Effect of Hexagonal Perforations on Convective Heat Transfer Coefficient in Forced Convection – Numerical 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. Analytical study is done using Ansys Fluent software for the validation of experimental results**

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.
This paper is the continuation of the paper published **(ISSN: 2455-2631) September 2016, IJSDR Volume 1, Issue 9**, on the experimental values, which leads to the analytical study of the experiment.

NUMERICAL SET-UP

Numerical analysis is carried out for one of the heat input conditions namely 80W and for inlet velocity of 3m/s. The basic mass conservation, momentum and energy equations are solved numerically using ANSYS FLUENT software (version 17.0). The numerical study was carried out on the plain and hexagonal perforated fins. The model was sectioned into 8 equal parts and the analysis has been carried out on one of the sections.
Inlet: Inlet velocity = 3m/s,
Outlet: Outlet pressure condition = 1 atm. Pressure and temperature
Heat Input: In terms of heat generating unit = 2.711E-04 W/m^3

The fins have the different number of mesh size and the skew values. The 20% perforated fins 958737 number of mesh element and the skew value 0.9-1. 11.2% hexagonal perforated fins have 1103416 numbers of mesh elements and the skew value of 0.8-1. In 5% perforated fins the 1157987 numbers of mesh element and the skew value of 0.8-1. The plain fins have 232320number of mesh element and skew value of 0.9-1

The module has been meshed in Abaqus CAE, using hexahedral mesh. Figure1 shows the mesh pattern used for CFD analysis.

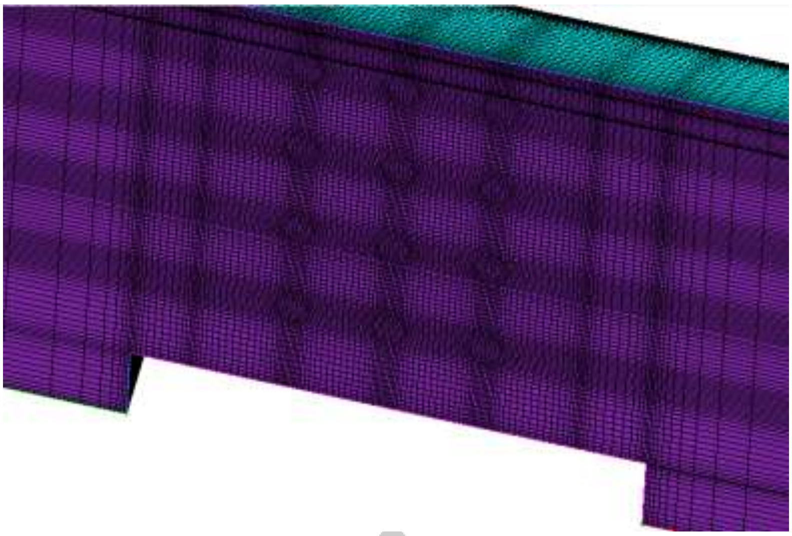

Fig 1: The mesh pattern for the analysis of hexagonal perforated fin

RESULTS

TEMPERATURE DISTRIBUTION

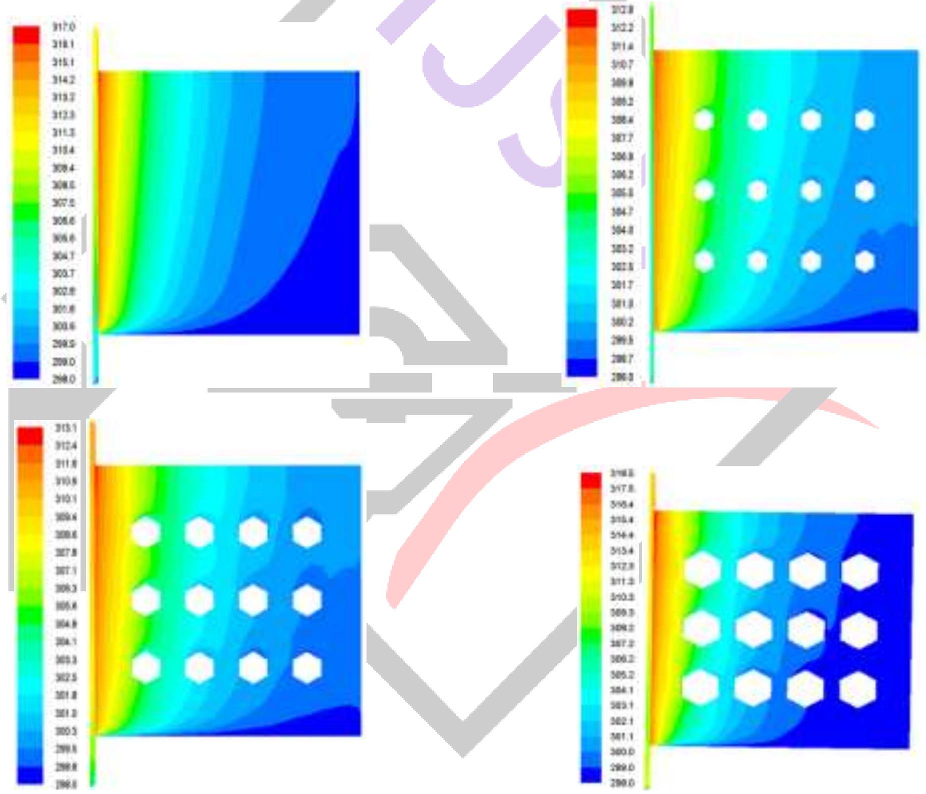

Fig 2: Temperature contours for fins of various configurations
(a) Plane fin (b) 5% perforated fin (c) 11.2% perforated fin (d) 20% perforated fin

Figure 2 shows the temperature contours of plain, 5%, 11 %, 20 % hexagonal perforated fins for inlet velocity of 3m/s and the heat supply of 80W. Temperature contours for different fins shows the effect of hexagonal perforation of different size on temperature distribution.

VELOCITY CONTOUR

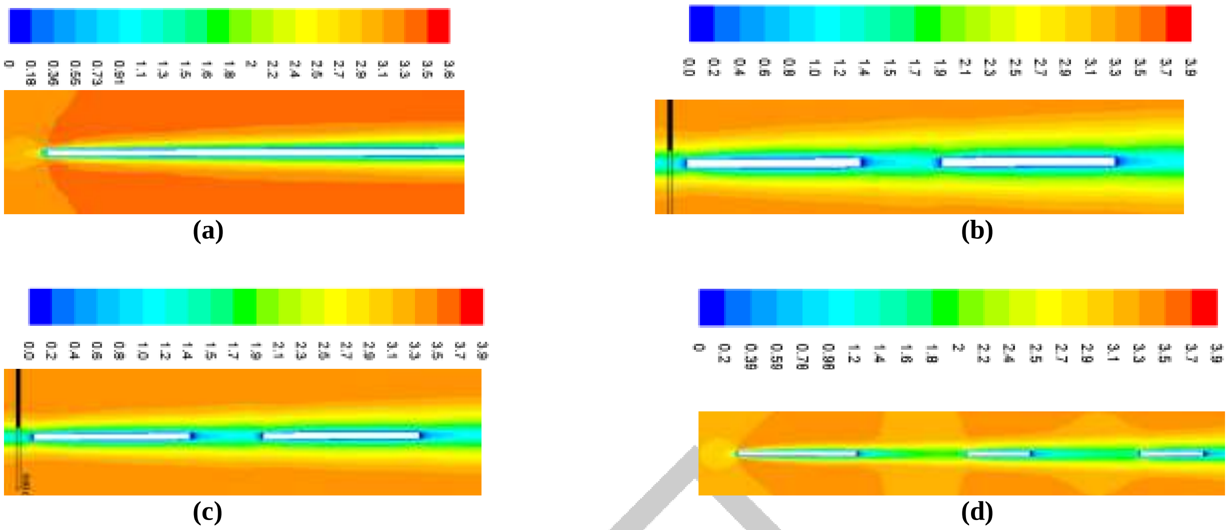

Fig 3: Velocity contours for fins of different configurations along the cut plain passing at the center of the fin
(a) Plane fin (b) 5% perforated fin (c) 11.2% perforated fin (d) 20% perforated fin

Figure 3 shows velocity contours for fin having perforation of 5%, 11.2% and 20% hexagonal perforated square fin for heat input 80W, about section taken along the centre of the fin. From the velocity contours, it is observed that presence of perforation changes the velocity of air and its diffusion in the perforation. The magnitude and extension depends upon the size of the perforation.

VELOCITY VECTOR

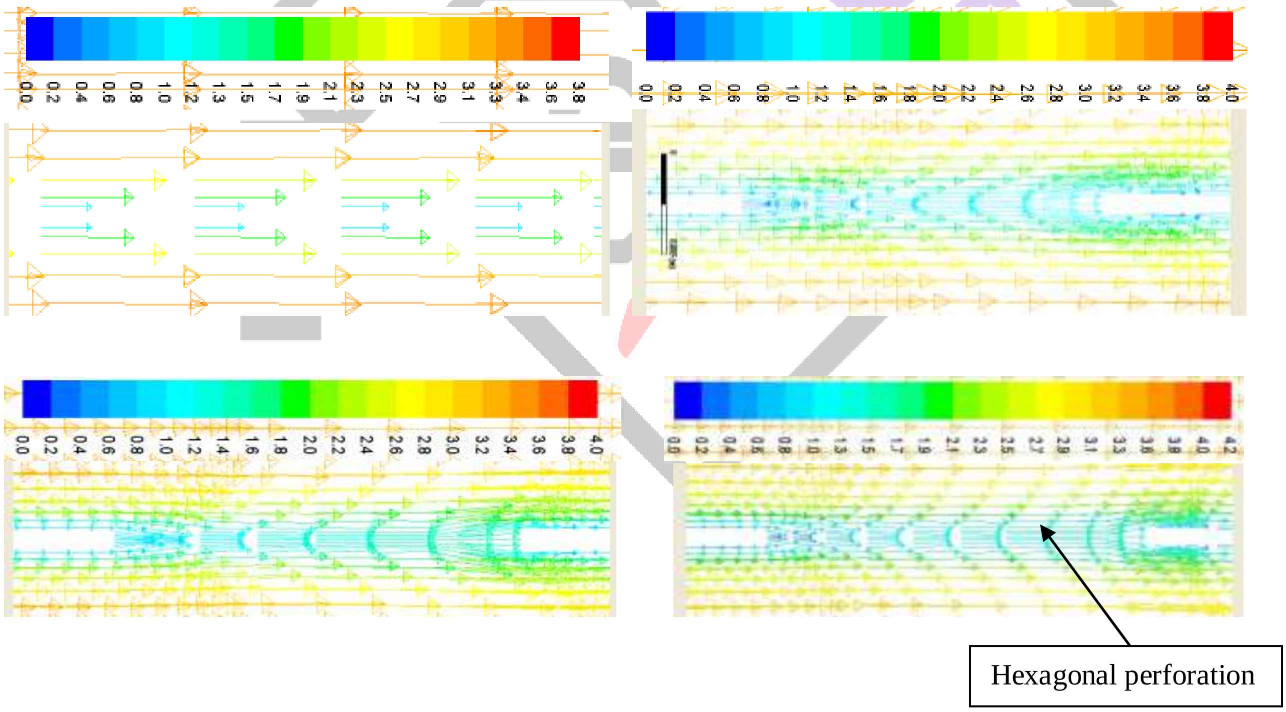

Fig 4: Velocity vectors for fins of different configurations
(a) Plane fin (b) 5% perforated fin (c) 11.2% perforated fin (d) 20% perforated fin

Velocity vectors for heat input of 80W and inlet velocity of 3m/s section taken along the plain at the center of the fin as shown 4. Color bar chart in the figure shows the magnitude of the velocity. It is observed that for plane square fin, the velocity vectors are straight and parallel to the plate. For fins with hexagonal perforation, it is observed that the velocity vectors converge in the presence of perforation and diverge after hole and pattern is continued. Convergence and divergence pattern of velocity vectors changes depending upon the size of the perforation and this may lead to higher convective heat transfer coefficient.

CONVECTIVE HEAT TRANSFER COEFFICIENT

The numerical results of convective heat transfer coefficient for the plain and hexagonal perforated fins obtained from FLUENT software are given below.
(a)20% perforated fins, (b)11.2% perforated fins, (c)5% perforated fins and (d) plain fin

"Surface Integral Report"

Area-Weighted Average Surface Heat Transfer Coef.	(w/m2-k)
fin	40.054533

20% Perforated fins

"Surface Integral Report"

Area-Weighted Average Surface Heat Transfer Coef.	(w/m2-k)
fin	37.281235

11.2% Perforated fins

"Surface Integral Report"

Area-Weighted Average Surface Heat Transfer Coef.	(w/m2-k)
fin	36.184786

5% Perforated fins

"Surface Integral Report"

Area-Weighted Average Surface Heat Transfer Coef.	(w/m2-k)
fin	31.555909

Plain fin

CONCLUSION

The effect of hexagonal perforation size on convective heat transfer coefficient for different values of heat input and Reynolds number. Number of perforations and pitch are maintained constant and only the size of the hexagonal perforation was varied. Three sizes of the hexagonal perforation were considered, namely 6mm, 9mm and 12mm as its side value. Enhancement of heat transfer coefficient is compared with that of square fin without perforations. Three heat inputs and five speeds of the fan are considered. Experimental and numerical studies are conducted. Numerical analysis was conducted using ANSYS FLUENT (version 17) software for heat input of 80W and velocity 3m/s and validated against the experimental results. Results are expressed in terms of variation of convective heat transfer coefficient and Nusselt number for various values of Reynolds number. Reynolds number varied from 36059.2 to 67611.1 and heat input of 35.5W, 55.5W and 80W were considered.
On the basis of experimental and numerical analysis results, the following observations are made.

- Convective heat transfer coefficient (CHTC) of hexagonal perforated fin is more compared to fins without perforations.
- Convective heat transfer coefficient change with the size of the perforation and velocity of the incoming air.
- As heat input increases, convective heat transfer coefficient also increases irrespective of perforation size.
- Numerical results showed maximum deviation of 7.9% from the experimental results.
- The convective heat transfer rates of hexagonal perforated fins are higher than the plain fins. Thus the perforation of fins enriches the convective heat transfer rate than the plain fins.