"EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER ENHANCEMENT FOR USING DIFFERENT ARRANGEMENT OF RECTANGULAR FIN"

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Abstract: In many engineering situations the equipment are 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 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 behaviour which is carried out by means different types of fin attachments, their orientation & angle of inclination of base plate

Nomenclature:-

g – acceleration due to gravity

β- Dimensional parameter

S- Characteristic length

Θ- Inclination of fins

Ra- Rayleigh No.

Pr- Prandlt No.

h – Heat transfer coefficient

Ab- Area of Base plate

Af – Area of Fin

w- Width of fin

1. Introduction

Natural convection occurs when the fluid circulates by virtue of the natural differences in densities of hot & cold fluid; denser portion of the fluid moves downwards because of 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 available surface is found inadequate to transfer the required quantity of heat with the available temperature drop and where 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 uniform straight fin, annular fin, splines, pin fin etc. are used to increase the heat transfer rate from surface. Fins orientation and geometry of fins array are the main parameters which affects the enhancement ratio of heat transfer. S. V. Kadbhane et al [1] developed an experimental set up to test 25 different fin arrays. Natural convective heat transfer from rectangular vertical fin array can be enhanced by optimizing the geometrical parameters such as fin length, width, height, and spacing. It was found that natural convective heat transfer rate first increases with increase in spacing upto certain limit, reaches to maximum at a certain value of spacing i.e. at an optimum value of spacing and then decreases with further increase in spacing, and For present study value of optimum fin spacing was found between 9mm to 11mm. Sk. Farooq et al [2] studied the variation of convective heat transfer coefficient and the base temperature of fins by positioning the fins at various angle of inclinations ranging from 35˚ to 90˚ to its base surface, and varying the thickness and height of fins by using Ansys16.0 Icepack tool. The study showed the considerable variation in heat transfer coefficients and base temperature of fins by varying inclination angles, height and thickness of fins. GanduSandeep et al [3] conducted an analysis of Natural convective heat transfer from flat plates inclined at an angle to the vertical in laminar flow regions. They analyzed fluid flow characteristics considering laminar flow under natural convection using CFD analysis. CFD analysis showed that, the pressures, velocity, Nusselt's Number are increasing with increase of inclination angles. So placing the plate with maximum inclination is better since the heat transfer rates are increasing. Dr. N.P. Salunke et al [4] investigated heat transfer coefficient enhancement in natural convection from horizontal rectangular fin arrays with perforations experimentally and numerically using ANSYS 14.0 so as to obtain the temperature distribution along the fin height and fin length. Experimental and numerical results for the temperature distribution showed a difference of 5-9%. M.Fujii [5] developed an enhancement technique for natural convection heat transfer from vertical heated plate with inclined fins & varied the inclination from 30˚ to 90˚. The result showed that convective heat transfer rate for the vertical heated plate with inclined fins at an inclination angle of 60˚ was found to be 19 % higher than that for a vertical heated plate with vertical fins. A.Sattyanarayana Reddy et al [6] investigated a free convection heat transfer from array of vertical tubes experimentally for different inclination angles. The experiment was carried out for Rayleigh no. (Ra) from 4.5×10^4 to 8.5×10^8. The local Rayleigh no. and Nusselt no. were estimated along the tube length. The result showed that for higher values of Rayleigh no & higher inclination angles the temperature differences from the tube to atmosphere air decreases. Ilker Tari, Mehdi Mehrtash [7] has studied using correlations plate-fin heat sinks in both horizontal and slightly inclined of the base plate from horizontal orientations to the inclination angles of ±60°, ±75°, +80°,±85°, ±90° from the vertical. S. V. Naidu et al. [8] has studied experimentally and theoretically to determine the effect of inclination of the base of the fin array on heat transfer rate and found a good agreement for different inclinations like 0˚, 30˚, 45˚, 60˚ and 90˚

2. Experimental set up & methodology:-

An aluminium plate of 155mm × 100mm × 5mm is taken as base plate. 4 holes are done on the base plate for screwing in the inclined fins. The inclination angle of the fins can be easily changed by tightening or turning the screws. The inclination angle 'θ' is measured from a horizontal plane. Silicon grease is used to fill the gap between fin & base plate to enhance the thermal contact conductance. The plate is then placed inside the duct for the experimentation. While performing experiments power input will be varying through dimmer stat. Power input is varied from 20 W to 80 W. After attaining steady state base plate temperatures is measured. The base plate temperature Tb, the ambient temperature Ta and the power input P to heater is recorded at steady state. The experimentation has been carried out at different fin inclination of 30˚, 45°, 60˚, 80˚ & 90˚. After all of the flow properties of air are known, Ra and Nu can be found as follows,

for inclined fins

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

for vertical fins

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

$$Nu(s) = \frac{0.67\times(Ra)^{\frac{1}{4}}}{[1+(\frac{0.492}{Pr})^{\frac{9}{16}}]^{\frac{4}{9}}}, \qquad Ra = Gr \times P$$

$$Q_{conv} = h\,(A_b + A_f) \times (Tb - Ta)$$

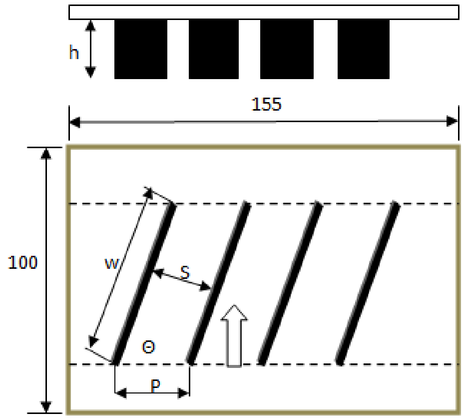

Fig: 2.1Schematic view of base plate

Fig: 2.2 Experimental Set up

3. Result & Discussion:-

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.

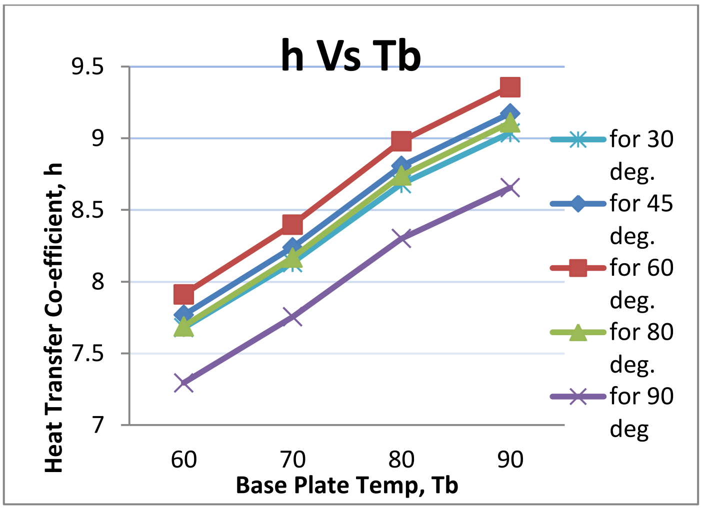

Fig.3.1: Effect of inclination angle on heat transfer coefficient

It is clear from the graph 3.1 that as the temperature of base plate increases, the heat transfer coefficient also increases. The above figure shows that with the increase in inclination angle, the heat transfer coefficient also increases up to 60˚ but beyond 60˚ inclination angle it tends to deteriorate. This means thermal performance at 80˚ & 90˚ is less than that at 60˚ inclination angle. Hence 60˚ inclination angle is better for heat transfer under natural convection.

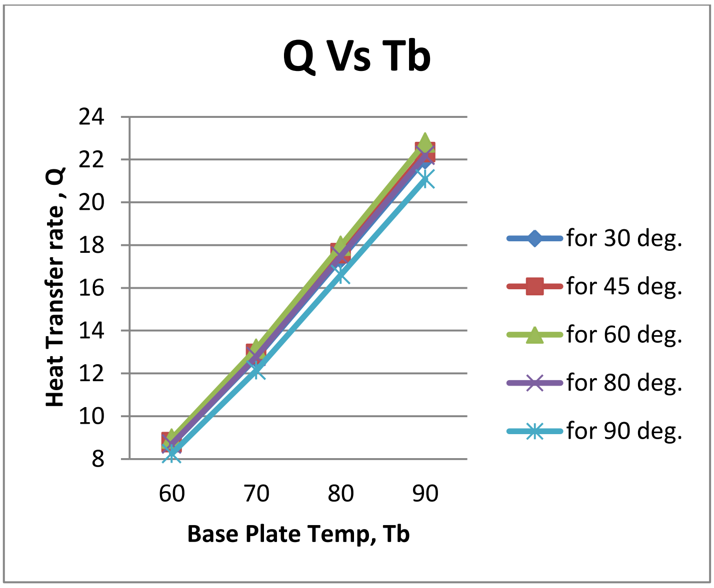

Fig.3.2: Effect of inclination angle on heat transfer rate

From the figure 3.2 it is clear that the heat transfer performance declined rapidly under the Rayleigh number of 5 $\times 10^{7,}$ where the heat transfer performance rose until the inclination angle of the inclined finned surface reached to 60˚. For practical applications, an inclination angle of 60˚ is the optimum value because the heat transfer performance is better for wide range of Rayleigh number. The convective heat transfer rate for the inclined finned surface at an angle of 60˚ is found to be 8.46% higher than that for the vertical finned surface.

4. 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;

- It has been observed that the experimental results shows enhancement of heat transfer coefficient is strongly dependent on the Rayleigh number & fin spacing.

- 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.

- The convective heat transfer rate is enhanced by 8.46 % at maximum temperature of base plate, Tb= 90˚C and θ = 60˚ from horizontal plane in comparison with the vertical finned surface.

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