Effect of Hexagonal Perforations on Convective Heat Transfer Coefficient in Forced Convection – Experimental Study

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***Abstract*— Heat dissipation is important requirement in many applications, for which fins are used. Perforated fins offer increased heat transfer with reduction in weight and cost. In this project, effect of hexagonal perforations in a square fin is investigated for different values of heat flux and Reynolds numbers. Aluminium 5052 sheets having dimension of 150mm x 150mm with a thickness of 1mm are used for experimentation. Eight fins were mounted in the slots (1mm thick, 2mm wide and150mm long) provided circumferentially on a hollow cylinder. The cylinder is heated by using cylindrical electrical heater. Entire cylinder with fins is placed in a duct of square cross section 350mm x 350mm and 1.5m long. Air is induced in the duct by using fan. Experiments were conducted for three different heat flux values of 35.5, 55.5 and 80 and six different Reynolds number under steady state conditions. Results are expressed interms of variation of convective heat transfer coefficient and Nusselt number with Reynolds number. From the results, it is observed that, convective heat transfer coefficient and Nusselt number increases with increase in the Reynolds number. It is also observed that both convective heat transfer and Nusselt number for perforated fins are higher compared to plane fin. Fin with 20% perforation showed higher values compared to 5% and 11% perforated fin while fin with 11% perforation showed lower compare to 20% and 5% perforated fin.**

I. INTRODUCTION

Fins are the extended surfaces used to enhance the rate of heat transfer. The rate of heat transfer depends on the amount of conduction, convection and radiation of an object.

The heat generated while operating several engineering system may gets overheating and consequently leads to collapse of the system. So it is imperative to add superior heat transfer elements having smaller mass, more compatible and less expenditure. The heat generated in a system such as diesel engine, heat exchangers in the gas turbine, boiler, super heated tubes, condenser coils, etc. must be dissipated to surroundings in order to maintain the system functioning at its recommended working condition with reliably and effectively.

Mehedi Ehteshum et. al., [1] conducted experimental investigations into the effect of Circular perforations in a rectangular fins for Reynolds number varied from $6*10^4 – 25*10^4$. Fins with perforations showed increased heat transfer compared to fins without perforations. It was also observed that as the number of perforations and size of the perforations increases, thermal resistance and dimensionless pressure drop decrease while efficiency and effectiveness increases. Abdullah H AlEssa and Mohammed Al-odat [2] investigated heat transfer enhancement from a horizontal rectangular fin embedded with triangular perforation under natural convection compared to equivalent solid fin. The parameters considered were geometrical dimensions and orientation of the perforations. This study focused on the gain in fin area and extent of heat transfer enhancement due to perforations. It was found that the heat dissipation from the perforated fin for certain range of perforation dimension can result in improvement in heat transfer over the equivalent solid fin, and the heat transfer enhancement of the triangular perforation that its base is parallel to the fin side was the highest. Saurabh .D. Bahadure and G. D. Gosavi [3] conducted a theoretical and experimental study on enhancement of natural convection heat transfer from perforated pin fin. Pin fins having 1, 2 and 3 perforations along the length of the pin were considered for three different materials namely Mild Steel, Aluminum and Copper. Fins with circular perforations showed higher heat transfer compared to solid pin fins and heat transfer coefficient for copper was higher compared to Mild Steel Aluminum. Narendra R patil and S Y Bhosale [4] experimentally investigated optimum hole size on perforated fin to fin length under natural convection heat transfer. Experiments were conducted for three heat input values of 55W, 65W and 75W. Abhijit G Dhere and Hemant S Farkade [5] carriedout the review of the effect of circular perforation in pin fins and square fins for inline and staggered arrangement. Rajput and Kulkarni [6] investigated the effect of different perforations namely circular, square, elliptical, triangular and hexagonal on heat transfer using FEM for natural convection process. Fin with elliptical perforation showed better heat transfer compared to other perforations.

Literature review shows that effect of hexagonal perforation in square or rectangular fins on heat transfer is not carriedout. Hence there is need to study the effect of hexagonal perforations on convective heat transfer coefficient in forced convection.

EXPERIMENTAL SET-UP

The experimental setup consists of aluminium 6062 cylinder. Cylinder of inner diameter 25mm and outer diameter 50mm is selected. The outer diameter of the cylinder is provided with eight slots having dimension of 2mm depth and 1mm width and 150mm long. Cylindrical electrical heater of 25mm diameter is places inside the cylinder. Square Aluminium 5052 sheets having dimension of 150mm x 150mm and 1mm thickness is used as fin material. Fins are then placed in the grooves provided on the circumference of the hollow cylinder and fins are surrounded by insulating material so that end is insulated and entire air flow over the fins. Fin arrangement is placed in a duct having cross-section of 35cm x 35cm and 1.5m long. At the top of the duct, an exhaust fan is used to induce air into the duct. For experimentation, three values of heat flux were considered namely 35.5W, 55.5W and 80W. Figure shows the dimensions of different hexagonal perforations. Experimental set up is shown in figure .

MEASUREMENTS

Air temperature at inlet, exit and near the fins are measured by using K-type thermocouple having accuracy less than 1°C and surface temperature of the fin by using hand held K-type thermocouple having accuracy less than 1°C and least count of 0.1°C. Thermocouples were used to measure inlet, exit and ambient temperature surrounding the fins, while the fin surface temperature was measured using hand held thermocouple. Velocity of air at the exit is measured by using handheld anemometer having least count of 0.1m/s. Voltage supplied to the heater is regulated by using dimmerstat having least count of and voltage is measured by using multimeter having least count of 0.1V. Resistance of the coil is also measured by using Multimeter having least count of 0.1Ω.

PROCEDURE

1. Before starting the experiments, consistency of the thermocouple were checked by exposing them to the same ambient.
2. Exhaust fan is switched on and speed is regulated by using regulator.
3. For considered fin, required heat is supplied to the heater using dimmer stat.
4. Once the system attains steady state, all the thermocouple readings and velocity of air at exit of the duct are noted down and power supply is switched off.
5. For the same input, experiment was repeated for two times to check the consistency in the readings.
6. For the same heat input, experiments were conducted for different values of fan speeds.
7. Again heat input was changed and repeated for different values of fan speeds.
8. Fins were changed and same procedure was repeated.

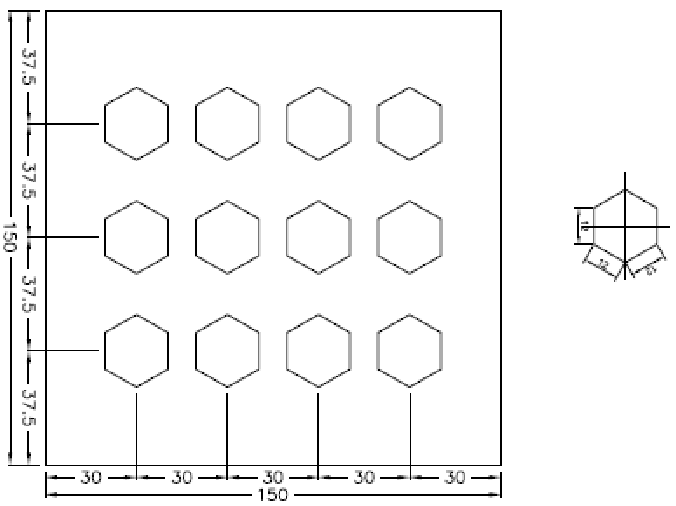

Fig1: 20% hexagonal perforated square fin

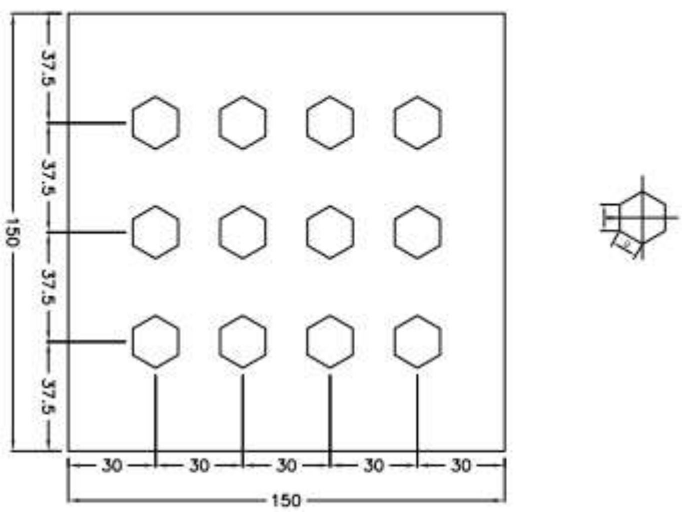

Fig2: 11.2% perforated square fin

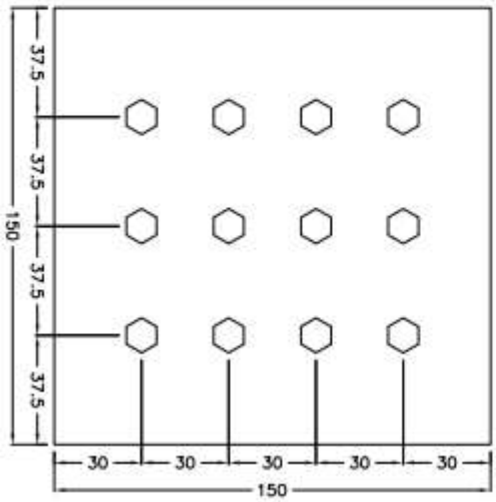

Fig3: 5% perforated square fin


Fig4: Experimental set up (Plain fin)

EQUATIONS:

$Q = V^2/R$ W
$q = Q/n$ W
$q_{condu} = q$ (W)
$q_{condu} = q_{conve} + q_{rad}$ W
$h = q/A_s (T_s - T_{inlet})$ W/m^2-K

RESULTS AND CONCLUSION

Experiments were conducted to investigate the effect of hexagonal perforation size on convection heat transfer coefficient in forced convection for three different values of heat fluxes. In this study, effect of radiation is neglected as it is forced convection and emissivity of the surface is low. Results are expressed in terms of variation of convective heat transfer coefficient and Nusselt number with Reynolds number.

Figure 6 shows variation of convective heat transfer coefficient and Nusselt number with Reynolds number for heat flux value of 35.5W. From the graph, it is observed that as Reynolds number increases, both 'h' and Nu number increases irrespective of perforation size. Convective heat transfer coefficient and Nusselt number is higher for fin having 20% perforation compared to 5% and 11% perforations, where as plain fin shows lower value compared to perforated fin.

From the figures 7a, 7b, 8a and 8b, it is observed that as heat flux increases (55.5 W and 80W), convective heat transfer coefficient and Nusselt number increases and follows similar trend as that of heat flux of 35.5W. Even though heat transfer surface area decreases due to perforations compared to plain fin, presence of holes alters flow pattern, mixing and hence convective heat transfer coefficient. Flow pattern can be observed if CFD analysis is conducted.

For higher size of hexagon perforation, experiments were not conducted as perforations overlap.

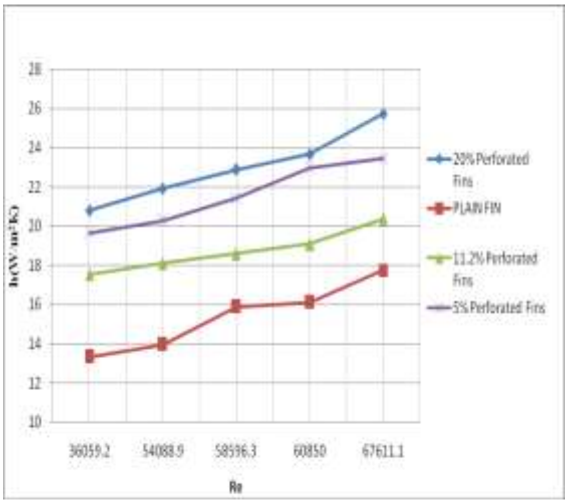

Fig5: Variation of CHTC with Reynolds number for 35.5W

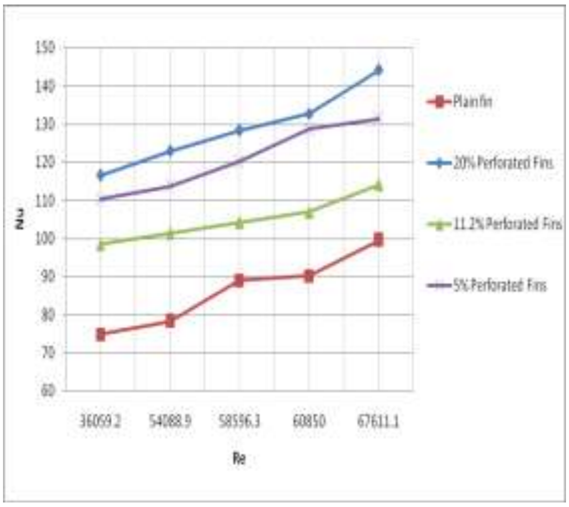

Fig6: Variation of Nusselt number with Reynolds number for 35.5W

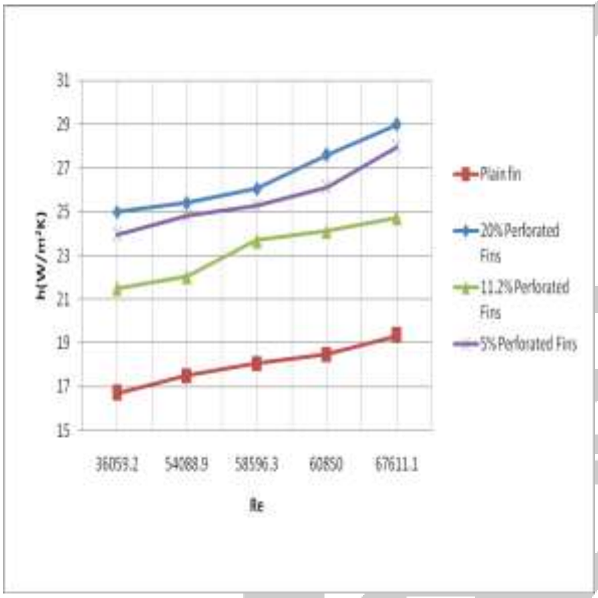

Fig.7: Variation of CHTC with Reynolds number for 55.5W

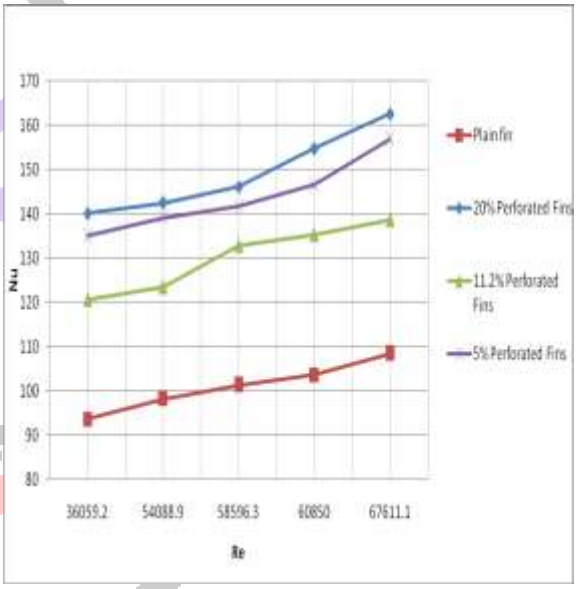

Fig.8: Variation of Nusselt number with Reynolds number for 55.5W

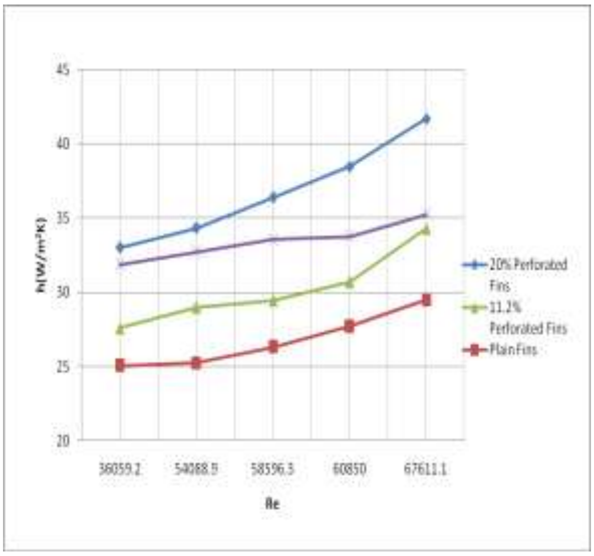

Fig.9: Variation of CHTC with Reynolds number for 80W

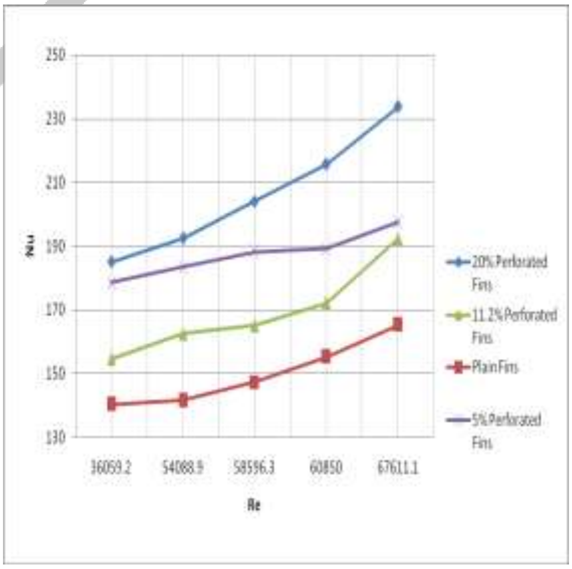

Fig.10: Variation of Nusselt number with Reynolds number for 80W

CONCLUSION

From the experimental study conducted, following conclusions are drawn:

1. Presence of perforations increases the heat transfer coefficient and Nusselt number compared to plain fin,
2. As heat flux increases, both heat transfer coefficient and Nusselt number increases.
3. It is observed that holes having higher size show higher heat transfer coefficient and Nusselt number, while the one having lower size lies in between.

NOMENCLATURE

Q – Heat input (W)
Q – Heat input per fin (W)
q_{condu} – Heat transfer by conducted (W)
q_{conve} – Heat transfer by convection (W)
q_{rad} -- Heat transfer by radiation (W)
h – Convective heat transfer coefficient (W/m^2-K)
A_s – Surface area (m^2)
T_s – Surface temperature (K)
T_{inlet} – Inlet air temperature (K)

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