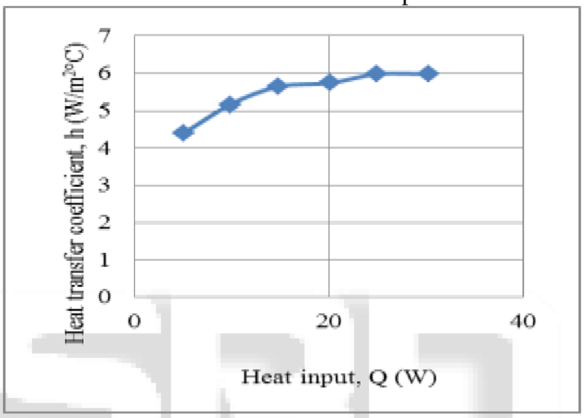


Fig. 5: Heat transfer coefficient h (Total Area) values plotted against the corresponding heat input values.

It can be seen from the graph that the heat transfer coefficient h values increase with heat input.

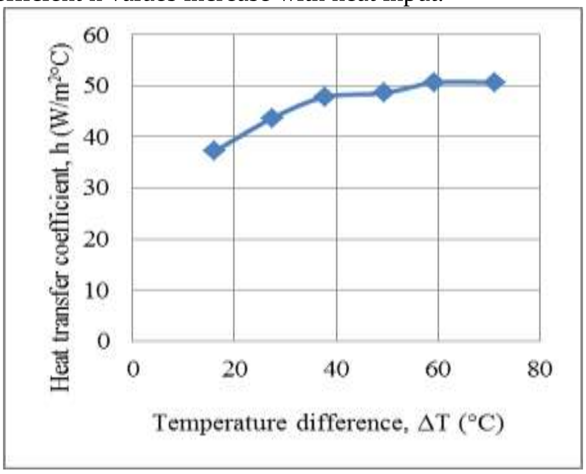


Fig. 6: Heat transfer coefficient h (Base Area) values plotted against the corresponding Temperature difference.

It can be seen from the graph that the heat transfer coefficient h values increase with Temperature difference.

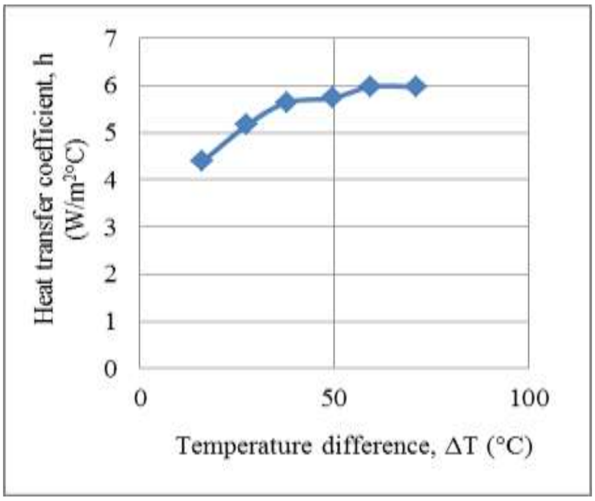


Fig. 7: Heat transfer coefficient h (Total Area) values plotted against the corresponding Temperature difference.

It can be seen from the graph that the heat transfer coefficient h values increase with Temperature difference.

## VI. CONCLUSIONS

1) Temperature difference ΔT values increase with heat input.
2) Heat transfer coefficient h values increase with heat input.
3) Heat transfer coefficient h values increase with Temperature difference.
4) Heat transfer coefficients h on (Base Area) values are higher than h (Total Area) values.
5) From the study it was found that the variation of heat transfer coefficient for both h (Base Area) and h (Total Area) with respect to heat input should be similar variation suggesting that the area consider doesn't affect the heat transfer coefficient with heat input.
6) It was also seen that the variation of heat transfer coefficient with respect to temperature difference was independent of the area considered.
7) Thus this study shows that the area doesn't influence the heat transfer coefficient.

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