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Natural Convective Study of Heat Transfer from Plate-Finned Heat Sinks

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ABSTRACT

Natural convection heat transfer from vertical rectangular plate finned heat sink was experimentally examined. An experimental setup was constructed, 25 sets of vertical rectangular plate finned heat sink were tested in natural convection. The fin height was varied from 5mm to 25mm for 200mm length fin array. The thickness of fin and length of fin was kept constant for all sets of heat sink. The fin spacing was varied from 5.5mm to 17mm.The base to ambient temperature difference was also varied systematically ranging from heat input 10 W to 50 W. The experimental results have shown that the convective heat transfer rate from plate finned heat sink depends on base to ambient temperature difference and geometric parameters. The effects of geometric parameters such as fin height, fin spacing and base to ambient temperature difference were obtained for different heat input.
Keywords: Natural convection, plate fin heat sink

I. INTRODUCTION

Heat sink is widely used to help remove heat from electronic components. Use of plate finned heat sink is one of the cheapest and easiest ways to dissipate unwanted heat and it has been commonly used for many engineering applications successfully. Purpose and analysis of finned heat sink is explained in almost all the heat transfer books [1]. The convective removal of heat from a surface can be substantially improved if we put extension on that surface to increase its area.Starner and McManus [2] conducted the studies to determine the average heat transfer coefficient for four fin arrays positions with the base vertical, 45 degrees and horizontal. They found that vertical arrays performed 10-30 percent below the similarly placed parallel plates. 45 degree arrays result 5-20 % below the vertical arrays and performance of horizontal arrays is low. Charles Jones and Lester Smith[3] has studied experimental average heat transfer coefficient for free convection of rectangular fin arrays on horizontal surfaces .Their result shows good agreement with Starner and McManus. H. Yuncu, G. Anbar [4] investigated natural convection heat transfer for 15 sets of rectangular fin array with horizontal base. They concluded that fin spacing to fin height ratio is strong factor influence for convective heat transfer. F. Harahap, Daru Setio[5]studied experimental data for heat dissipation from five duralumin vertical rectangular fin arrays with base horizontally oriented. The inter fin spacing distance varies from 6.25mm to 7.95mm, length was from 127mm to 254mm,the height from 6.35mm to 38.10mm.The effect of fin length and optimal inter-fin distance was investigated. F. Harahap, H. Lesmana[6] studied heat dissipation from miniaturized vertical rectangular fin arrays. They concluded that effect of the parameter W/L on heat dissipation rate is relatively less for the vertically base array. B. Yazicioglu, H. Yuncu[7] performed experiments over thirty different fin configurations with 250 and 340 mm fin length. Optimum fin spacing of aluminum rectangular fins on vertical base was examined. It was found that optimum fin spacing varies for each fin height which is between 6.1 and 11.9mm. Dialameh et al. [8] conducted numerical study to predict natural convection from a horizontal array of aluminium rectangular fins. It was observed that natural convection heat transfer increase with increase in fin spacing and temperature difference and decreases with fin length. V.S.Daund et al [9] review on experimental and numerical studies on natural and mixed convective heat transfer through rectangular finned array. This paper focusing on the effect of fin height, fin spacing and base to ambient temperature difference for different heat input of plate finned heat sink.

The experimental set-up primarily consists of an aerated concrete base and supporting frame on which the concrete is mounted and various instruments for measuring the ambient temperature, base-plate temperature and the power input for the heater. A Schematic view of the experimental set-up is shown in figure.1 .To ensure natural convection the heat sink was placed in an enclosure. Upper and lower sides of the enclosure were kept open in order to ensure proper natural convection currents of air. The front surface of the frame is covered with acrylic sheet, which has arrangement to replace fin arrays.

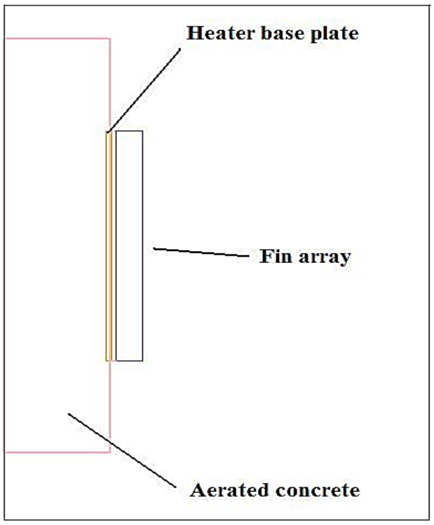

Figure 1. Schematic view of the experimental set-up

Heater plate is made of nichrome wire which is sandwiched in Mica sheets. It is used for heating the aluminum fins. Capacity – 300 W, 50 Hz 200 mm×75 mm. The base plate temperatures of heat sink were measured at five points using copper-constantan thermocouples and ambient temperature was measured by thermocouple number six. To avoid disturbing the flow past the front surface, temperature measurements were not made at the fin tip. Since fin material (aluminum) has high thermal conductivity and fin heights are short, it was assumed that the temperature along the fin and at the fin tip was constant. A calibrated volt meter and ammeter is used to measure the input power.

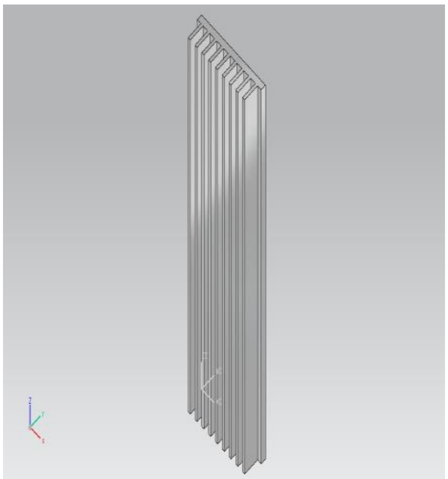

Figure 2. Model of heat sink

The heat sink block is as shown in fig.2 were placed in the enclosure. Tests were conducted over a range of 10 W to 50 W. A dimmer stat was used to vary the heat input in steps. After attaining steady state, temperatures were measured at five points. The average of these readings was taken as the base plate temperature. The power supply to the heater was increased by 10W and the apparatus was allowed to reach the steady state. This procedure was repeated for until a heater input of 50W was reached.

II. METHODS AND MATERIAL

Data Reduction

Under steady state condition total heat supplied in to the system is equal to the total heat flow out of the system. The following equations were used for data reduction. In order to find Nu and Ra, the flow properties must be obtained. Therefore the film temperature is required. T_f= (Tw+Ta)/2

Then thermo physical properties are calculated like β= $1/T_f$, k, α, ν then Ra and Nu can be found as follows

$$Ra = \frac{g\times\beta\times Lc^3\times(Tw-Ta)}{\nu\times\alpha} \quad \text{......... (1)}$$

The heat transfer coefficient based on the surface area was determined as:

$$h\ expt. = \frac{Qc}{As\times(Tw-Ta)} \quad \text{............ (2)}$$

Nusselt numbers were also evaluated from the definitions as

$$Nu = \frac{h \times Lc}{K} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The radiation heat transfer rate was estimated at ambient temperature Ta.

$$(Q)_r = \varepsilon\ \sigma\ A_s\,(T_w{}^4 - Ta^4) \quad \ldots\ldots(4)$$

After determining experimental Nusselt numbers various correlations from literature were used to compared the Nusselt numbers

McAdam's correlation

$$\mathrm{Nu} = 0.59 \times Ra^{0.25} \ldots\ldots\ldots (5)$$

Churchill and Chu's first correlation

$$\mathrm{Nu} = \left[0.825 + \frac{0.387 \times Ra^{1/6}}{\left[1+\left(\frac{0.492}{Pr}\right)^{9/16}\right]^{8/27}}\right]^2 \ldots (6)$$

Churchill and Chu's Second correlation

$$\mathrm{Nu} = 0.68 + \frac{0.67 \times Ra^{1/4}}{\left[1+\left(\frac{0.492}{Pr}\right)^{9/16}\right]^{4/9}} \ldots\ldots\ldots (7)$$

The theoretical and experimental Nusselt numbers were plotted in the same graph as shown in Figure3 in order to display the agreement between them.

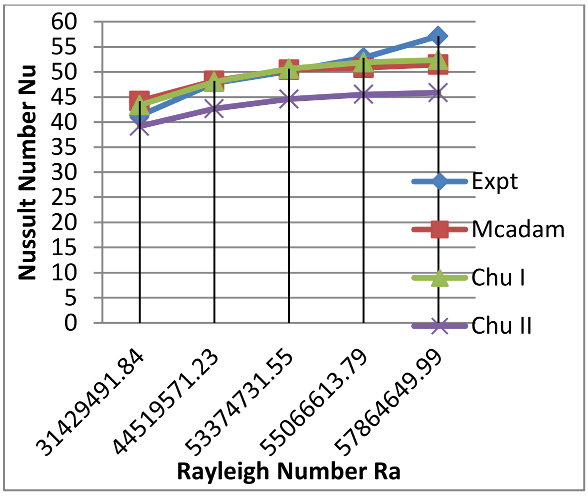

Figure 3. Comparison of Experimental and Theoretical Nussult Numbers

Examination of Figure3 reveals that the experimental data are in a good agreement with the correlations

III. RESULTS AND DISCUSSION

The experimental data obtained from different heat sink configurations are utilized to reveal the effects of geometric parameters, fin spacing, fin height and the effects of base-to-ambient temperature difference on the steady-state heat transfer rates from finned heat sink.

1. Effect of temperature difference over convective heat transfer rate for different heat input

The convection heat transfer rates from finned heat sink and the vertical flat plate are plotted as a function of base-to-ambient temperature difference for fin spacing's, s = 5.5 mm, s = 7 mm, s = 9.5 mm, s = 13.5 mm and s = 17 mm .Each figure involves the results plotted for fin heights H = 5 mm, H =10 mm, H = 15 mm,H=20mm and H=25mm and for a vertical flat plate.

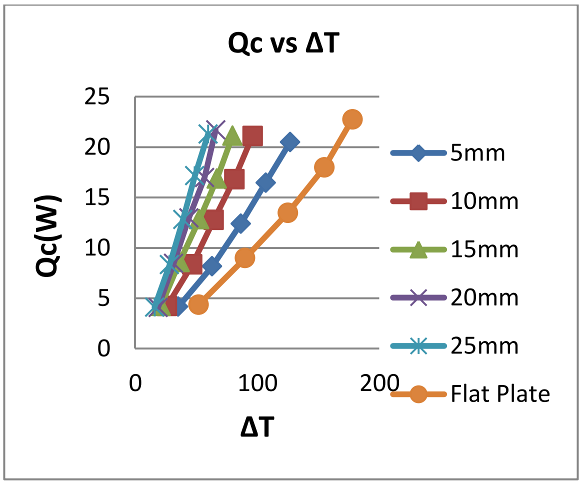

Figure. 4 Variation of Convection Heat Transfer Rate with

Fin Height at a Fin Spacing of s=5.5 mm

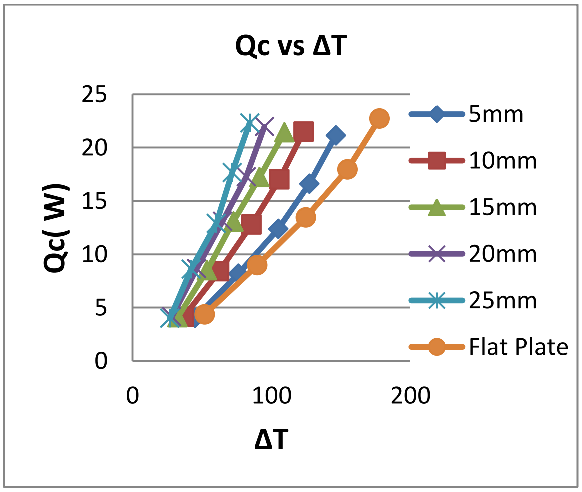

Figure. 5 Variation of Convection Heat Transfer Rate with Fin Height at a Fin Spacing of s=17mm

It is observed from fig.4 to 5that the Qc of heat sink depends on fin height fin spacing and base to ambient temperature of heat sink. Same trends is observed for other spacing. It is also observed that the convective heat transfer rates from the rectangular plate finned heat sink increases with fin height and base-to-ambient temperature difference. The heat transfer rates from all fin heights are close to each other at low temperature differences while at high temperature differences it diverge with the variation in fin height. With increasing fin spacing, the convection heat transfer rates from fin arrays approach the values measured from vertical flat plates, regardless of the presence of fin height parameter.

2. Effect of fin spacing on convective heat transfer rate for different heat input

The convection heat transfer rates from finned heat sink are plotted as a function of fin spacing for various heat inputs.

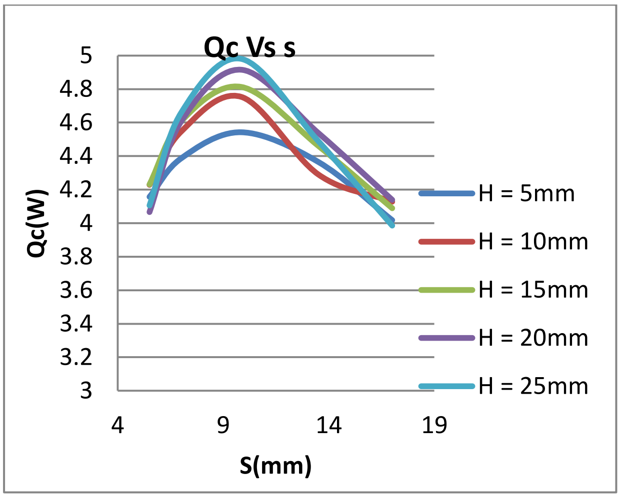

Figure. 6 Variation of Convection Heat Transfer Rate with Fin Spacing for different height at Q=10W

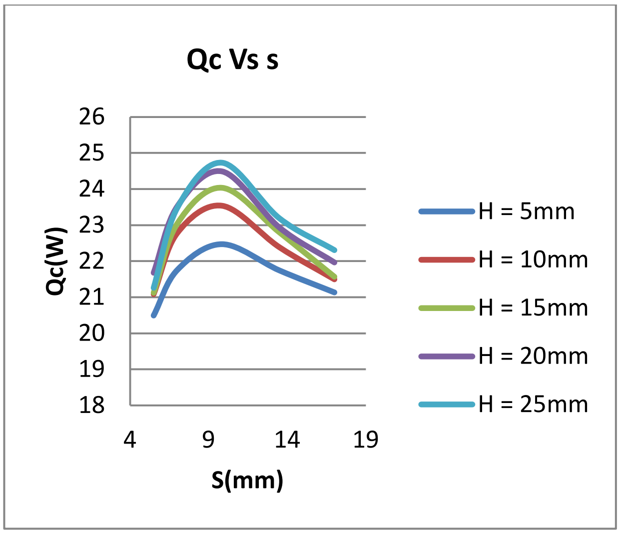

Figure.7 Variation of Convection Heat Transfer Rate with Fin Spacing for different height at Q=50W

From figure 6 and 7 it is observed that Convection Heat Transfer Rate of heat sink increases with fin spacing and after reaching its maximum point, it starts decreasing at a given fin height, fin length and base-to-ambient temperature difference. The corresponding fin spacing value of the maximum convection heat transfer rate point is called optimum fin spacing, Sopt. It is observed that the optimum fin spacing varies between 9.5 mm and 13.5 mm.With increase in fin height Sopt increases slightly

IV. CONCLUSION

In this study natural convection heat transfer from rectangular plate finned heat sink on vertical base has been investigated experimentally.From the experimental results ,it can be concluded that

1. The convective heat transfer rate of plate finned heat sink strongly depends on geometric parameters such as,fin height and fin spacing and base to ambient temperature difference.
2. The heat transfer rate increses with fin height and base to ambient temperature difference.
3. It is concluded that at higher temperature differences the convective heat transfer rate increases significantly with fin height as compared with low base to ambient temperature difference.
4. For a given fin height and base to ambient temperature difference heat transfer rate increses first,reaches to maximum and then starts

decresing.The value of fin spacing at this maximum is called optimum spacing.

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