

ENHANCEMENT OF HEAT TRANSFER FROM PLATE FIN HEAT SINKS

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Abstract

Heat Sinks are an extremely useful component used to lower the maximum temperature of various electronic devices during operation so as to increase their thermal efficiency and performance. Fins constitute an important and integral component of sinks. It is a passive cooling technique. Plate fin heat sinks are used in varied applications owing to its low manufacturing cost, ease of manufacture and its economical way to dissipate unwanted heat. Steady state natural convection is experimentally investigated for 03 sets of vertically mounted fin heat sinks. Aluminum is used because of its high conductivity. Length and fin thickness is kept constant at 200 mm and 05 mm respectively. Fin height is successively increased as 10mm, 30mm, 50mm. Aspect Ratio for above three sets is thus 0.05, 0.15 and 0.25 respectively. Effect of varying height, heat input and aspect ratio, keeping length constant is investigated on heat transfer through the sinks.

Keywords: Heat Sinks, Fins, Natural Convection, Aspect Ratio.

ABBREVIATIONS AND SYMBOLS

h	- Convection heat transfer coefficient, W/ (m ² K)
A	- Area, m ²
Nu	-Nusselt number
Gr	-Grashof number
S	- Fin spacing
H	-Fin height, mm
N	- Number of fins
L	- Fin length, mm
W	- Fin width, mm
T	- Fin thickness, mm
Sopt	- Optimum fin spacing, mm
Ra	- Rayleigh number
Qin	- Power supplied to heater base plate, W
Qc	- Total convection heat transfer rate from fins, W
T _{avg}	- Average base plate temperature, °C
T _{amb}	- Ambient temperature, °C
T	- Temperature, °C
ΔT	- Base-to-ambient temperature difference, °C
T _f	- Film temperature, °C
k	- Thermal conductivity, W/ (m K)
g	- Gravitational acceleration, m/s ²
β	- Volumetric thermal expansion coefficient, 1/K
σ	- Stefan-Boltzmann constant, W/ (m ² K ⁴)
ν	- Kinematic viscosity, m ² /s
α	- Thermal diffusivity, m ² /s
ε	- Emissivity
Set A	- (L=200mm, H=10mm)
Set B	- (L=200mm, H=30mm)
Set C	- (L=200mm, H=50mm)

1. INTRODUCTION

Heat sink is an object that absorbs and dissipates heat from another object by thermal contact. Heat sinks find use in wide range of applications, providing efficient heat dissipation. Some applications include cooling of electronic devices, lasers, heat engines and refrigeration. Thermal energy transfer between two objects rapidly brings first object into thermal equilibrium with second lowering temperature of first object thus accomplishing heat sinks role as a cooling device. If temperature limits exceed a certain value in above applications it may even lead to total system failure. Therefore different methods are used by engineering systems so as to minimize this overheating problem as much as possible. Fins form one of the easiest and cheapest ways to dissipate this heat. Owing to low production costs and high effectiveness, rectangular fins are the most popular fin type. Vertical orientation of fins is widely used from a combination of horizontal and vertical orientation as it is highly effective. Heat dissipation from fins to surroundings takes place by two modes convection and radiation. As aluminium is used for fins, it has low emissivity value hence radiation heat transfer value is low. So convection heat transfer is dominant mode of heat transfer from fins. Heat transfer coefficient and surface area of fins are two important parameters on which rate of heat dissipation depends. Fluid can be forced to flow over fins by fans and in this manner heat transfer coefficient 'h' can be increased. But it is costly and requires more volume to include fan. Surface area can be increased by addition of more fins. But distance between adjacent fins reduces due to addition of more fins. This may result in offering resistance to air flow thereby reducing heat transfer coefficient.

2. EXPERIMENTATION

Main components include channel, concrete block, base plate, fin array, plate heater and power mains. Aerated concrete block 250x200x100 mm, is fixed on frame which ensures one dimensional heat dissipation. A removable acrylic sheet is placed on front surface to replace fin arrays. Base thickness of arrays is kept as 05mm. The heater consists of nichrome wire wound around thin mica plate and mica sheet. Rating of heater plate is 250W and 230 V, AC. 05 mm depth is provided on aerated concrete block to include heater plate. Extruded surface is kept over fin array for fitting to aerated concrete block. Concrete block has in-built 04 bolts to tighten fin array over heater plate. Thus air gap between fin array and heater plate is considered to be negligible. A concrete block has high insulation quality and temperature resistance. ($K \approx 0.15 \text{ W/m k}$).

Table -1: Set-up Dimensions

Sr.No	Component	Dimensions(mm)
1	Frame Channel	550x550x550
2	Heater	180x200x5
3	Concrete	250x200x100

Fin configurations are produced on D.R.O milling. The fin arrays are produced from rectangular bars with dimensions 180x200x60 mm. Fins are integral with base plate of thickness 05mm and fin thickness is kept constant at 05mm.



Fig -1: Experimental Set-up



Fig -2: Fin Arrays

The fin array specifications are given in the following table

Table 2: Fin Specifications

Sr. No.	Fin Length (mm)	Fin Width (mm)	Fin Thickness (mm)	Fin Height (mm)
1	200	180	05	10
2	200	180	05	30
3	200	180	05	50

3. EQUATIONS

(1) Heat Loss by Convection, Q_c :

$$Q_c = (\text{heater input}) - (\text{heat loss by radiation, } Q_r)$$

$$Q_c = h A \Delta T.$$

$$Q_r = \epsilon \sigma A_t (T_{\text{avg}}^4 - T_{\text{amb}}^4)$$

(2). Average Heat Transfer Coefficient.

$$h_{\text{avg}} = Q_c / (A \Delta T)$$

(3) Mean Film Temperature:

$$T_f = (T_{\text{avg}} + T_{\text{amb}}) / 2$$

(4) Experimental Nusselt Number:

$$Nu_{\text{exp}} = (h_{\text{avg}} L) / K$$

$$Ra = \{g \beta L^3 (T_{\text{avg}} - T_{\text{amb}})\} / (\alpha \nu).$$

4. EXPERIMENTAL PROCEDURE

Heat inputs can be adjusted by a dimmer stat. The temperature of heat sink at different locations and ambient temperatures are recorded at time interval of 30 minutes till steady state is reached. Generally it takes around 02 hrs to attain steady state condition. Temperature variation of around 0.5°C is taken for steady state approximation. Six thermocouples are used. Five of them are attached to the base and one is kept suspended inside the channel to record ambient temperature.

Parameters used for study are as follows:

Heat Input (Qin) : 20W, 40W, 60W, 80W, 100W
 Base Temperature : T₁, T₂, T₃, T₄, T₅
 Ambient Temperature : T₆

5. EMPIRICAL CORRELATIONS

Empirical relations are used to validate the vertical orientation model. Following correlations are considered:

(1) Mc Adam's correlation:

$$Nu = 0.59 \times Ra^{0.25}$$

(2) Churchill and Chu's first correlation:

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

(3) Churchill and Chu's Second correlation:

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

(4) Churchill and Usagi's correlation:

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

6. RESULT ANALYSIS

6.1 Variation of Nusselt Number with Different Power Input

Figure 3 shows variation of Nusselt No. With different power input for arrays. Figure shows experimental Nusselt Number with that of calculated from various existing Equations. Value of Nu number from experimentation is close to that of from existing equations. Three sets are plotted for 10, 30, 50 mm height and length of 200mm.

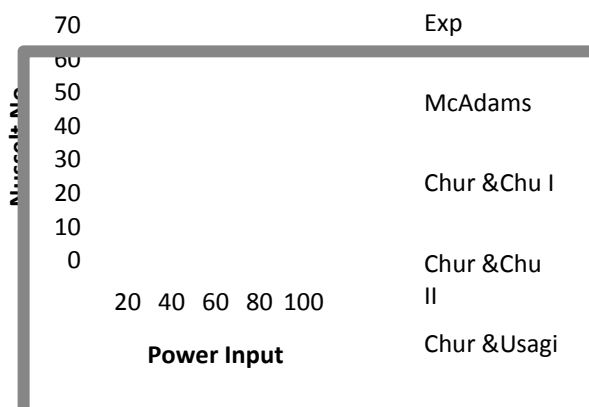


Chart -1: Nusselt Vs Input Power Set A

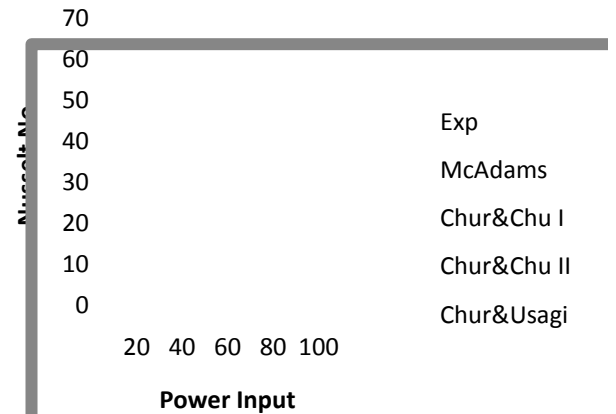


Chart -2: Nusselt Vs Input Power Set B

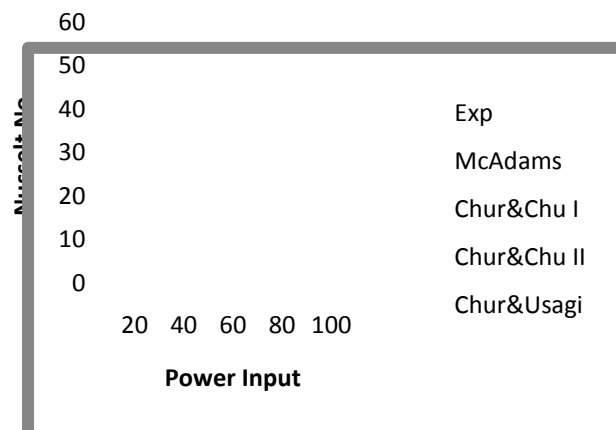


Chart -3: Nusselt Vs Input Power Set C

6.2 Variation of Convective Heat Transfer with Different Power Input for Different Fin arrays

Figure 4 shows variation of convective heat transfer with different power input for various fin arrays. As power input increases 'h' increases for all arrays. Convective heat transfer 'h' is more for arrays with small height when length and input power is constant.

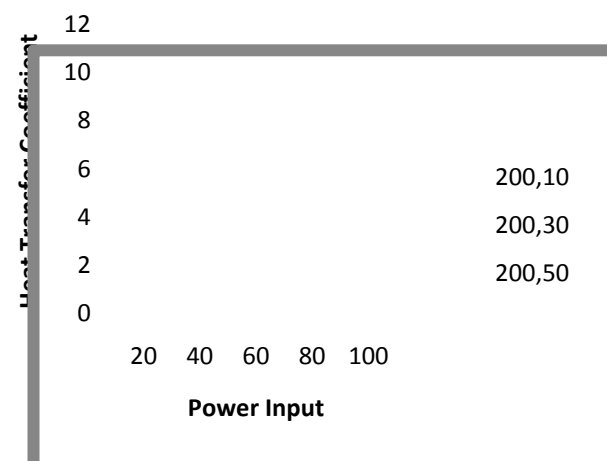


Chart -4: Heat Coefficient Vs Input Power

6.3 Variation of Convective Heat Transfer Rate with Fin Height for Different Power Input

Convective heat transfer rate from fin arrays increases with an increase in fin height. As fin height increases total heat dissipation area also increases. Convective heat transfer rate is directly related to surface area in contact with air

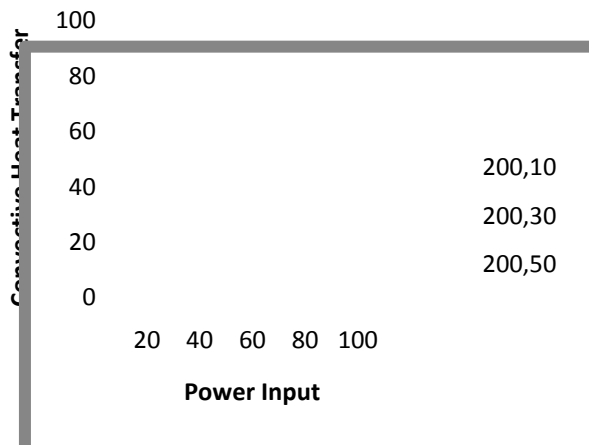


Chart -5: Convective Heat Transfer Vs Input Power

7. CONCLUSION

- Natural convective heat transfer depends on fin height.
- Convective heat transfer rate from fins increases with an increase in height of fin arrays.
- Experimental Nusselt Number is quite close to the value obtained from correlation
- With an increase in heat input and temperature difference, natural convective heat transfer also increases.
- With an increase in heat input, heat transfer by radiation mode also correspondingly increases.
- Convective heat transfer increases with aspect ratio for given power input.

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BIOGRAPHY



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