Experiment Investigation of Heat Transfer Rate of Fins with Blind Holes in Natural Convection

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Abstract - *Many mechanical systems are facing the problem of overheating due to internal heat generation of the system Though there are solutions like fins, cooling systems but still there is need of more effective solution. . The main purpose of this experimental study is increasing the heat transfer rate of the fin array with minimum weight of the fin. The surface modification in the form of the perforations and blind holes is passive method of increasing heat transfer rate with the additional benefit of weight reduction. This study includes comparison of natural convection heat transfer of solid, perforated and fins with blind holes at various inclinations(0 to 90^0) of the fins. Experimentation is to be done by taking different configurations of fins and different inclination of fins. Comparison will be done by taking differentiating coefficient of heat transfer and Heat transfer rate.*

1. INTRODUCTION

Fins are used to enhance convective heat transfer in wide range of engineering application and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surf ace area. Natural convection heat transfer is often increased by provision of rectangular fins on horizontal and vertical surface in many electronic applications, motor and transformers. To increase further heat transfer rate from the fin, research on different techniques is carried out by different researchers one of these techniques is a perforations. Perforation in fins increase heat transfer rate from surface. There is also technique of providing inclination to the fin surface to enhance heat transfer.

Nowadays many researchers are working on the heat transfer enhancement processes as it is main requirement of industry. The heat transfer enhancement efforts are broadly classified as active and passive methods of heat transfer enhancements. Heat transfer enhancement is the process to increase the amount of heat transfer done by equipment by using fins, flow pulsation, using inserts, using nano fluids etc. The objectives of heat transfer enhancement are higher thermal performance, reduced size of heat transfer equipment, increased heat transfer rate at same area (size) etc. For last a century, efforts have been made to produce more efficient heat exchanging devices by employing different methods of heat transfer enhancement. Research on this study of enhanced heat transfer has gained serious attention of different researchers during recent years, however, due to increase demand by industry for heat exchanging equipment that have low cost of production and low cost of operation than conventional heat exchange device. Saving in materials and energy required also provide strong motivation for the development of improved methods of enhancement. While designing cooling systems for automobile and spacecraft, it is imperative that the heat exchangers are especially compact and lightweight. And enhancement devices are necessary for high heat duty exchangers found in power plants (i.e. air-cooled condensers, nuclear fuel rods).

This work consists of the study of heat transfer enhancement perforated rectangular fin array at different inclinations. In this study heat transfer from rectangular fin array will be studied for two types of fins one with perforations and other with blind holes and different angle of inclinations of fin array. First heat transfer from a fin array at horizontal position is studied then the angular position of fin array will be changed and it is made inclined then effect of this inclination on heat transfer from fin array will be studied. In this way for same diameter of through holes and blind holes and different inclination angle the heat transfer rate will be studied. Then same study will be undertaken for different heat inputs. In this way effect of perforation diameter as well as inclination of fin array will be studied in this dissertation work.

2. LITERATURE REVIEW

A.V. Zoman et al [1] investigated experimental analysis of natural convective heat transfer performance from rectangular fin array with perforations. In these experiment different rectangular perforated fin array is compare with the sample of rectangular fin array. The seven test sample of alxuminium fin array is produced by machining then different perforations are made on lateral surface on the fin of six test sample. In this experiment checked the effect of number of perforation, increasing and decreasing the diameter of perforation on the heat transfer rate of fin array. In experimental studies concluded that rectangular fin array with circular perforation gives more heat transfer rate than the solid fin array.

All rectangular fin arrays with circular perforation of 12 mm diameter gives more heat transfer rate than 10 mm diameter for same number of perforation. Highest heat transfer rate is achieved using 5 number of perforation of 12 mm diameter. Less is the value of temperature difference more is heat transfer coefficient. Fins with more number of perforations increase the heat transfer rate reducing the area as well as weight of system.

G.A. Chaudhari et al [2] performed experimental work the effect of percentage of perforation on the natural convection heat transfer from a fin array. The steady state natural convection heat transfer from vertical rectangular fins extending perpendicularly from vertical rectangular base was investigated experimentally. In the experiment to take measurement from four different configurations base and ambient temperature were measured in order to calculate the heat transfer rate from fin array.

These experimental studies concluded that the total heat transfer rate from fin array depends on base to ambient temperature difference and percentage of perforation. As these temperature difference increases, the total heat transfer rate is increases. For the same base to ambient temperature difference, total heat transfer is minimum for vertical flat plate while it increases for plane finned surface and goes on increasing as percentage of perforation increases. The total heat transfer is maximum for 30 percent perforated fin array.

S.G. Khomane et al [3] studied enhancement of heat transfer by natural convection from discrete fins. In these experimental study comparing the natural convection heat transfer rate of solid fin array and different types of discrete fins. Where the experiment is done by the cutting the fin along the length of fin and width of cut was 2 mm constant while the input was 15 W, 30 W, and 45 W.

The minimum cut is 1 and maximum cut is 5 of 2 mm width. As increasing the heat input, Nusselt number increases. Result of that experimental study is the Nusselt number of the discrete fin is more as compare to solid fins. Discrete fins show 8 percent enhancement in Nusselt number. Nusselt number for 45 W heat input with 5 cut in fins shows improvement in Nusselt number that means high heat transfer rate.

Wadhah Hussein et al [4] investigated enhancement of natural convection heat transfer from rectangular fins by circular perforations. In this experimental study was conducted to investigate the heat transfer by natural convection in rectangular fin plate with circular perforation as heat sink. The pattern of perforation for first fin for 24 and is increased by 8 up to 56 in the fifth fin. The result carried out the heat transfer rate and the coefficient of heat transfer increased with an increasing the number of perforations on the fin plate

3. EXPERIMENT INVESTIGATION

i) Fin Array:

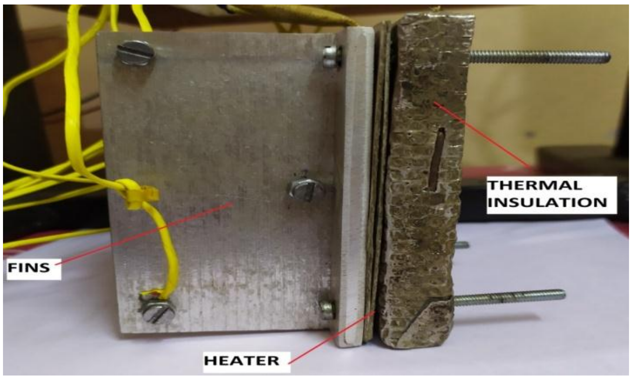


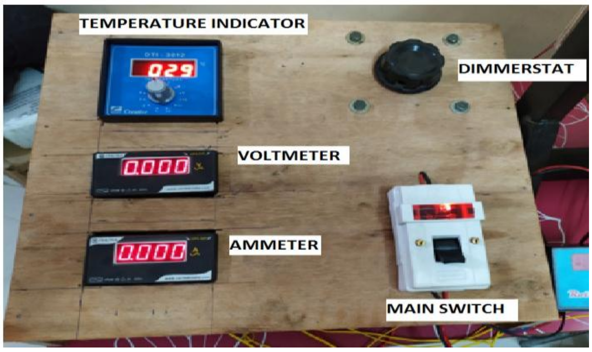
Fig i: Fin Array and Heater

In this work a fin array is used as a heat transfer from heater to air. The heater is placed in between the fin array and the thermal insulator as shown in Fig. 3.6 heat from this heater will travel through the fin array and it will be finally removed by the air. This fin array has three fins. The material of this fin array is aluminium. The height of each fin is 45 mm and thickness is 4 mm. The base area of the fin array is 4*100 mm^2. The total surface area of the fin array is 0.0359 m^2.Total eight thermocouples of Chromium-Aluminium alloy (k type) having 18 gauge sizes are used in this experimental setup, out of these 8 thermocouples 7 thermocouples are connected to the fin array. To increase the accuracy of temperature recording, these thermocouples are connected at base as well as at the tip of the fin. Fig.i shows the positions of the thermocouples on the fin array. All the thermocouples are connected to the temperature indicator where recording of these temperatures can be done.

ii) Control Panel:

Fig ii: Control Panel

Fig. ii. shows the control panel of the experimental set up used for this research work. On this control panel different control elements and indicator are attached. The main switch on control panel controls the electric connection to the set up. Dimmerstat shown in the Fig. is used to control the input to the heating element. The dimmerstat control the voltage and current supplied to the heater. The temperature indicator is used to record the temperatures of different points on the fin array and air. 13 thermocouples are connected to the temperature indicators and they provide signal to the temperature indicator. Ammeter and voltmeters are used to observe the voltage and current provided to the heater. All these elements are attached on the control panel made of sheet metal and having dimensions of (800 mm x 500 mm x 200 mm). Following are the specifications of the voltmeter, ammeter and dimmerstat used on this control panel.



iii) Experimental setup:

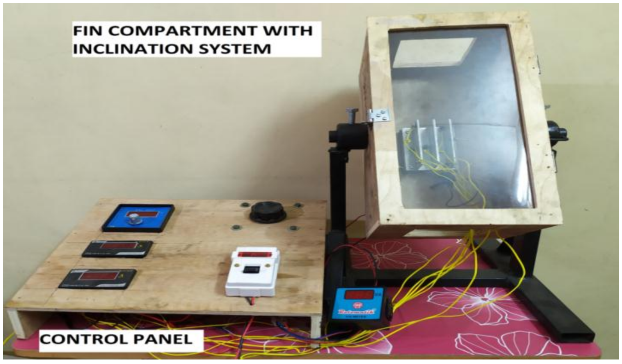


Fig.iii. Experimental Setup

From Fig iii different components of experimental setup used for experimental analysis of heat transfer from perforated rectangular fin array at different inclinations by natural convection can be observed. This experimental setup is used to study the heat transfer from fin array with increasing diameter of perforations and change angular position of the fin array. This figure shows the control panel, angular inclination mechanism and test section of the experimental setup. In this experimental setup fin array with different diameters will be placed and different angular positions and the observations are recorded. To change the angle of the fin array angular inclination mechanism is used.

Iv) Experimental Procedure:

Fig. iv : Flow chart

4. RESULT AND DISCUSSION:

4 i) Effect of Q input and angle of inclination on heat transfer coefficient for fins without perforations

T_1 to T_7 = Temperatures at various positions on fins

Fig. 4 i) shows the effect of change in the heat available for convection and angle of inclination of fin array on the heat transfer coefficient of the process. It can be observed from the graph that as heat input increases the heat transfer coefficient of the heat transfer process increases with it. This phenomenon occurs due to the fact that with more heat available to transfer any system will actually transfer the heat in that proportion. Hence as more heat available more heat will get transferred and more will be the heat transfer coefficient. All the other set of observations shows same type of behavior in the graph.

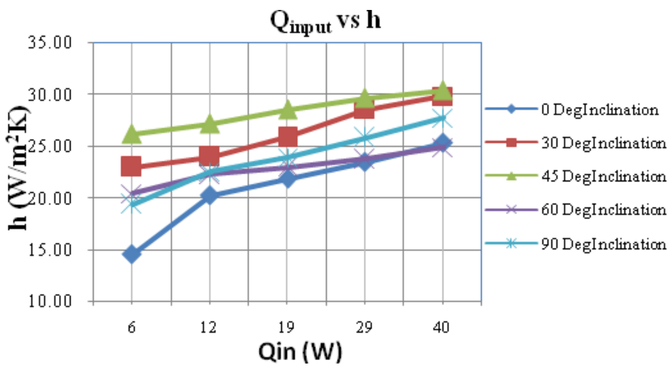


Fig. 4. i) Heat Input Vs Heat Transfer Coefficient for fin array without perforations

This graph also shows the effect of change in angle of inclination of the fin array on the heat transfer coefficient. This graph shows that at 0° inclination the heat transfer coefficient has lowest values compare to the all other angle of inclinations of the fin array. It is observed that at 45° angle of inclination the heat transfer coefficient of the heat transfer process is highest compare to the all other angle of inclinations of the fin array, it is averagely 35% higher than the heat transfer coefficient at 0° angle of inclination as the average value of heat transfer coefficient at the 0° inclination is 21.07 W/m²K and average value of heat transfer coefficient at the 45° inclination is 28.36 W/m²K. In this graph it can be also observed that heat transfer coefficient increases for change in angle in order of 0° inclination, 60° inclination, 90° inclination, 30° inclination and finally it reaches to highest value at 45° inclination.

This phenomenon occurs due to the fact that due to increase in temperature of air density of air decreases and natural convection current starts. Air starts moving in the direction opposite to that of gravity due to buoyancy effect. At 0° inclination simply get heat ted and leave the surface of fin while at 45° inclinations the air will be in contact with more surface area while leaving the surface after getting heated. Hence heat transfer will be more in 45° inclination of fin array.

IV ii) Effect of Q input and angle of inclination on Nusselt number for fins without perforations

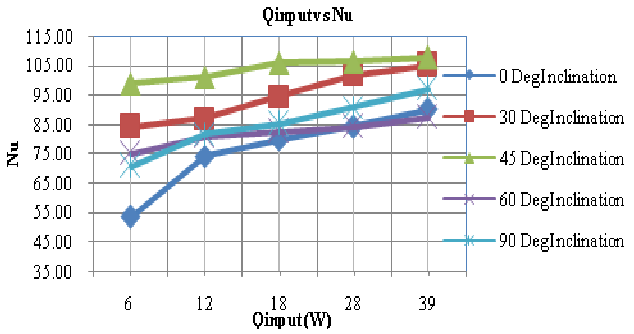


Fig. 4.ii): Heat input vs Nu for fin array without perforations

Fig. 4.ii) shows the effect of variation in heat available for transfer and angle of inclination on Nusselt number. Nusselt number is nothing but the ratio of amount of heat transfer by convection to the amount of heat transfer by conduction. As conductive heat transfer from fin array to air is not dominant it generally gives idea about amount of heat transfer by the convection. It can be observed from this graph that as the convection heat transfer increase the Nusselt number increases with it. This graph also shows that with change in angel of fin array Nusselt number changes, it is highest for the 45° inclinations and lowest for the 0° inclinations. The results shows that at 0° inclinations the average value of Nusselt number is 76.38 which increase for 60° inclinations to 82.01 , for 90° inclinations it is 85.15 and for 30° inclinations it becomes 94.56. Finally it reaches to 104.09 for 45° inclinations.

4.iii) Effect of Qinput and angle of inclination on heat transfer coefficient for fin array with single row perforation

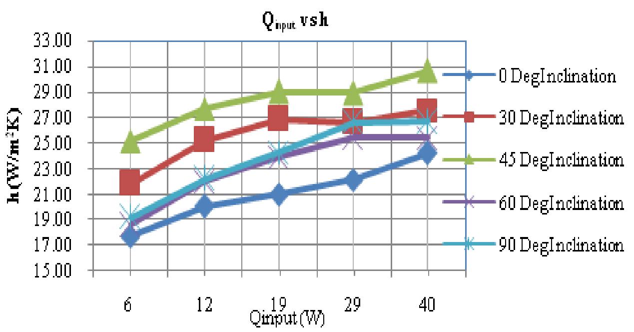


Fig.4 iii) Heat input Vs Heat Transfer Coefficient for single row perforation fin array

From Fig. 4.iii) it can be observed that the heat transfer coefficient of the heat transfer process changes with change in heat input and angle of inclination of fin array. It can be observed from the graph that the heat transfer coefficient of the heat transfer from the fin array increases with the increase in the heat input available for convection. It is also observed that at 45° inclination of the fin array the heat transfer coefficient is maximum and for 0° inclination of the fin array heat transfer coefficient is minimum. It is observed that with 45° inclination heat transfer coefficient can be increased by 34.57 % compared to the 0° inclination of the fin array. In this graph it can be also observed that heat transfer coefficient increases with change in angle, for 0° inclination it is lowest and it increases for 60° inclination, 90° inclination, 30° inclination and finally it reaches to highest value at 45° inclination. For 0° inclination the heat transfer coefficient is 21.01 W/m^2K which increases to 28.28 W/m^2 K at 45° inclination. Due to perforation, surface area and turbulence increase this allows fresher air comes in contact with fin and thus heat transfer coefficient increases greatly. Perforation helps to increase turbulence as well as heat dissipation rate.

IV iv) Effect of Q input and angle of inclination on Nusselt number for single array perforation

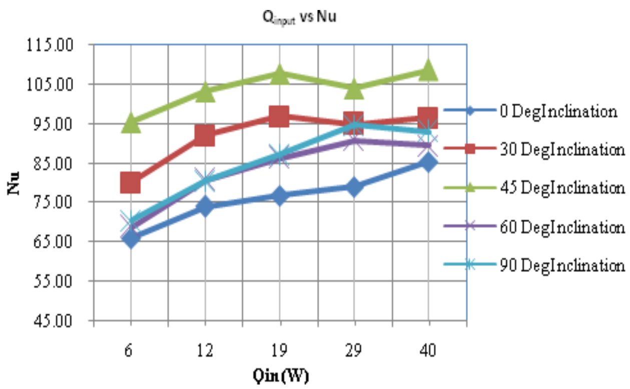


Fig IV iv) Heat input vs Nu for single row perforation fin array

Fig. 4.iv shows the effect of heat supplied and change in the angle of inclination of the fin array on the Nusselt number. Graph shows that with change in the angle of inclination, the Nusselt number also changes. At 0° inclination average value of Nusselt number is 76.18 which increase for 60° inclination to 83.16, for 90° inclination to 85.56, for 30° inclination to 92.08 and finally reaches to the highest value of Nusselt number 103.78 to 45° inclination. The orientation of fin array in these inclinations affects the buoyancy force which results into change in heat transfer which leads to change in Nusselt number

4 v) Effect of Q input and angle of inclination on heat transfer coefficient for single row blind hole fin array

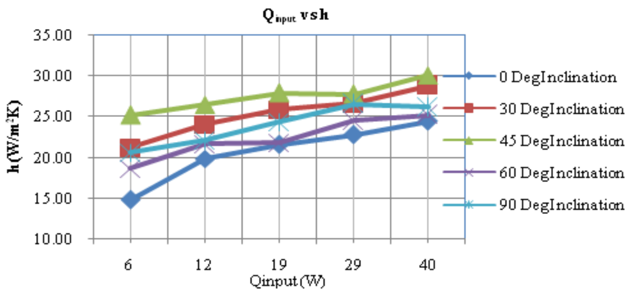


Fig 4 v) Heat input vs Heat Transfer Coefficient for single row blind holes fin array

From Fig.4 v) effect of variation in convection heat transfer and angle of inclination on heat transfer coefficient can be observed. In this graph it can be observed that 45° inclination of the fin array gives best solution for highest heat transfer for coefficient. With 45° inclination the heat transfer coefficient has highest average value of 27.47 W/m2K which 32.91% higher than the value of heat transfer coefficient at 0° inclination which is 20.67 W/m 2K. Due to blind holes and slots, increase in surface area and turbulence increase this allows fresher air comes in contact with fin and thus heat transfer coefficient increases greatly. Blind holes may help to increase turbulence as well as heat dissipation rate.

4 vi) Effect of Q input and angle of inclination on Nusselt number for single row blind hole fin array

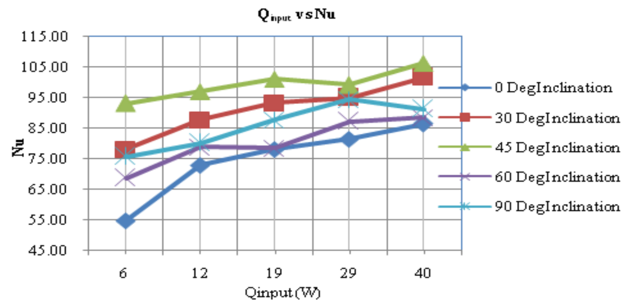


Fig IV vi) Heat input vs Nu for single row blind holes fin array

Fig. IV vi) shows that the Nusselt number of the heat transfer process changes with change in heat input and angle of inclination of fin array. Due to increase in heat input heat available for convection increases which also leads to increase in heat transfer through convection hence Nusselt number is increases with increase in the heat available for convection. With change in angle of perforation the Nusselt number is increases, for 0° inclination Nusselt number has lowest average value of 74.76 which increases to highest value of 99.37 at 45° inclinations.

4 vii) Effect of Q input and angle of inclination on heat transfer coefficient for fin array with double row of perforations

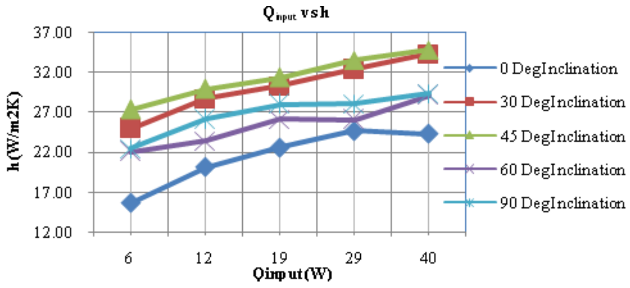


Fig.4 vii) Heat input Vs Heat Transfer Coefficient for double row perforation fin array

From Fig. 4.vii effect of variation in heat transfer and angle of inclination on heat transfer coefficient can be observed at double row perforation fin array. It can be observed that the heat transfer coefficient of fin array increases with increase in heat supplied, when heat available for convective heat transfer increases from 6 to 40 Watt the average heat transfer coefficient for all variants increases by 46.28% from 21.42 W/m²K to 31.33 W/m²K. It is also observed from the graph that change in angular inclination of the fin array has great impact on the heat transfer coefficient; it can be observed from this graph that the heat transfer coefficient at 0 inclination has lowest magnitude (21.4 W/m²K) among all the tested conditions. Due to perforation, surface area and turbulence increase this allows fresher air comes in contact with fin and thus heat transfer coefficient increases greatly. Perforation helps to increase turbulence as well as heat dissipation rate. The heat transfer coefficient then increases with change in angle of inclination stating from 0° inclination it increases for 60° inclination (25.32 W/m²K), 90° inclination (26.75 W/m²K), 30° inclination (30.08 W/m²K) and 45° inclination (31.33 W/m²K) respectively.

4 viii) Effect of Q input and angle of inclination on Nusselt number for double row perforation fin array

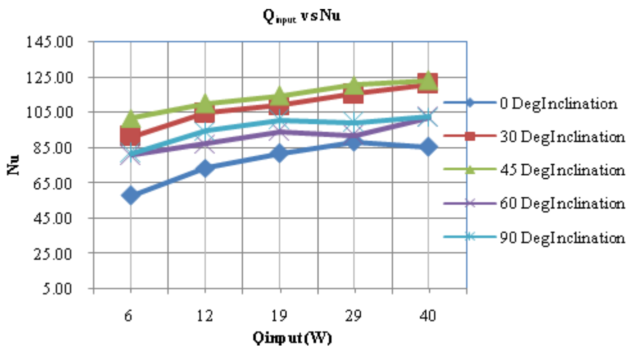


Fig. IV viii) shows the effect of variation in convection heat transfer and angle of inclination on Nusselt number at double row perforation fin array. It can be observed that the

Nusselt number increases with heat supplied as well as with change in angular inclinations.

At 0° inclinations Nusselt number has lowest value at all heat supplies, the average value of Nusselt number at 0° inclinations is 77.57, which increase for 60° inclination to

91.35, for 90° inclination to 95.93, for 30° inclination to 108.42 and finally reaches to the highest value of Nusselt number 114.13 at 45° inclination.

4 ix) Effect of Q input and angle of inclination on heat transfer coefficient for fin array with double row of blind holes

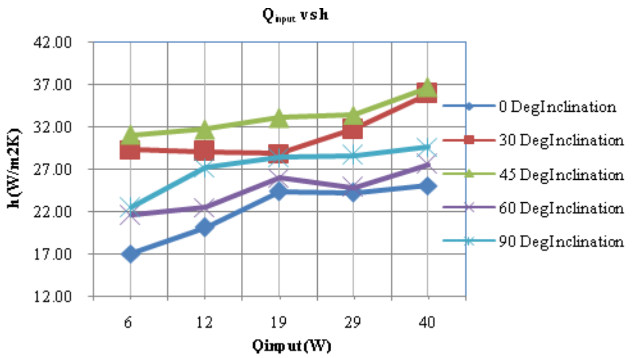


Fig. 4 ix) Heat input Vs Heat Transfer Coefficient for double row blind holes fin array

From Fig. 4 ix) effect of variation in heat transfer and angle of inclination on heat transfer coefficient can be observed at double blind holes. It can be observed that the heat transfer coefficient of fin array increases with increase in heat supplied, when heat available for convective heat transfer increases from 6 to 40 Watt the average heat transfer coefficient for all variants increases by 49.94% from 22.15 W/m²K to 33.21 W/m²K. It is also observed from the graph that change in angular inclination of the fin array has great impact on the heat transfer coefficient; it can be observed from this graph that the heat transfer coefficient at 0 inclination has lowest magnitude (22.15 W/m²K) among all the tested conditions.

Due to perforation, surface area and turbulence increase this allows fresher air comes in contact with fin and thus heat transfer coefficient increases greatly. Perforation helps to increase turbulence as well as heat dissipation rate. The heat transfer coefficient then increases with change in angle of inclination stating from 0° inclination it increases for 60° inclination (24.49 W/m²K), 90° inclination (27.27 W/m²K), 30° inclination (31 W/m²K) and 45° inclination (33.21 W/m²K) respectively.

4 x) Effect of Q input and angle of inclination on Nusselt number for double row perforation fin array

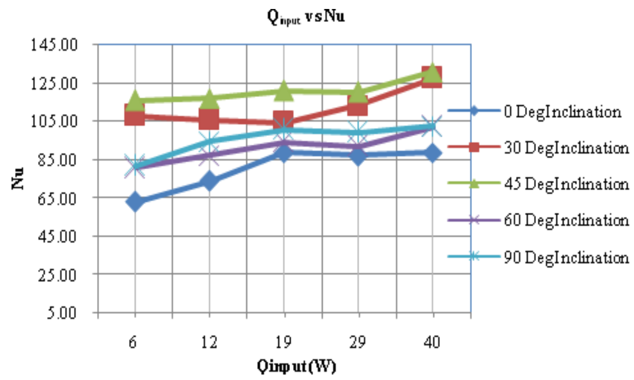


Fig 4 x) Heat input Vs Nu for double row blind holes fin array

Fig. 4 x) shows the effect of variation in convection heat transfer and angle of inclination on Nusselt number at double row perforation fin array. It can be observed that the Nusselt number increases with heat supplied as well as with change in angular inclinations. At 0° inclinations Nusselt number has lowest value at all heat supplies, the average value of Nusselt number at 0° inclinations is 77.57, which increase for 60° inclination to 91.35, for 90° inclination to 95.93, for 30° inclination to 108.42 and finally reaches to the highest value of Nusselt number 114.13 at 45° inclination.

4 xi) Effect of variation in geometry of fin array on Heat Transfer Coefficient at 6 W to 40W Heat input

From fig. 5.11 to Fig. 5.15 the effect of variation in geometry and inclination on Heat transfer coefficient at various heat inputs can be observed. It can be seen that the geometry and inclination of the fin array has significant effect on the heat transfer coefficient of the heat transfer process. The heat transfer coefficient is highest in fin array with two rows of blind holes at 6W heat input. The peroformance of fin array with double row of perforations tend to coincide with that of the fin array with blind holes as the heat input increases. This may be attributed to the fact that the turbulence increases with higher surface temperature leading to higher bouyount forces in case of fin array with double row of perforations although there is lesser area of heat transfer as compared to the fin array with blind holes. It can be observed from the graph that the plain fin has lowest values of heat transfer

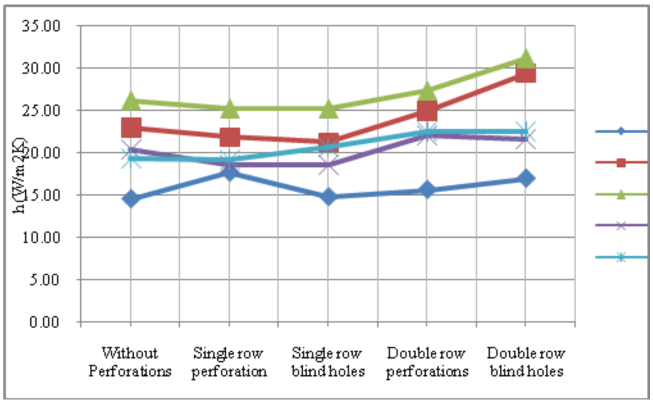


Fig 4 xi) Effect of geometry and inclination on heat transfer coefficient at 6W heat input

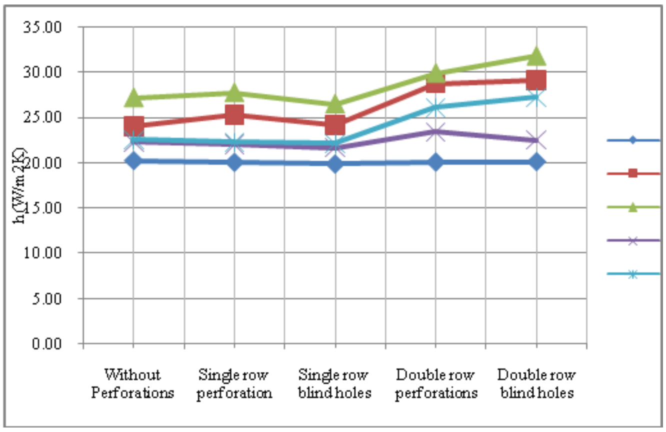


Fig 4 xii) Effect of geometry and inclination on heat transfer coefficient at 12W heat input

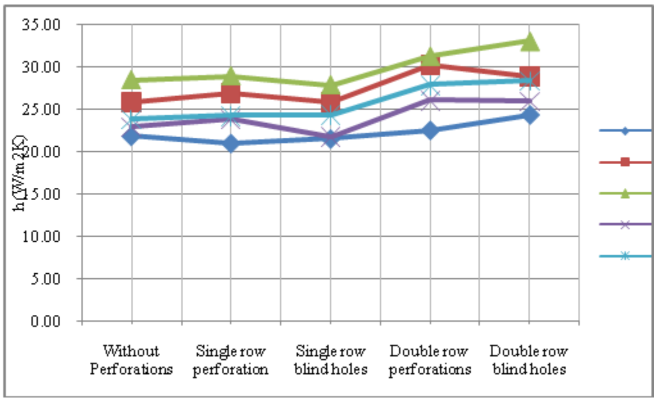


Fig.4 xiii) Effect of geometry and inclination on heat transfer coefficient at 19W heat input

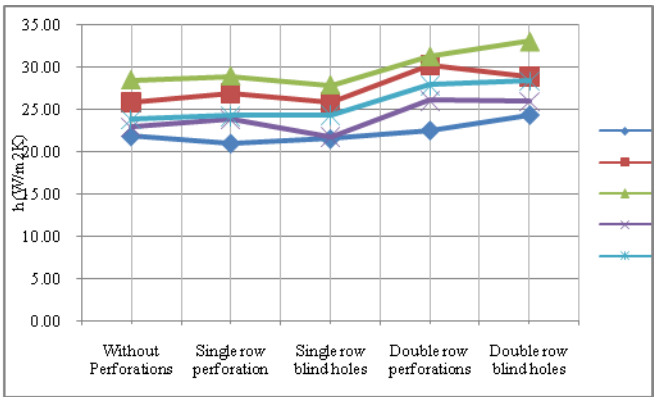


Fig 4 xiv) Effect of geometry and inclination on heat transfer coefficient at 29W heat input

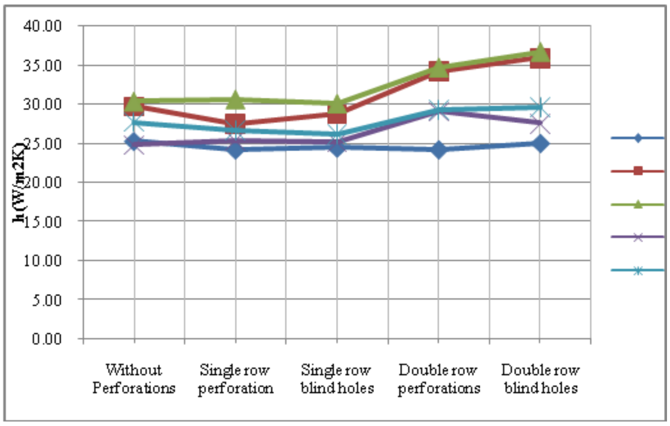


Fig. 4 xv) Effect of geometry and inclination on heat transfer coefficient at 40W heat input

5 Result Summary:

In this experimental work, heat transfer from perforated rectangular fin array at different inclinations by natural convection is studied. The heat transfer characteristics of rectangular fin array are studied at different inclinations of fin array and perforations diameters. The findings of this work are presented below; It is observed that as the heat input to the fin array increases the heat transfer coefficient and Nusselt number also get increased. This happen due to as the amount of heat supplied is higher the average fin array temperature also increases and atmospheric temperature remains almost constant which changes temperature gradient between air and surface due to this more heat transfer from surface to the air and hence the heat transfer coefficient and the Nusselt number increases. The results of this study shows that with change in angle of inclinations the heat transfer coefficient and the Nusselt number also changes. At 0° inclinations both the heat transfer coefficient and the Nusselt number has lowest magnitudes in entire study. At 45° inclinations both the heat transfer coefficient and the Nusselt number has highest values. It is also observed in this study that the presence of perforation on the fin body have a positive effect on the heat transfer. In this study fin array with no perforation, single row perforation, single row blind holes , double row perforation and double row blind holes are used and it is found out that the fin array double row blind holes gives the highest heat transfer characteristics i.e. Nusselt number and heat transfer coefficient . From above it can be observed that the average values of heat transfer coefficients and Nusselst no are highest for fin array with two rows of blind holes for the entire range of angle of inclinations.

6. CONCLUSIONS

- Evaluation of effect of geometry and inclination on heat transfer rate from fin array is carried out and result obtained is found to be satisfactory. Application of Fin arrays with two rows of blind holes increase the heat transfer coefficient and Nusselt number up to 15%.

- It was observed that in case of all types of fin arrays angle of inclination of 45° with the horizontal gives the highest values of heat transfer coefficient and Nusselt number irrespective of the heat input.

- Experimentation was carried out to obtain all possible combination of geometry and angle of inclination. From analysis of data obtained, best possible combination is found Fin arrays with two rows of blind holes and 45° angle of inclination.

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