Study of Natural Convection Using Rectangular Finned Heat Sinks with Base and Fins in Vertical Orientation

K.S. Shashi Shekar, S George Milton, Sameer Kulkarni

***Abstract:** Natural convection heat transfer can be enhanced by using heat sink. Experiments will be carried out to investigate the heat transfer in vertical heat sinks in natural convection with considering geometrical similarity approach with constant S/H (fin spacingto fin height) ratio of the fins and even a correlation is obtained between Nusselt number and Rayleigh number. Using this correlation, size of the heat sink can be obtained for various heat loads by interpolation.*

***Keywords:-** Natural, Nusselt, (fin spacingto fin height), S/H, Correlation, Transfer*

I. INTRODUCTION

Any new non-conventional idea of application in the field of electronics, electrical and optoelectronics systems must address and mitigate the problem of waste heat rejection during its early design stage. This is thermal management of the system and itis picking up by an extraordinary significance with miniaturising of these systems. This miniaturising bringing about a tremendous increase in the measure of heat produced per unit area. The magnitude of heat generated is of the order of hundreds of kilowatts. Unless properly designed and controlled, high rates of heat generation would bring about high working temperatures for these system, which risks systems reliability and safety. The failure rates of these systems increase exponentially with temperature. Also, one of the major causes of failure are the high thermal stresses resulting from temperature variations in the solder joints of electronic components mounted on circuit boards. Therefore, thermal control has turned out to be critical factor in the design and operation of these systems. Different types and shapes of fins are used. Fins are used on plane surfaces or cylindrical surfaces. Fins may be of having different cross sections. Depending on cross section we may have rectangular, circular or triangular fins. The heat dissipation from fins under natural convection condition depends on the geometry and orientation of finned surface. Here in the present study we are considering rectangular finned heat sinks in vertical orientation.

Revised Version Manuscript Received on November 06, 2015.

K.S.Shashi Shekar, Professor, Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumakur, (Karnataka). India.

S George Milton, Professor, Department of Mechanical Engineering, Sri Siddhartha Institute of Technology, Maralur, Tumakuru (Karnataka). India.

Sameer Kulkarni, M.Tech. Student, Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumakur, (Karnataka). India.

II. LITERATURE SURVEY

Elenbaas (1942) has done extensive work with channels and parallel plates on an experimental and semi-empirical basis. His experimental results for square, vertical parallel plates dissipating heat to air are used as a basis of comparison for the vertical arrays Starner and McManus (1963) conducted one of the earliest studies about the heat transfer performance of rectangular fin arrays from experimental data it was found that heat transfer rates obtained from the tests with vertical arrays fell 10 to 30% below those of similarly spaced parallel plates. For the 45-degree base position, heat transfer rates were 5 to 20% below from the values taken at vertical position.

They also showed that incorrect application of fins to a surface actually might reduce the total heat transfer rate. Harahap and McManus (1967) Gave average heat-transfer coefficients for fin arrays positioned with the base oriented horizontally. The flow field associated with the natural convection from the fin arrays was investigated and used as a model to find parameters to generalize the data. The proposed correlation overcomes the inadequacy of parameters available previously for horizontal rectangular fins. Culhamet.al. (1995) presented the method for calculating the thermal performance of rectangular heat sinks cooled by natural convection using a flat plate boundary layer model and examined several heat sink geometries over a range of Rayleigh number between 10^3 and 10^{10}. Seri Lee (1997) developed analytical simulation model for predicting and optimizing the thermal performance of fin heat sinks in a partially confined configuration. It is observed that the actual convection flow velocity through fins greatly affect the overall thermal performance of a heat sink. Yazicioglu and Yüncüare (2007), analysed and demonstrated importance and distinct role of fin height, fin spacing and fin base to ambient temperature difference on convective heat transfer rate from the fin arrays.

III. EXPERIMENTAL MODEL

In the present work rectangular finned heat sinks with geom. etricalsimilarity have been studied. The ratio between fin spacing S and fin height H (S/H) =0.25. There is symmetry of geometry in the Heat sinks used for this study. Two geometrically similar halves are joined together with the heating-coil sand witched between them as shown Fig 01and the geometric details are given in the Table: 01. This makes the heat sinks geometrically symmetric and they are employed in experiments in such a way that the flow around the heat sinks is also symmetric. Since the geometry and

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.*

flow are symmetric, the configuration is equivalent to study of one half of the heat sink with the base thermally insulated .This will be akin to the studies undertaken by all authors mentioned is literature survey.

Table: 01Geometric detail of heat sinks

Heat Sink	S/H Ratio	Fin Height	Fin Spacing	Base plate Width	Base plate Length L (mm)	Fin Thickness t_f (mm)	Base plate Thickness t_b (mm)	No. of Fins n
1	0.25	32	8	52	40	4	8	5
2	0.25	64	16	104	80	8	16	5

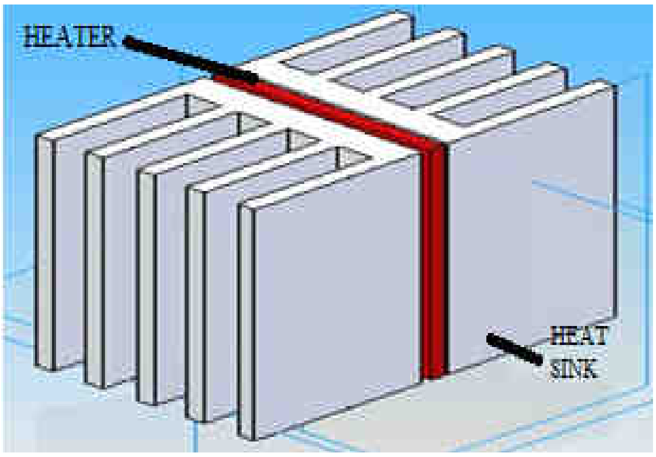


Fig: 01Two geometrically similar heat sinkssand witching heating-coil

Fig: 02 Experimental Setup

IV. EXPERIMENTAL SET-UP AND INSTRUMENTATION

The experimental set-up primarily consists of various instruments for measuring the ambient temperature, base-plate temperature and the power input for the heater all fixed in a console as explained below. The electrical power was supplied through a regulated AC supply. The output of supply was fed to variable transformers or autotransformer so that, the power inputs could be varied as desired.The voltage across the heater coil and the current passing through it are indicated by the digital voltmeter and ammeter. The digital voltmeter with a scale 0-200Volts indicates the voltage values with a 4-digit display and accuracy of one decimal place. The digital ammeter with a scale 0-5 Amps indicates the current values with a 4-digit display and accuracy of three decimal places. The temperature indicator used in the temperature measurements has 4-digit display and accuracy of one decimal place. Heating coils made for the Heat sink consists of a Nichrome wire wound around a thin mica plate and mica sheets on both sides of mica plate for insulation. They are rated for 330 W-230 V, AC and 75 W-230V, AC.

The base-plate temperatures of fin arrays were measured at four points by thermocouples. Four thermocouples T_{C1} ,$T_{C2,}$ $T_{C3,}$ $T_{C4}$are fixed tightly with screws and nuts at the drilled-hole locations. The ambient temperature was measured using thermocouple (T_{AMB}).All the thermocouples were calibrated against the temperature of the water measured using a mercury-in-glass thermometer.

V. EXPERIMENTAL METHODOLOGY

In order to be able to determine the convective heat transfer performance of the finned heat sink under steady-state conditions the following procedure was followed. The method used for determining the heat transfer coefficient is to supply a known heat input to the heater coil and measure the temperature attained by the heat sink. Before undertaking the experiments an uncertainty analysis was performed to determine the effect of each of the parameters involved on the uncertainty in the heat transfer co-efficient values. The steps given below were followed

1. A.C. power is supplied to the heater coil from mains through a stabilizer and UPS which, in turn, is connected to an auto-transformer.
2. The voltage V and current I are set at the required values and the temperature readings of the all the thermocouples T_{C1} ,$T_{C2,}$ $T_{C3,}$ T_{C4}andT_{Amb} the thermometer reading are noted.

It should be noted that in the formulae only one half of the heat sink geometry is considered.

$$Q=\frac{V*I}{2} \quad (1)$$

$$T_{Avg}=\frac{Tc_1+Tc_2+Tc_3+Tc_4}{4} \quad (2)$$

$$\Delta T = T_{Avg} - T_{Amb} \quad (3)$$

$$h_{BA}=\frac{Q}{A_{BA}*\Delta T} \quad (4)$$

$$h_{TA}=\frac{Q_{input}}{A_{TA}*\Delta T} \quad (5)$$

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Where,

Q = Heat input by the heater coil (W).

V = Voltmeter reading (V).

I = Ammeter reading (A).

Tc_1, Tc_2, Tc_3 Tc_4 =Temperature readings of thermocouples (°C).

T_{Amb} = Ambient temperature measured by the thermocouple (°C)

T_{Avg} = Average temperature of heat sink as obtained by the digital temperature indicator (°C).

h_{BA} = Heat transfer coefficient calculated based on base area of the heat sink (W/m^2°C).

h_{TA} = Heat transfer coefficient calculated based on Total area of the heat sink (W/m^2°C).

A_{BA} = Base plate area (with fins) available for heat transfer (m^2).

A_{BA} = (L * W) (3.6)

A_{TA} = Total area of heat sink available for heat transfer (m^2).

A_{TA} = L*W + 2n*H (L + t_f) + 2t_b (L + W) (3.7)

Where,

L = Length of the base (m).

W = Width of the base (m).

H = Height of the fin (m).

t_b= Thickness of the base (m).

t_f= Thickness of the fin (m).

n = Number of fins.

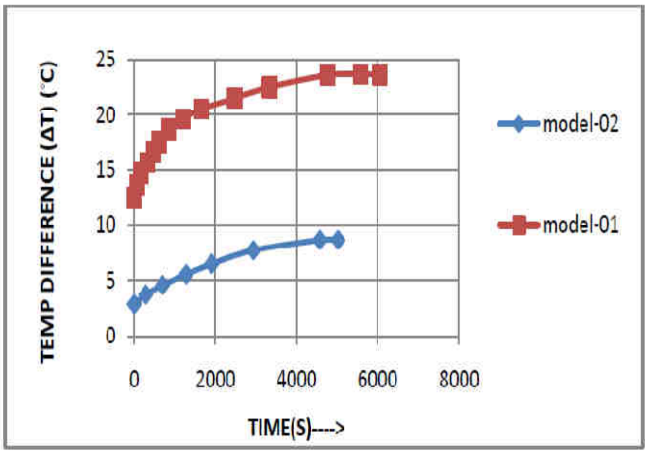
VI. EXPERIMENTAL RESULTS AND DISCUSSION

Results of Heat Sinks with S/H ratio 0.25

In this section first the results are presented for finned heat sink-1 and heat sink -2 with S/H ratio 0.25 in open air with fins in Vertical Orientation in open air in the way of comparison.

Fig.03 Photograph Heat Sink model-2 with S/H =0.25 in open air with fins in Vertical Orientation

Experiments conducted in the present work are summarized as follows. All the results presented in this work are for Heat sinks with fins in vertical orientation.



Graph 01: shows a typical time v/s Temperature difference for Heat Sink-1 and Heat Sink-2 with S/H =0.25, Q=5 watts

Non Dimensional plots - Rayleigh number v/s Nusselt number

Rayleigh numbers (Ra) and Nusselt number (Nu) are calculated using the relations given below. The Fin Height H has been used for length scale in both Rayleigh number and Nusselt number as it has been thought to be appropriate dimension.

$$Gr = \frac{g\beta H^3 \Delta T}{\nu^2} \quad (1)$$

$$Ra = Gr\,Pr \quad (2)$$

$$N_u = \frac{hH}{k} \quad (3)$$

Where,

Gr = Grashof number

Pr = Prandtl number

H = Fin Height (m).

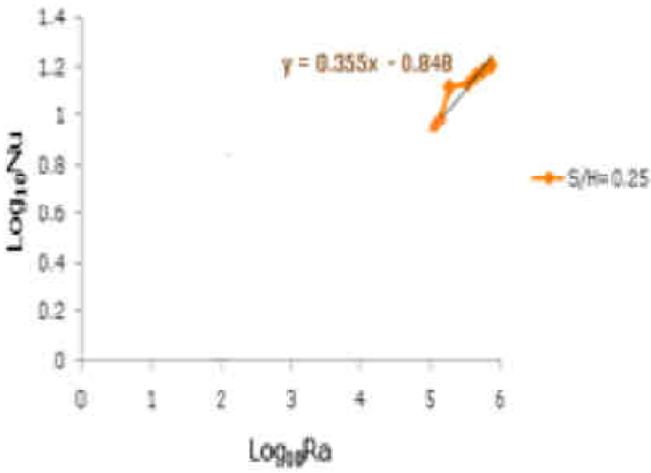
ΔT = Temperature difference (°C).

k = Thermal conductivity of air (W/mK).

ν = Kinematic viscosity of air (m^2/s).

h = Heat transfer coefficient (W/m^{2}K).

T_f= Film temperature= $\frac{T_{avg} + T_{\infty}}{2}$ (K)



TOTAL AREA

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

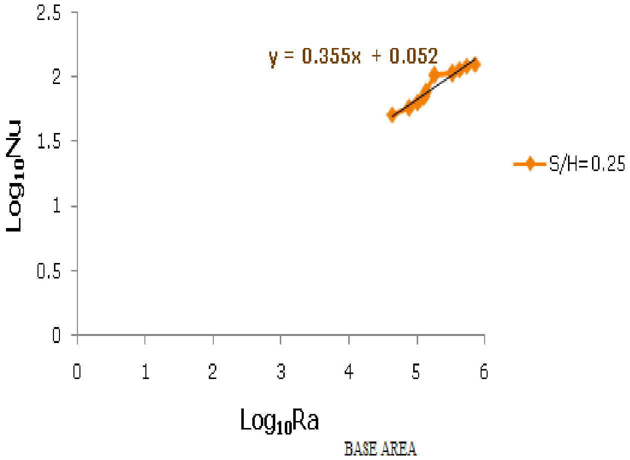


Fig.04 Nusselt number based on Total area and base area plotted against Rayleigh number for both Heat sinks with S/H =0.25

VII. SUMMARY AND CONCLUSIONS

Experiments have been conducted for heat sinks with base and fins vertically oriented on the two different models which are geometrically similar to establish relation between heat sink temperature and corresponding heat inputs and associated heat transfer coefficient values. Variation of Nusselt number with Rayleigh number has been obtained in the form of logarithmic plots. A few conclusions drawn from the present work are as follows:

1. Heat transfer coefficient h_{BA}values are the highest for Q=30 W. This is true for the both cases, namely, Heat sink model-1 and Heat Sink model-2.
2. Heat transfer coefficient h_{TA}values are the highest for Q=30 Watts. This is true for the both cases, namely, Heat Sink-1 and Heat Sink-2.
3. From the experimental results it could be seen that the heat transfer coefficient values are the higher in case of Heat Sink-1 when compared to Heat Sink-2.
4. It is interesting to note that in non-dimensional form using Nusselt number and Rayleigh number based on fin height H, the results fall into a single curve for all S/H ratios. This is true for Nusselt number based on both h_{TA} and h_{BA}.
5. The co relation developed is also important for determining the size of the heat sink for different heat loads.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.