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# Analysis of Notched Fin Array dissipating heat by Convection Mode

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**ABSTRACT**

The purpose of this analysis is to study the effect of the combination of rectangular and triangular notch in the center bottom of the fin on natural convective heat transfer. In the horizontal fin arrangement (L/H~5) [1], it is observed that due to the decrease in air density, the air entering from both ends is heated and rises towards the center of the fin duct. Therefore, a stagnant zone is created in the bottom center of the channel of the fin array, which does not contribute much to heat dissipation [1]. In this experimental study, material was removed from this stagnant region in the form of a rectangular and triangular notch at the bottom center of the fin, and material was added at the top to reshape it for analysis. Fin weight remains the same. Three types of fin assemblies, 0%, 20% and 40% notched fin assemblies were analyzed. Compare the result with the heat transfer coefficient of the Nusselt number. and notch effect. For this analysis, the heat input is varied from 20 W to 100 W in 20 W steps. The analysis runs until steady state is reached. It can be observed that the heat transfer coefficient of the notched fins is increased by 20% and 40% respectively compared to the non-notched fins.

**Keyword:** Fin Array, Natural Convection, Triangular Notch, Notched Fin Array, Single Chimney Flow

## INTRODUCTION

Today's demand for smaller devices reduces the surface area available for heat transfer and increases the risk of overheating problems. Therefore, optimization of heat transfer area and fin shape is very important.

## NEED OF INVESTIGATION

Generally, in natural convection heat transfer with vertical fin array on horizontal fin base, it is observed that single chimney flow pattern as shown in fig. 1 is observed. In single chimney flow pattern, there is sideway entry of the air in case of natural convection cooling of fin array. The air coming inwards gets heated as it moves towards the center of the fin and this heated air it rises up due to decrease in density.

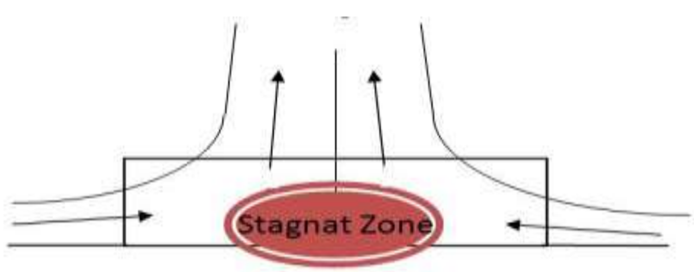


**Fig. 1: Single Chimney Flow Pattern**

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So, the central portion of the fin becomes ineffective because hot air-stream passes over that part and therefore it does not bring about large heat transfer through that portion. To optimize the fin geometry some portion of this stagnant zone is removed in various shapes and sizes and its effect on other parameters arestudied in this investigation.

**A. Area Compensation Method:**

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. The area from the stagnant zone is removed in the form of notch and added at fin top to modify its geometry for enhancement of heat transfer. This is called Area compensation [14].

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. This area of fin near its central bottom portion thus becomes relatively less useful for heat transfer. Now when this area is removed and added at a place where it is more useful for heat transfer, the heat transfer increases and so that the convective heat transfer coefficient can increase.

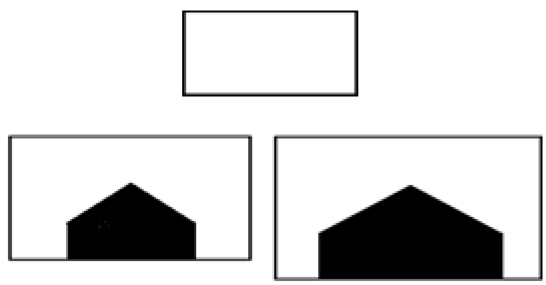

**Fig. 2: Area Compensation Method with combination of Rectangular and Triangular Notch**

In this investigation, the fin flats were modified by removing the central fin portion by cutting a notch of combined shapes and adding it at the top of fin surfaces, where it may be more effective and thereby keeping fin surface area same with height increases. Experimental analysis is done for three types of arrays mainly Fin array without Notch, Fin with 20 % (notch) area removed and compensated, Fin with 40 % (notch) area removed and compensated.

**EXPERIMENTATION ANALYSIS**

Size of Fin Arrays:
Three types of fin arrays were used for analysis. The size of each finis given in below. Size of baseplate = 110 mm x 175 mm,

Fin spacing, S = 11 mm,
Number of fins in an array = 7,
Thickness of fin and baseplate, t = 1.5 mm. Size ofeach fin is shown below.

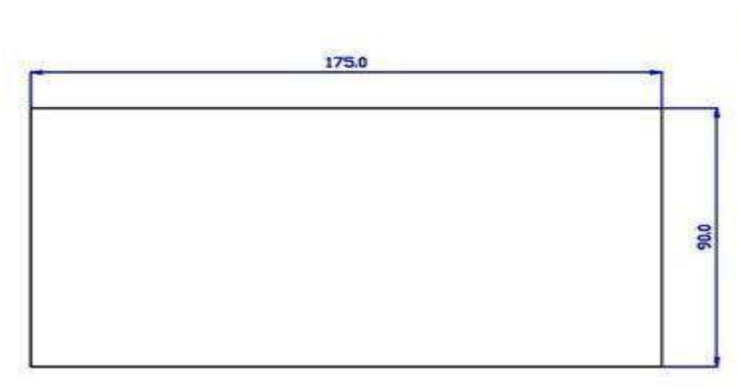


**Fig. 3: Fin without Notch**

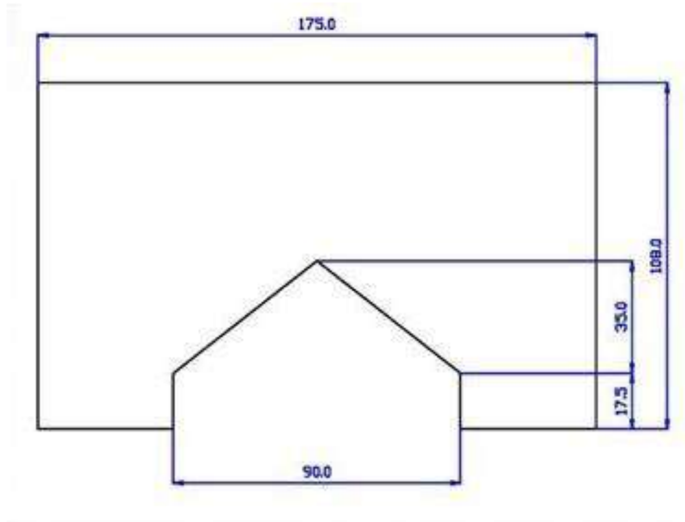


**Fig 4. Fin with 20 % Notch**

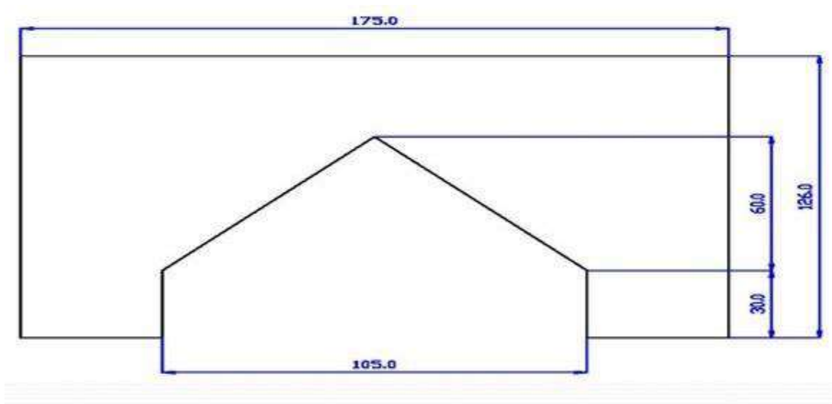


**Fig 5. Fin with 40 % Notch**

**Material Selection:**

The material used for fins is aluminum. Thermal conductivity of aluminum is 225 W/mK and melting and boiling point of aluminum are 658˚C and 2057˚C.

**Experimentation:**

Figure 6 shows the schematic representation of experimental set-up. The fin array consists of 7 fins fixed to the base plate by using aluminum welding operation. Heating coil was placed in the base portion of the fin array. The heating coil was fixed in an insulating box. An array was placed on insulating box to minimize heat loss by conduction through base of the fin array and this assembly was kept in acrylic box to achieve natural convection.

Calibrated thermocouples (k-Type) with temperature indicator were used to measure temperatures at variouslocations of fin array. Voltmeter and ammeter were connected to measure heater input. Temperature indicator, voltmeter, ammeter and rheostat are provided on control panel. Experiments were performed and at steady state conditions readings wererecorded. Heat input used are 20 w, 40 w, 60 w, 80 w,100 W.

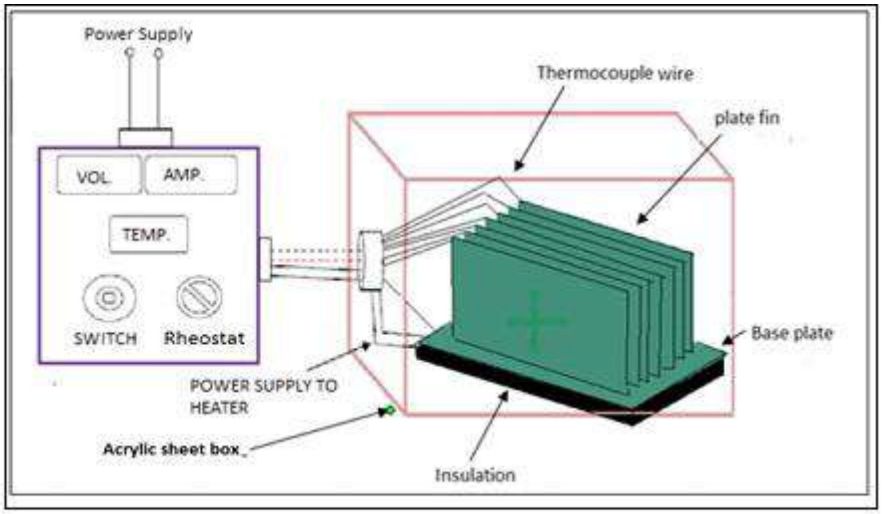


**Fig. 6: Schematic Representation of Experimental Setup**

**Fig. 7: Actual Experimental Setup**

**Experimentation Procedure:**

Fin array without notch was placed on heater plate which is placed on insulating box. Around fin array acrylic box was placed. Heat input of 20W was given to heater and allowed to reach steady state. Under steady state conditions, the temperatures of baseplate and tip of each fin were recorded. The power supply to the heater was increased by 20W and the apparatus was allowed to reach the steady state. This procedure was repeated until a heater input reached to 100W. Then fin array is replaced and same procedure is followed for 20% and 40% notch fin arrays.

## PROCEDURE FOR CALCULATION

The formulae that are used for calculating heat transfer coefficientare taken from book, "Heat Transfer'' by J. P. Holman

### *A.* To find average temperature of fins (Tf )

$$Tf = \frac{T_1+T_2+T_3+T_4+T_5+T_6+T_7}{7}$$

Where, T1, T2, T3, T4, T5, T6 and T7 are the temperatures of tip of finsin ° C.

### *B.* To Find Temperature of Whole Body (Tbody)

$$Tbody = \frac{T_f+T_b}{2}$$

Where, Tb are the temperatures of base plate in °C

### *C.* To Find Temperature Difference Between Body (Tbody ) & Surrounding Temperature (Tsurr)

$$\delta T = ( Tbody - Tsurr ) °C$$

### *D.* To find mean film temperature (Tm)

1) $Tm = \frac{T_{body}+T_{surr}}{2}$ °C
2) From this temperature find out following propertiesof fluid
3) $\upsilon$ = kinematic viscosity of the fluid, $m^2/s$
4) Pr = Prandtl number
5) k = thermal conductivity of fluid, W/mk

### *E.* To find coefficient of volume expansion (β) $\beta = \frac{1}{T_m+273}\ k^{-1}$

### *F.* To find Grashof number (Gr)

$$Gr = \frac{g\beta\delta T\, L_c^3}{\upsilon^2}$$

Where,
Lc= height of the fin, m

### *G.* To find Rayleigh number (Ra)

Ra = Gr*Pr
If $10^4 < Gr*Pr < 10^9$, then, $Nu = 0.59\,(Gr*Pr)^{1/4}$
If $10^9 < Gr*Pr < 10^{12}$, then, $Nu = 0.59\,(Gr*Pr)^{1/3}$

### *H.* To find heat transfer coefficient (h)

$$Nu = \frac{hL_c}{k}$$

Where, h is heat transfer coefficient, $W/m^2k$ Using theseformulae h is calculated.

## RESULT AND DISCUSSION

After performing calculations, results were tabulated and a comparison was made, also graphs are obtained, which clearly shows effect of notch made in this way with this dimension on heat transfercoefficient.

### *A.* Variation of Heat Transfer Coefficient (H):

From graph it can beobserved that with increase in heat input, heat transfer coefficient (h) also increases for all types of fin arrays whether it is notched or without notch fin array which pattern matches with the pattern of all researchers. Heat transfer coefficient for notched fin is less than without notch fin.

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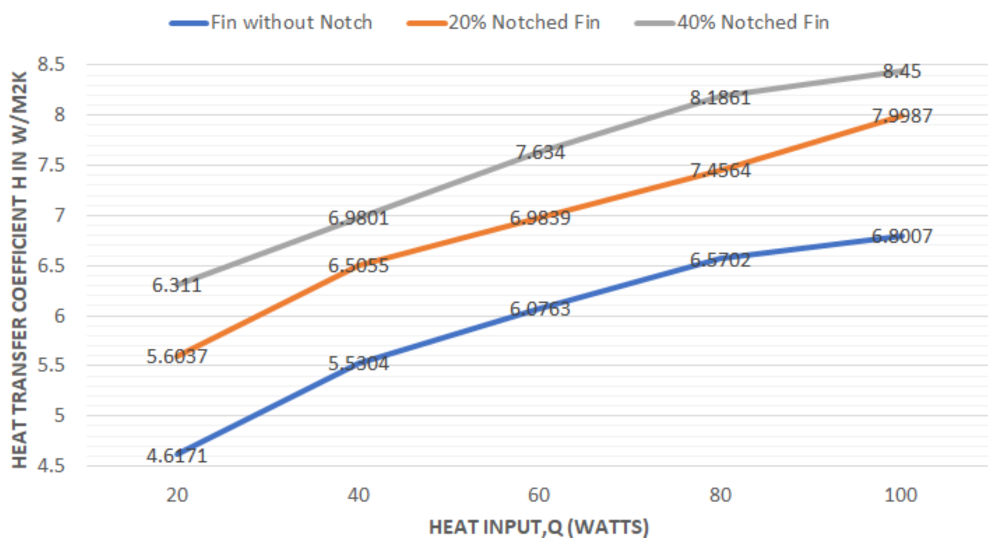


**Fig. 1: Variation of H with Heat Input for Different Fin Arrays**

### *B.* Variation of Nusselt Number (Nu):

Nusselt no. is directly proportional to heat transfer coefficient and height of fin. As heat input increases heat transfer coefficient (h) increases, so Nusselt no. also increases as shown in figure. Also, for 20% notch and 40% notch fin due to addition of compensating material on top sides their height increases than fin without notch, so Nusselt no. increases for 20% notch and 40% notch than fin without notch.

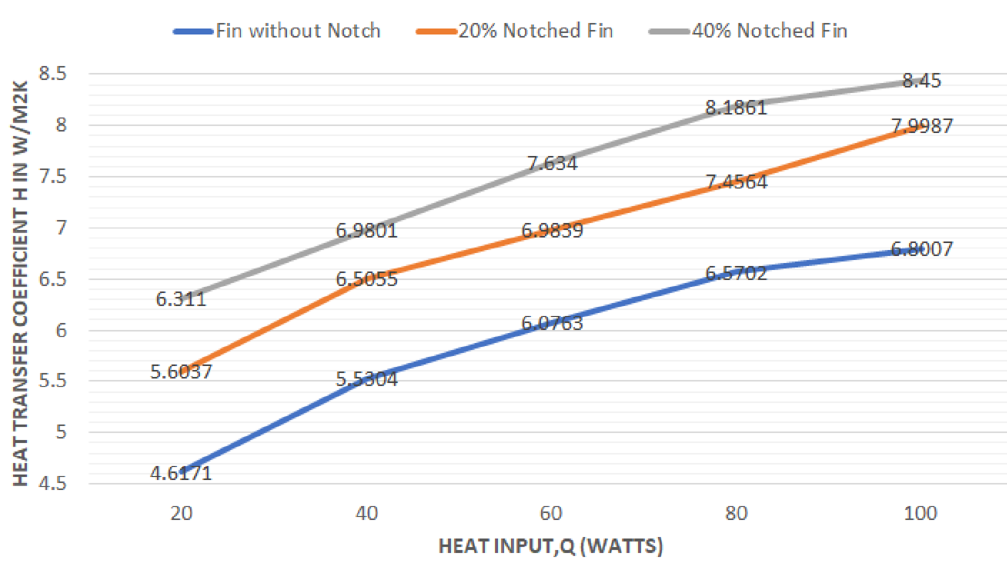


**Fig. 2: Variation of Nu with Heat Input for Different Fin Arrays**

### *C.* Effect of Notch on Heat Transfer Coefficient (H):

Graph 3 shows effect of notch on heat transfer coefficient (h). As shown in graph h of fin without notch is lower than fin with notch and h goes on increasing with increase in area removed though it is compensated by adding on top. So, h is higher for 20% and further increases for 40% notch fin array. So, making notch in this way is effective method.

At 20-watt heat input there is approximately 7% increment in heat transfer coefficient for 20% notch fin over fin without notch and approximately 4% increment on further heat inputs. At 20-watt heat input there is approximately 10% increment in heat transfercoefficient for 40% notch fin over fin without notch and approximately 4% increment on further heat inputs.

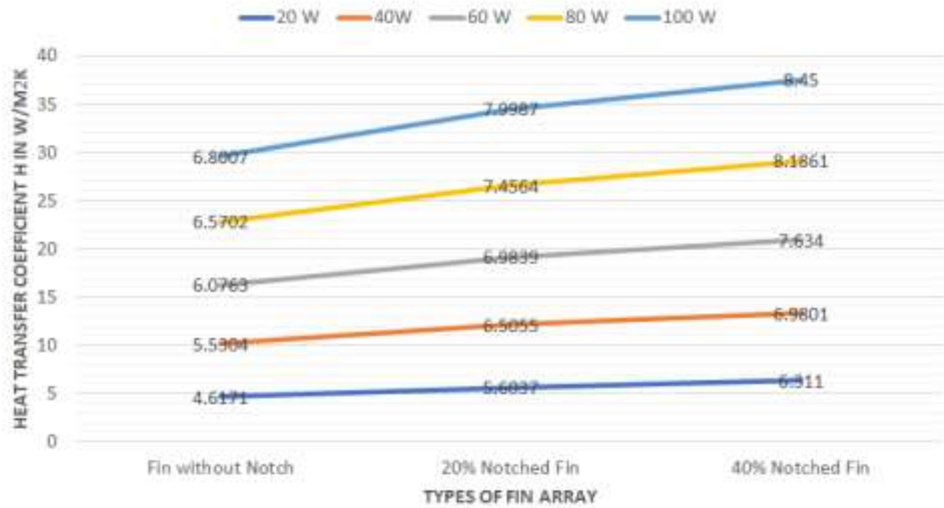


**Fig. 3: Effect of Notch on Heat Transfer Coefficient (H)**

### *D.* Justification for the Error:

The experimental and computational analysis results are in close agreement. It is found that there is small error between both the results. This may be due to small error in measurement of temperature by thermocouple, or measurement of power by ammeter, and voltmeter. Also, it may be possible that there is small change in place from where temperatures of tip of fins are taken in experimentation and in computational analysis though it is very close to tip, so because of this temperature recorded by experimentation aremore than computational analysis and giving more values of heat transfer coefficient.

Fins of array are attached to baseplate by gas welding. It is very difficult to weld on both sides also with small spacing, so welding is done on one side of fin and that also with non-uniform thickness. This may be cause of error in experimentation also.

## CONCLUSION

Experimental and computational analysis is done three types of arrays mainly fin array Fin without Notch, FIN with 20 % (notch) area removed and compensated, FIN with 40% (notch) area removed and compensated. Area compensation method was used by removing material from center in the form of triangular notch and adding at top of fins. The conclusions drawn from this study are given below.

1) Heat transfer coefficient is higher in notched fin array compared to without notch fin array.
2) There is approximately 7 % increment in heat transfer coefficient for 20 % notch fin over fin without notch. There is approximately 10 % increment in heat transfer coefficient for 40 % notch fin over fin without notch. Means with increase in notch area heat transfer coefficient goes on increasing. So, making notch in this way is an effective method for increasing heat transfer.
3) With increase in heat input, heat transfer coefficient (h) also increases for all types of fin arrays whether it notched or without notch fin array which pattern matcheswith the pattern of all researchers.

Nusselt number increases with increases with increase in heatinput as well as increases in notch area.

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