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Natural Convective Heat Transfer from Inclined Narrow Plates

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Abstract: In many engineering situations, the equipment is placed at different geographical locations which are not accessible to regular maintenance and which requires cooling of the surfaces continuously and natural/free convection heat transfer process is preferred for this applications. Natural Convection is one of the major modes of heat transfer that can be classified in terms of being natural, forced, gravitational, granular, or thermomagnetic. In the past decade, several studies on convection heat transfer in much geometry, enhancement of heat transfer by adding narrow strip (fin), effects of the magnetic field in heat transfer, heat transfer in a porous medium have been reported. The effects of Prandtl (Pr), Reynolds (Re), Grashof (Gr), and Rayleigh numbers (Ra), fin length, fin height, fin spacing, and their orientation have also been investigated. This paper reviews various researchers work on fluid flow and heat transfer behavior which is carried out by means different types of fin attachments, their orientation & angle of inclination of the base plate.
Keywords: Natural Convection, Inclined Narrow Plates, Aluminum Material

I. INTRODUCTION

Natural convection occurs when the fluid circulates by virtue of the natural differences in densities of hot & cold fluid; the denser portion of the fluid moves downwards because of a greater force of gravity, as compared with the force on the less dense. Heat transfer by natural convection between a system and surrounding can be increased by using an extended thin strip of metal called fin. Fins are used where the available surface is found inadequate to transfer the required quantity of heat with the available temperature drop and where the heat transfer coefficient is low. The selection of fin depends on different parameters like geometrical shape, fin spacing, fin height, base thickness, kind of material, surface finish, etc. There are different fin geometries like a uniform straight fin, annular fin, splines, pin fin, etc. are used to increase the heat transfer rate from the surface. Fins orientation and geometry of fins array are the main parameters which affect the enhancement ratio of heat transfer.

II. EXPERIMENTAL METHOD

Here pin fin is selected for heat transfer enhancement. Following parameters were selected: Determination of the size of fin, selection of fin material, Design fin with respect to my project job, Collection of the raw material, Construction of fin array as required size and shapes, Construction of a fin box as equal to the box of heat laboratory and fin shown in Table. Then experimental set up was performed with a heater and a thermocouple in the box. And finally we have taken the experimental data by doing experiment in several times and calculate the effectiveness from the data.

Sr.no.	Particulars	Dimensions
1.	Width, w	70 mm
2.	Height, h	50 mm
3.	Thickness, t	5 mm
4.	No. of Fins	04
5.	Thermal conductivity (K)	205 W/mK

III. EXPERIMENTAL PROCEDURE

A. Switch on the power supply. Supply power first passes to the voltage regulator where we get supply voltage and then passes to the multi-meter to get the current. Finally, it passes to the heater and the heater becomes heated. The heater heated the base plate & heat is transferred to fins.

B. Sufficient time is allowed to reach the base plate at a steady state before noting the temperatures.

C. Measure the atmospheric temperature of air & collect the air properties data required for the calculation of the heat transfer coefficient from the heat transfer data book.

D. Adjust the fins to 60° inclination by tightening or turning the screws. Silicon grease is used to fill the gaps between fin & base plate.

E. Once the steady state has been reached, note down the temperature of the base plate as well as fins by using thermocouples & readings will display on temperature detector.

F. Repeat the same procedure for the fin inclination of 45°.

IV. MATERIALS SELECTION

At first aluminum metal were selected for fin array & plate box. Then a voltage regulator was used for measuring voltage. K-type thermocouple was used to measure the temperature. Heater was used for heating purpose. Acrylic resins and Rubber were selected for heat insulating purposes. Ammeter was used for current measuring through the heater. Selection of aluminum plate fix the fin box and wooden plate for fix the setup.

V. GOVERNING EQUATION

A. Area Of Base Plate

$A_b = L \times W - 4(t \times w)$

Where, L- length of the base plate

W- Width of the base plate

t- Thickness of fin

w- Width of fin

B. Area of Fin

$A_f = [2 \times w \times h + w \times t] \times \text{no. of fins}$

Where, h – Height of fin

t- Thickness of fin

w- Width of fin

C. Efficiency of Fin

$\eta_{fin} = \frac{1}{ml}$; $m = \sqrt{\frac{hP}{kAcs}}$

Where, h – Heat Transfer coefficient

k- Thermal conductivity

P- Perimeter = [2(w+t)]

Acs- cross section area of fin = (w×t)

l- Length of fin

D. Grash off No

$Gr(s) = \frac{g \times \beta \times S^3 \times \cos(90-\theta) \times (Tb-Ta)}{\nu^2}$

Where, g – acceleration due to gravity

β- Dimensional parameter, $\beta = \frac{1}{tf+273}$

S- Characteristic length

Θ- Inclination of fins

Tb- Base plate temperature; Ta- Ambient Temperature

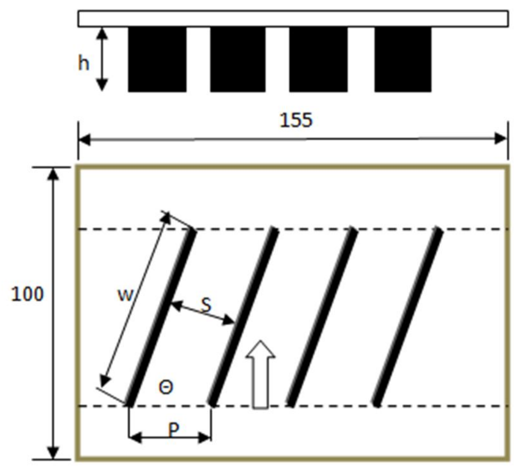
E. Nusselt No

$$Nu(s) = \frac{1}{24} Ra(s) \left(\frac{S}{w}\right) \{1 - e^{-\frac{12.5}{[Ra(s).\left(\frac{S}{w}\right)]^{0.75}}}\}$$

Where, Ra- Rayleigh No.
S- Characteristic length
w- Width of fin

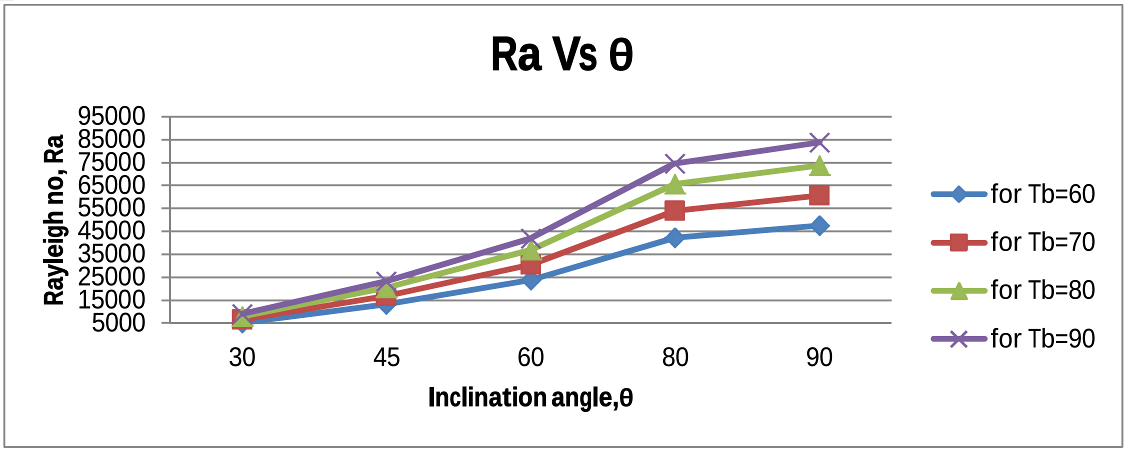
F. Heat Transfer Rate

$Q_{conv} = h\,(A_b + \eta_{fin}\,A_f) \times (Tb - Ta)$
Where, h – Heat transfer coefficient
Ab- Area of Baseplate
Af – Area of Fin
η_{fin} – Efficiency of fin



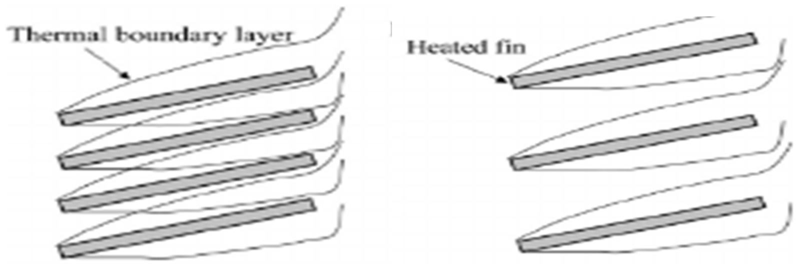
VI. RESULTS AND DISCUSSION

In the result and discusses heat transfer characteristics of inclined narrow plate under natural convection. It also discusses graphical relationship between heat transfer coefficients, convective heat transfer rate with respect to inclination angle.The experimentation is carried out to determine the effect of inclination angle (i.e. inclined fin) on the heat transfer performance. The fins are made inclined at an angle of 30˚, 45˚, 60˚, 80˚ & 90˚ (i.e vertical fin) respectively from horizontal plane. Power is given to the base plate with the help of electric heater ranging from 20 to 80 W so that the temperature of the base plate changed from 60˚C to 90˚C with the intervals of 10˚C each. The ambient temperature is maintained at 34˚C. For natural convection buoyancy related to the Rayleigh number drives flow. As the Rayleigh number becomes small, buoyancy becomes small to develop the thermal boundary layer.



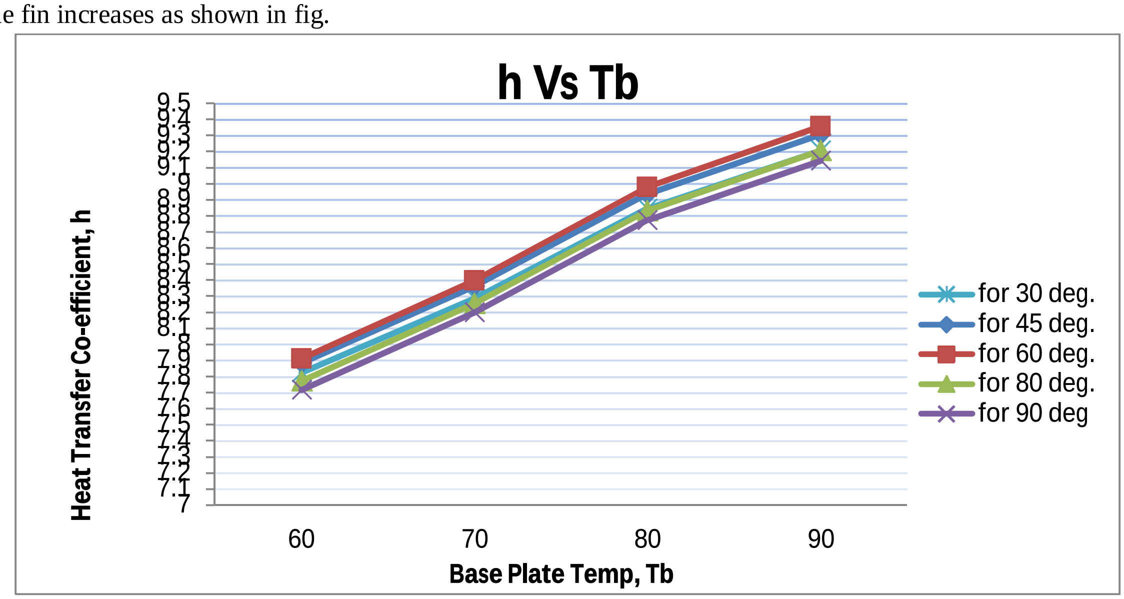
Effect of inclination angle on Rayleigh no.

Fig shows the experimental result of the effects of the different fin pitch varies at different inclination angle 30˚, 45˚, 60˚, 80˚ & 90˚ (i.e. vertical fin) respectively. At a different angle, the Rayleigh number is increasing. The Rayleigh number depends on GrPr for Natural Convection. The Rayleigh number is more when the inclination angle and base plate temp is increases. They also fig shows the temp of the base plate also increase the value of the Rayleigh number.



Interference of Thermal Boundary Layer

Fig shows the experimental result of the effects of the different fin pitch at a constant height of fins with different inclination angle 30˚, 45˚, 60˚, 80˚ & 90˚ (i.e. vertical fin) respectively. At the different fin pitch, the nusselt number decreases with a decreasing of Rayleigh number. GrPr for Natural Convection, buoyancy related to Rayleigh number drives flow. As Rayleigh number becomes small buoyancy becomes small to develop the boundary layer. Therefore the interference of the thermal boundary layer developing along with the fin increases as shown in fig.



Effect of inclination angle on heat transfer coefficient

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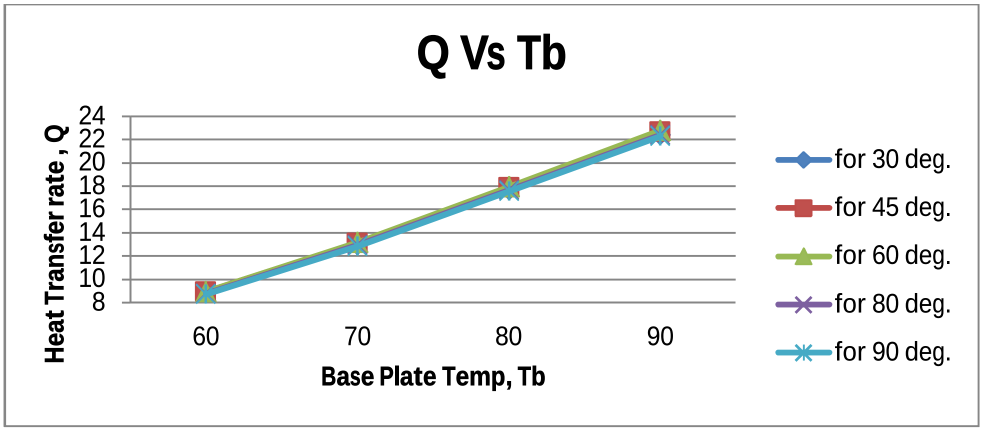
Fig shows the experimental result of the effects of the heat transfer coefficient with a constant height of fins with inclination angle 30˚, 45˚, 60˚, 80˚ & 90˚ (i.e. vertical fin) respectively. The heat transfer performance depends on the inclination angle and the constant temperature 90˚ as we can see in this figure the heat transfer coefficient 'h' rate increase as the angle increase from 30˚, 45˚, 60 at the constant temperature 90˚ then it is detouring the heat transfer coefficient 'h' with the angle are increases from 80˚ & 90˚ (i.e. vertical fin).



Effect of inclination angle on heat transfer rate

Fig. shows that experiential result of the effect of base plate increase the convective heat transfer increase as same as the different angle changes it means that

VII. CONCLUSION

The purpose of this work is to study the performance of inclined narrow plate under natural convection. The experimental study was conducted for vertical plated inclined fins & vertical plate with vertical fins. The parameters varied during the experimentation are base plate temperature & inclination angle of fins. As the inclination angle of fins changes, the fin spacing also changes according to the inclination angle. The experimental results are obtained can be summarized as below;

A. It has been observed that the experimental results shows enhancement of heat transfer coefficient is strongly dependent on the Rayleigh number & fin spacing.
B. The heat transfer performance improved until inclination angle reached to 60˚ and then began to deteriorate over an inclination angle of 60˚. Therefore for practical applications 60˚ inclination angle is best for better thermal performance.
C. The overall heat transfer coefficient is enhanced by 12 % at maximum temperature of base plate, Tb= 90˚C and θ = 60˚from horizontal plane.
D. The inclined finned surface had better heat transfer performance for a wide range of Rayleigh number than that of vertical finned surface.

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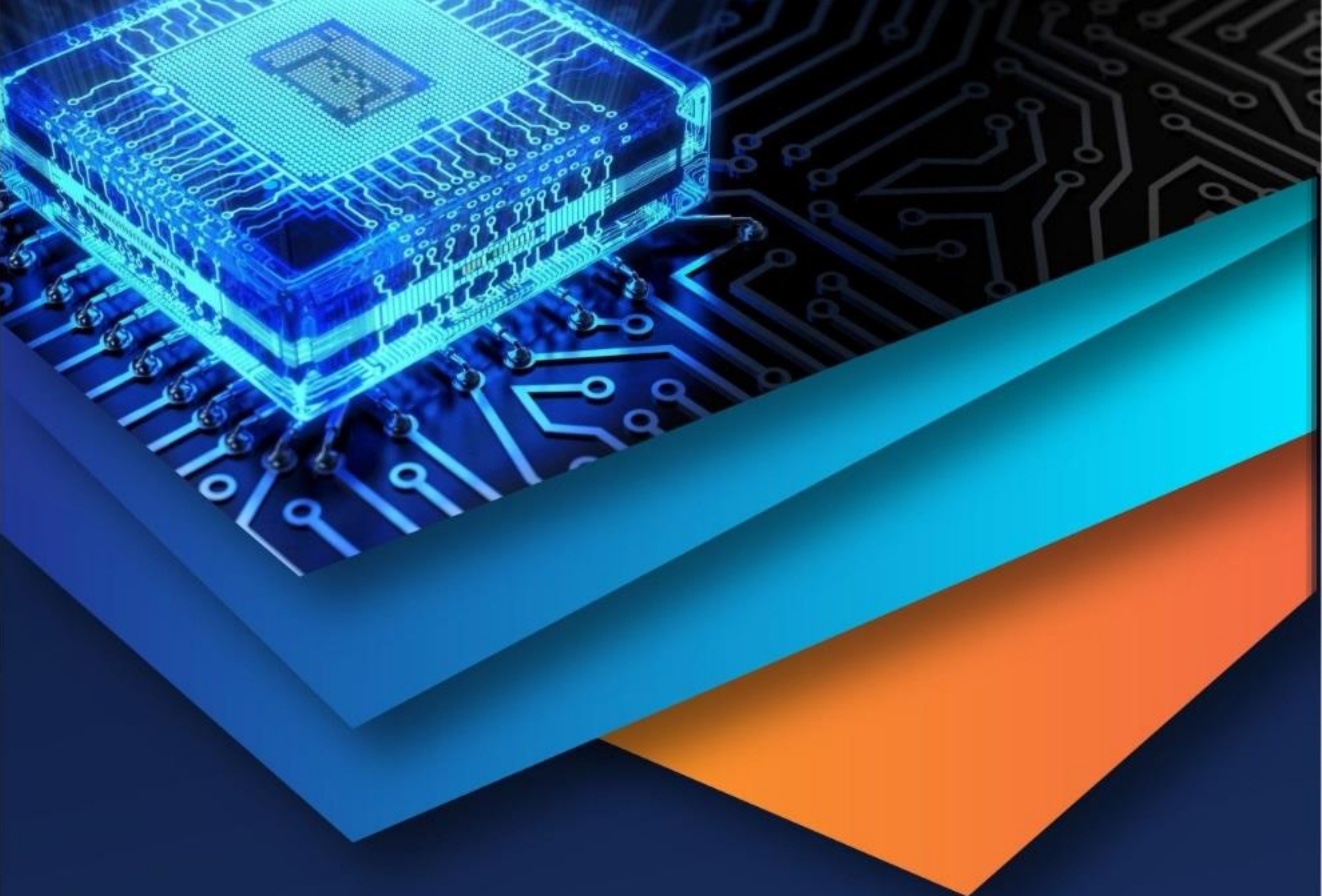

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