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Analysis of Heat Transfer From Horizontal Rectangular (Square Notched) Fin Arrays by Natural Convection

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Abstract: **Experimentation carried out as mentioned in this paper predicts the flow of air over the fin array and the heat transfer due to natural convection. Fin array is modeled using Pro/E and material used is aluminum. Nine rectangular fins are used and placed over a heat source. We consider three different heat inputs while keeping all other parameters constant. Experimentation is done for fin array without notches and with notches while keeping the end fins without notches. Notches with square cross section are used for experimentation. Variation in notch cross section is provided by reducing the notch area by 10%, 20% and 30% respectively..**

Keywords: **Natural Convection, Fins, Notches, Heat Transfer Coefficient**

1. Introduction

When available surface is found inadequate to transfer required quantity of heat with available temperature gradient, fins are used rate of heat dissipation from a fin configuration by convection heat transfer depends on the heat transfer coefficient and the surface area of the fins. The surface area of the fins can also be increased by adding more fins to the base material in order to increase the total heat transfer from the fins. But the number of the fins should be optimized because it should be noted that adding more fins also decreases the distance between the adjacent fins. Using fins is one of the cheapest and easiest ways to dissipate unwanted heat and it has been commonly used for many engineering applications successfully. Fins are used to enhance convective heat transfer in a wide range of engineering applications, and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. Other applications include Internal Combustion Engine cooling, such as fins in a car radiator. It is important to predict the temperature distribution within the fin in order to choose the configuration that offers maximum effectiveness. Natural convection heat transfer is often increased by provision of fins on horizontal or vertical surfaces in many electronic applications, motors and transformers. The current trend in the electronic industry is miniaturization, making the overheating problem more acute due to the reduction in surface area available for heat dissipation.

2. Ease of Use

Rectangular fins are the most popular fin type because of their low production costs and high effectiveness. Configuration of all fins protruding from their bases is popular because they offer economical and trouble free solution to the problem. Natural convection heat transfer is augmented by provision of fins on horizontal or vertical surfaces in many electrical and electronic appliances. Because of reduction in surface area available for heat dissipation and low heat transfer coefficient optimization of fin geometry becomes very important in natural convection heat transfer. Now a days in electronic industries microminiaturization of electronic packages are in trend. The thermal design problem is recognized as one of the factors limiting achievement of higher packaging densities. Natural convection occurs due to temperature difference which produces the density difference. Generally in natural convection heat transfer on horizontal fin array, we observe a chimney flow pattern which creates a stagnant zone near the central bottom portion of fin channel. This stagnant zone created becomes less effective or sometimes ineffective for heat transfer, because no air stream passes over this region. To optimize the fin geometry some portion of this stagnant zone is removed in various shapes and sizes and its effect on other parameters are studied in this investigation. Some of the material from that central portion is removed, and is added at the place where greater fresh air comes in the contact of the fin surface, it would increase overall heat transfer coefficient ‘h’. In present study the fin flats are modified by removing the central fin portion. Hence it can be studied with various modes of heat transfer. [3][4]

3. Heat Transfer

Heat transfer describes the exchange of thermal energy, between physical systems depending on the temperature and pressure, by dissipating heat. The fundamental modes of heat transfer are conduction or diffusion, convection and radiation.

A. Conduction

Conduction is the transfer of heat by direct contact of particles of matter. The transfer of energy could be primarily by elastic impact as in fluids or by free electron diffusion as predominant in metals or phonon vibration as predominant in insulators. In other words, heat is transferred by conduction when adjacent atoms vibrate against one another, or as electrons move from one atom to another. Conduction is greater in solids, where a network of relatively fixed special relationships between atoms helps to transfer energy between them by vibration.

B. Convection

Convection is the transfer of thermal energy by the movement of molecules from one part of the material to another. As the fluid motion increases, so does the convective heat transfer. The presence of bulk motion of the fluid enhances the heat transfer between the solid surface and the fluid.

The rate of convective heat transfer is given by:

$$q = hA(T_S - T_0)$$

where, q-Heat flux, W/m^2

h- Heat transfer coefficient, W/m^{2}K

A - Cross-sectional area, m^2

T_S - Surface temperature, K

T_0- Ambient temperature, K

There are two types of convective heat transfer:

- Natural Convection
- Forced Convection

C. Radiation

Radiation is the transfer of heat energy through empty space. All objects with a temperature above absolute zero radiate energy at a rate equal to their emissivity multiplied by the rate at which energy would radiate from them if they were a black body. No medium is necessary for radiation to occur, for it is transferred through electromagnetic waves; radiation works even in and through a perfect vacuum. The energy from the Sun travels through the vacuum of space before warming the earth.[8-10]

4.OBJECTIVE

From the literature survey it is observed that different researcher used different types of fin shapes, different types of notches in the fin and analyzed the effect of different parameters like length, height, spacing on heat transfer coefficient. But all of them use the material for fin as aluminum. Hence I planned to use the same material of fin i.e. aluminum is used as a fin material for the experimental work. A low feed rate will produce a large overcut and conversely a high feed rate will reduce the amount of overcut.[1-5]

5. EXPERIMENTAL SETUP

The dimensions of the fin for experimental work are length 70 mm by 40 mm and thickness of 1.1 mm. Spacing between fins is 9 mm. The length, height and spacing are fixed. The shape of the notch is a square. The aim is to compare the effect of heat transfer coefficient for notch and without fins. Number of fins is taken as 9.

The setup also consists of a base plate with dimensions of 101 mm by 70 mm. The fins are joined to base plate by brazing operation. The spacing between the fins is 9 mm. Thermocouples are used for temperature measurement. A heater coil is used for heating the base plate.

The plate is fixed using an insulating material to avoid heat losses from either sides of the plate. The whole assembly is placed in a wooden block for natural convection. Different heat inputs are given to the plate and we note down the temperature at the fins and plate. The experimental set up is shown belowin Figure 1.

Figure 1: Experimental setup

From Figure 1 we see the arrangement of the setup with the fin array at the left enclosed in box made out of wood so as to avoid external winddisturbances. The enclosure also helps in developing a pure natural convectiontransfer through the set of fins by isolating the experimental and the measuring devices at the center. Heat is supplied by using dimmer stat by turning the knob on the control panel at the right.

Temperatures at each odd fin were noted for three readings each and then the average temperature at each odd fin was calculated by varying the input voltagethat is at 40W, 60W and 80W.

6. OBSERVATIONS

Observations for heat supply of 40 W are tabulated below in Table 1

Table 1: Observation table for average temperature at each odd fin for with and without notch at 40W

Fin	1	3	5	7	9
Avg Temp (Plain Fin) °C	44.2	43.7	44.3	43.9	43.5
Avg Temp (10% reduction) °C	45.7	45.7	46.5	45.8	45.5
Avg Temp (20% reduction) °C	47.4	47.5	47.8	47.5	47.2
Avg Temp (30% reduction) °C	47.2	47.5	48.1	47.7	47.1

Similarly average temperatures for heat input of 60W and 80W were noted down for both with and without notch with variation in notch by reducing it by 10%, 20% and 30% of the cross-sectional area of the rectangular fin.

7. Calculations

Sample calculation for calculating '*h*'for without notch and for notch with 10% reduction where Q = 40W

Exposed area of fin array (A_e),

1. Without notch fin array,

Area for convective heat transfer for one fin,

= (Nominal height x Length x 2) + (Nominal height x Thickness x 2) + (Length x Thickness)

= (0.04 X 0.07 X 2) + (0.04 X 0.0011 X 2) + (0.07 X0.0011)

= 0.005765 m²

Total exposed area A_e

= (Area for one fin x No. of fins) + (Spacing between fins x Length of no. of fin channel)

= (0.005765 X 9) + (9 X 0.072)

= 0.699885 m²

Heat loss by convection is given by,

$Q_{Convection} = h A x \Delta T$

$h_{avg} = Q_{Convection} / A x \Delta T$

= 40/(0.699885 x 17.76)

= 3.21 W/m² k

2. Fin with notch having 10% reduction:

Where Area 'A' = **0.62989665 m²**

Heat loss by convection is given by,

$Q_{convection} = h A x \Delta T$

$h_{avg} = Q_{convection} / A x \Delta T$

= 40/ 0.62989665 x (319.4-300.2)

=3.30 W/m² k

8. Results

Using the observed average temperatures of the fins for both plain and notched fins and using the calculations shown above, the heat transfer coefficient *'h'* was calculated for heat inputs of 40 W, 60 W and 80 W. The calculated results are tabulated below in Table 2

Table 2: Results table for heat transfer coefficient for with and without notch

Q(W)	h for without notchedfin (W/ m²k)	h for 10% notchedfin (W/ m²k)	h for 20% notchedfin (W/ m²k)	h for 30% notchedfin(W/ m²k)
40	3.21	3.30	4.1	4.83
60	3.89	3.99	4.4	5.03
80	4.70	4.90	4.9	5.30

A plot of heat input vs. heat transfer coefficient was plotted using the values tabulated in Table 2 with heat input on the X-axis and heat transfer coefficient on the Y-axis for the case where in there is notch with 10% area reduction and plain fin(no notch). The plot is shown below in Figure 2

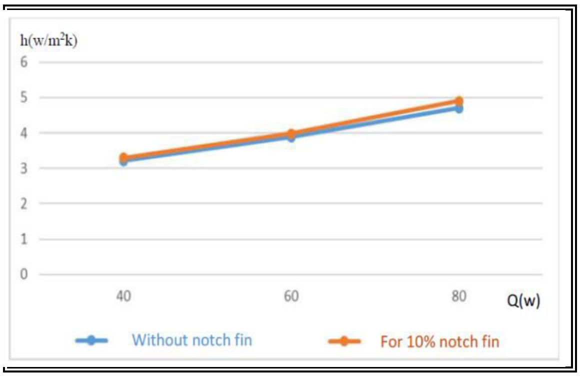

Figure 2: Plot of *Q* vs *h* for without notch and notch with 10% reduction

Similarly a plot of heat input vs. heat transfer coefficient was plotted using the values tabulated in Table 2 with heat input on the X-axis and heat transfer coefficient on the Y-axis for the case where in there is notch with 20% and 30% area reduction and plain fin(no notch). The plot is shown below in Figure 3 and Figure 4 respectively.

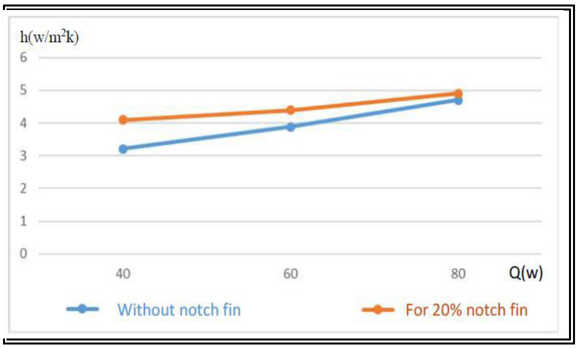

Figure 3: Plot of *Q* vs *h* for without notch and notch with 20% reduction

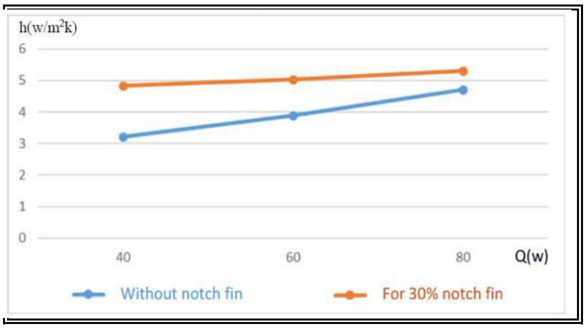

Figure 4: Plot of *Q* vs *h* for without notch and notch with 30% reduction

9. Conclusion

As observed from Table 2 and Figures 2 – 4,the total heat flux as well as the Heat transfer coefficient increases as the notch depth increases. This can be interpreted as below:-

As area removed from the fin is compensated at the air entry ends of the fin it provides chance to get greater amount of fresh cold air (getting sucked into the array through single chimney pattern) to come in contact with hot fin surface. As the air moves inwards along chimney profile, it gets heated and temperature difference between the fin and entering air decreases.

10. Future Plans in the Research

Comparing the above experimental results using Computational fluid dynammics. Using the analytical resuls, the experminental results can be verified to be true.

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