# Analysis of Natural Convective Heat Transfer From Cylinder Having Rectangular Notched Fins

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***Abstract---*To investigate the heat transfer coefficient of fin with different notch size for the given fin spacing using free convection heat transfer from the cylinder having longitudinal rectangular fin array. Longitudinal rectangular fin array with aluminium fin and aluminium cylinder to hold the fins is constructed. Fins with different rectangular notch size are used. The aim of this experiment is to determine the optimum notch size to maximize heat transfer by natural convection at different heat inputs.**

***Keywords -- Fins; Rectangular; Cylinder; notch.***

## I. INTRODUCTION

Fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. Increasing the convection heat transfer coefficient or increasing the surface area of the object increases the heat transfer. Sometimes it is not feasible or economical to change the first two options. Thus, adding a fin to an object increases the surface area and can sometimes be an economical solution to heat transfer problems

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 some experiments. 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'. [15] Hence it can be studied with various modes of heat transfer. Since heat transfer by convection depends on fluid flow, so we change the fluid flow by providing a notch. [5] By variation of heat input we can analyze the optimum notch size of fins for maximum heat transfer and natural convection air flow pattern around cylinder. Following is the diagram which shows the fin having notch by compensating area and without compensating area. [12]

In natural convection, fluid motion is caused by natural means such as buoyancy due to density variations resulting from temperature distribution. [4] Dr.M.K. Sinha determines of the optimum values of the design parameters in a cylindrical heat sink with branched fins. Investigations on the effect of the design parameters, such as the number of fins, length of fin, height of fin, and the outer diameter of the heat sink on heat transfer. [2]

Vijay Kumar experimental study deals with natural convection through vertical cylinder .The experimental set up is designed and used to study the natural convection phenomenon from vertical cylinder in terms of average heat transfer coefficient. Also practical local heat transfer coefficient along the length of cylinder is determined experimentally and is compared with theoretical value obtained by using appropriate governing equations [4] Shivdas S. Kharche Studied the natural convection heat transfer from vertical rectangular fin arrays with and without notch at the center have been investigated experimentally and theoretically. Moreover notches of different geometrical shapes have also been analyzed for the purpose of comparison and optimization.[13]

## II. PROJECT APPROACH

### *A. Objective of Project*

The main aim of the project is to perform experiment to investigate optimum notch size of the of fin having maximum heat transfer as well as to analyze convection air flow pattern over geometry by varying the heat input. For the purpose we had taken different notch sizes of fins having fix fin spacing using free convection heat transfer from the cylinder having longitudinal rectangular fin array. Longitudinal rectangular fin array with aluminium fin and aluminium cylinder is constructed. Fins with different rectangular notch size as 10%, 20%, 30% are used. We are varying the heat input as 40 watt, 70 watt and 90 watt. Also we are adding smoke to observe variation of flow pattern cause by variation of notch size at different heat input.

### *B. Outcome of Work*

Three methods are adopted as software analysis, mathematical analysis and experimental performance. Finally we calculate convective heat transfer coefficient, Nusselt no., Rayleigh no., heat flux, temperature gradient for all longitudinal rectangular notch fins taken of 3mm thickness by using software analysis, mathematical analysis and experimental performance. Then we compare the optimum notch size of fins by drawing graphs. Parametric models of cylinder with fins have been developed using Catia v5 to predict the steady thermal behavior.

### *C. Specifications of Apparatus*

- Longitudinal Rectangular fin of size (L x W x t) = (30 x 67 x 3) In mm


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- No. of fin: 24., Thickness of fins: 3mm., Angle between fins: 15°.
- Modification in Geometry of longitudinal rectangular fins: Fins without notch, Fins with 10% of notch without compensation of area and with compensation of area of fin., Fins with 20% of notch without compensation of area and with compensation of area of fin., Fins with 30% of notch without compensation of area and with compensation of area of fin.
- Heat inputs: 40 Watt, 70 Watt, 90 Watt.

*D. Steps Involved in the Project*

Solid modeling, Mathematical modeling of rectangular fin, Steady thermal analysis by Ansys, Interpretation of air flow pattern from cylindrical fin array, Experimental validation by apparatus, Comparison of result for optimum fin configuration by graphs.

*E. Load Applied*

The loads applied on Selected inside area 40 Watt, 70 Watt and 90Watt. Ambient Temperature 303 K. The given loads are applied on meshed models of aluminum. Now we calculate thermal gradient, heat flux and convective heat transfer coefficient for all notched fins configuration taken of 3 mm thickness by using Ansys software.

## III. MATHEMATICAL MODEL

*A. Experimental calculation of the Nusselt number*

After all of the flow properties are known Ra and Nu can be found as follows, the net power input to heater is given as [4]

$$Q_{in} = V \times I = h_{avg} A \Delta T \quad (1)$$

Where,

A= Area exposed for heat transfer

$\Delta T$ = Temperature difference

According to Newton's law of cooling we get the value of convective heat transfer coefficient: [4]

$$h = \frac{Q_c}{A_s x (T_w - T_a)} \quad (2)$$

By the standard formula of Nusselt no. can be calculated as follows: [4]

$$Nu = \frac{h x L_c}{k} \quad (3)$$

Where,

$L_c$ is the characteristic length.

*B. Theoretical calculation of Nusselt number using following correlations:*

Following are the theoretical correlation by which we can calculate the Nusselt no. and convective heat transfer coefficient to validate the result obtained by software analysis and experimental analysis [5][6] The Rayleigh no can be calculated by the following formula: [5][6]

$$Ra = \frac{g x \beta x L_c^3 x (T_w - T_a)}{\upsilon x \alpha} \quad (4)$$

Where,

$\beta$ = Thermal expansion coefficient

$$\beta = \frac{1}{T_{mf}} K^{-1} \quad (5)$$

$$T_{mf} = \frac{(T_w - T_\infty)}{2} \quad (6)$$

For Rayleigh number is in the range then we can find the Nusselt number and convective heat transfer coefficient theoretically,

$$10^4 < Ra < 10^9 \quad (7)$$

- Mc Adam's correlation: [5][6]

$$Nu = 0.59 x Ra^{0.25} \quad (8)$$

- Churchill and Chu's first correlation:[5][6]

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

- Churchill and Chu's Second correlation: [5][6]

$$Nu = 0.68 + \frac{0.67xRa^{0.25}}{\left[1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right]^{\frac{4}{9}}} \quad (10)$$

- Churchill and Usagi's correlation:[5][6]

$$Nu = \frac{0.67xRa^{0.25}}{\left[1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right]^{\frac{4}{9}}} \quad (11)$$


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## IV. EXPERIMENTAL SET UP

### *A. Description of experimental set up*

Our experimental set up consists of cylinder placed on the concrete block. We use 4 types of fins, without notch, 10% notch, 20% notch, 30% notch. Dimensions of fins used for our experiment are as follows, we used 24 longitudinal rectangular fins array connected to cylinder of specified dimensions. With the help of heater we provide heat the inner surface of cylinder. K- Type thermocouple wires are used to measure the temperature of the fins. Heater is connected through wattmeter and dimmer stat to mains. Dimmer stat is used to give desired input to the heater. We had selected a room with no fans and windows or any other ventilation to avoid forced convection.

### *B. Apparatus required*

Wattmeter, Dimmer stat, Thermocouple, Temperature indicator, Concrete block, Four side walls.

### *C. Overview of experimental set up*

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) :40W, 70W,90 W and Base Temperature : T1, T2, T3, T4, T5,T6

### *D. Experimental Procedure*

- Connect the dimmer stat, wattmeter to the heater.
- Connect the probes of digital temperature indicator at different locations on the base of cylinder and on the fins as per requirement.
- Wait until the temperature indicated by digital temperature indicator becomes steady. It took us 3- 4 hours to reach steady state.
- Once the steady state is reached, note down the temperatures at required locations Now conduct the same procedure for different set of fins at different voltages. In our case we will conduct experiment for 40 W, 70 W and 90 W heat input. with un-notched fins, 10%, 20%, 30% notched fin.

## V. THREE DIMENSIONAL MODELLING

### *A. Three dimensional model of cylinders having rectangular longitudinal notch fin without compensation of area and with compensation of area*

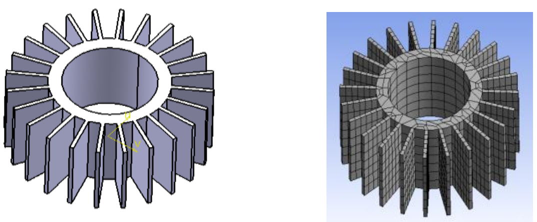

Fig. 1. Cylinders having rectangular longitudinal fin (a) without notch (b) its mesh geometry

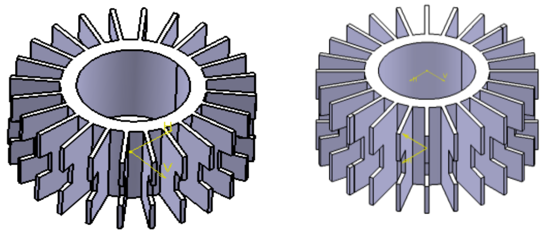

Fig. 2. Cylinders having rectangular longitudinal fin with 10% of notch a) without compensation of area b) with compensation of area.

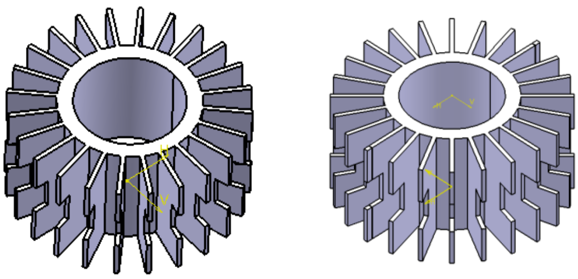

Fig.3. Cylinders having rectangular longitudinal fin with 20% of notch a) without compensation of area b) with compensation of area.

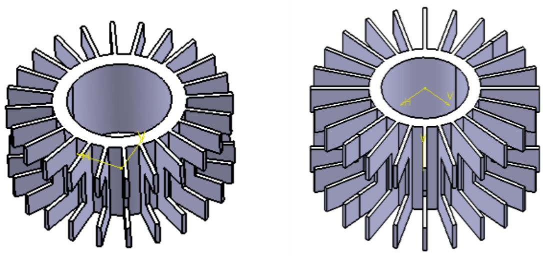

Fig. 4. Cylinders having rectangular longitudinal fin with 30% of notch a) without compensation of area b) with compensation of area.

## VI. EXPERIMENTAL RESULT AND VALIDATION

### *A) Result obtained by software analysis and Mathematical correlation for 70watt heat input*

Table I. Result for heat flux

| Notch variation | 40 watt | 70 watt | 90 watt |
|---|---|---|---|
| Without | 4889.00 | 8668.00 | 11228.00 |
| 10% | 5462.00 | 9558.50 | 12289.00 |
| 20% | 6691.60 | 11710.00 | 15056.00 |
| 30% | 7143.90 | 12502.00 | 16074.00 |

As we vary the heat input from 40 watt to 90 watt it is found that the heat flux is increasing. From readings it is also analyze that by increasing percentage notch heat flux will increase.


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Table II. Result for convective heat transfer coefficients

| Notch variation | 'h' By Software | 1 rel$^n$ | 2 rel$^n$ | 3 rel$^n$ | 4 rel$^n$ |
|---|---|---|---|---|---|
| Without | 78 | 108 | 99 | 106 | 94 |
| 10% | 80 | 110 | 100 | 107 | 96 |
| 20% | 92 | 112 | 101 | 109 | 9 |
| 30% | 89 | 114 | 103 | 110 | 99 |

From readings it is also analyze that by increasing percentage notch convective heat transfer coefficient will increased

Table III. Result for Nusselt no. by experimental calculation.

| Notch variation | 'Nu' by Software | 1 rel$^n$ | 2 rel$^n$ | 3 rel$^n$ | 4 rel$^n$ |
|---|---|---|---|---|---|
| Without | 4.6 | 6.4 | 5.8 | 5.6 | 6.3 |
| 10% | 4.7 | 6.5 | 5.9 | 5. | 6.4 |
| 20% | 5.4 | 6.6 | 6.4 | 5.8 | 6.4 |
| 30% | 5.3 | 6.7 | 6.1 | 5.9 | 6.5 |

From readings it is also analyze that by increasing percentage notch Nusselt number will increase.

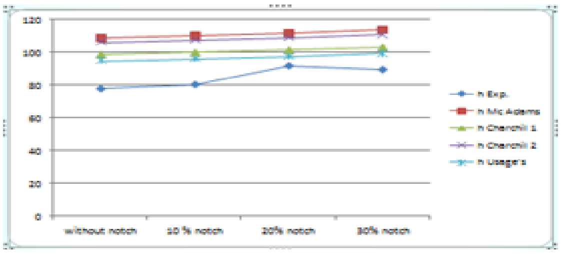

Fig. 5. Graph of convective heat transfer coefficient VS Percentage notch size

*B) Graphical analysis of results for 70watt heat input*

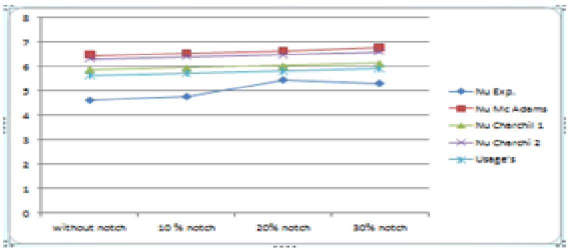

Fig. 8. Graph of Nusselt number VS Percentage notch size

## VII. CONCLUSION

By performing experiment it is observe that convective heat transfer coefficient and Nusselt no. is increased comparing to without notch fins. As we taken the two methods to provide the notch i.e compensation of area and without compensation of area. In first case without compensation of fin area though area of fin will decrease still heat transfer increase and in second case with compensation of fin area the unused central material of fin is exposed to fresh cold air again it is found heat transfer is increasing.

By changing of notch position on fin, geometry of notch position, thickness of fins, spacing between fins, material composition we can increase heat transfer.

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