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Enhancement of heat transfer using perforated fin

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ABSTRACT

In many engineering applications extended surfaces referred to as fins are used to enhance convective heat transfer. The problem of forced convection heat transfer for perforated fins was investigated in this work. An experimental study was conducted to investigate the heat by forced convection transfer in a rectangular non-perforated fin and circular perforated fin. The investigation is conducted to compare the heat transfer rate of two different fins one is with circular perforation and another one is without perforations. The work done on various kinds of fins, the effect of perforation shape or geometry on the heat transfer was simulated in ANSYS 17.2 to work out the simplest type of fin to be used. The parameters which were considered are the thermal properties of the fin and perforations. The study takes into account the gain in fin surface area and the extent of heat transfer enhancement due to perforations. The comparison between experimental results and software results the kinds of fins perforation was analyzed for the heat transfer coefficient to clarify the simplest perforation shape for the specified application.

***Keywords**: Fins, Circular Perforation, Forced Convection, Simulation, ANSYS 17.2, Experimentation.*

1. INTRODUCTION

Advanced technologies need high-performance heat transfer equipment. Methods for improving heat transfer grouped into two categories: active and passive methods [1]. Active methods require external power to reinforce heat transfer and passive methods do not require external power. Extended surfaces or fins are examples of passive methods of heat transfer that are commonly used in a variety of industrial applications to enhance the speed of warmth transfer between the primary surface (heat sink) and ambient fluid. Rectangular fins which are commonly used for heat exchangers, the understanding of convection mechanisms, and prediction of heat transfer performance on rectangular fins are usually analyzed by the flow and warmth transfer simultaneously [4]. In electric and electronic systems, the generated heat may cause burning or overheating problems that lead to system failure and costly damages. The fin industry has been engaged with regular searches to reduce the size of the fin, weight of fin, and cost of the fin. The reduction in fin size and cost is achieved by increasing the heat transfer carried out by the fins. The increment can be completed by different methods such as [8,9]. Firstly, by increasing the ratio of the heat transfer surface area of the fin to the quantity of the fin. Secondly by producing fins from materials having high thermal conductivity, and increasing the warmth transfer coefficient between the fin and its surroundings. Several investigations are conducted to seek out the optimum shape of fins (rectangular, square, triangular, pin, wavy, serrated, and slotted). Some studies introduced some shape modifications by cutting some material from the fin to form cavities, holes, slots, grooves, or perforations through the fin body so as to increase the heat transfer coefficient through effective heat transfer surface area [10,11,12]. The modifications in this work are Horizontal Circular perforations made through the fin thickness with a different number of perforations. The study investigates the influence of circular perforation and lateral spacing on heat transfer ratio, heat transfer rate, heat transfer coefficient of perforated surface, and heat transfer within the perforation. The heat dissipation of the solid fin is compared with that of the fins with a different number of parallel perforations. Perforated fin creates more turbulence as compared to solid fin. More turbulence means a high Reynolds Number and a high Nusselt Number which gives rise to the heat transfer rate. The present market trend is predicated on best-optimized quality parameters with low quantity, so the market demands economical, compact, lightweight, and good effective fins. The optimization of the size of the fin is of bigger significance. Therefore, fin must be designed to achieve the maximum amount of heat removal with low material expenditure.

2. NOMENCLATURE

T_x=Tip temperature of the fin

T_o=Root temperature of the fin
T_∞=Ambient temperature of the fin
P= Perimeter of the fin
h= Convective heat transfer coefficient
K= Thermal conductivity of the material in w/m^2 k
A= Cross section of the fin in mm^2

3. METHODOLOGY

A. Material selection

Generally, there are two sorts of materials used for fins aluminum and copper. The thermal conductivity of aluminum is 200 W/m K and that of copper is 385 W/m K. The melting of copper is 10840 and the boiling point is 25950 and that of aluminum are 6580 and 20570. Aluminum selected for the experimental and simulated analysis.

B. Design of Fin and Heater plate

Fins and heater are designed using Solid works Software. The heater is made of aluminum material with a length of 200 mm, width of 100 mm and 20 mm thickness. There are five fins on base plate. Fin dimension are 90 mm length 40 mm width and 43 mm height and 3 mm thickness. Two fins are manufactured one is solid rectangular fin and the other one is rectangular fin with circular perforations of 5 mm.

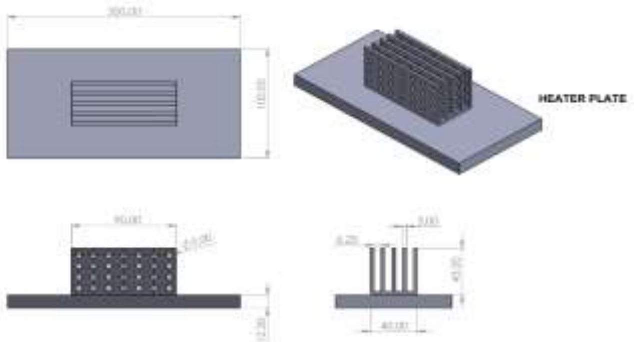

Fig. 1. Design of Heater Plate and rectangular fin with circular perforation.

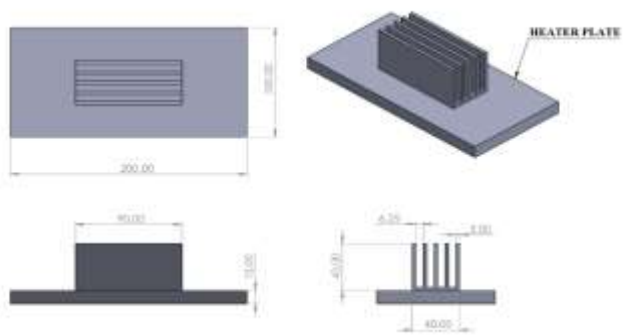

Fig. 2. Design of Heater Plate and rectangular fin non-perforation.

C. Manufacturing of Fin

An Aluminum block of 100mm length 50mm width and 50mm height is selected for the manufacturing of the fin. Two fins are manufactured one is solid rectangular fin and the other one is rectangular fin with circular perforations of 5 mm. The fin is designed in Solid Works software. Fin dimension are 90 mm length 40 mm width and 43 mm height and 3 mm thickness. There are five plates on both the fins. Fins are manufactured using CNC milling machine. It is used to obtain required dimensions of specimen, after machining in milling machine fins are transferred to drilling machine for the perforations.

Fig. 3. Manufactured Aluminum perforated fin

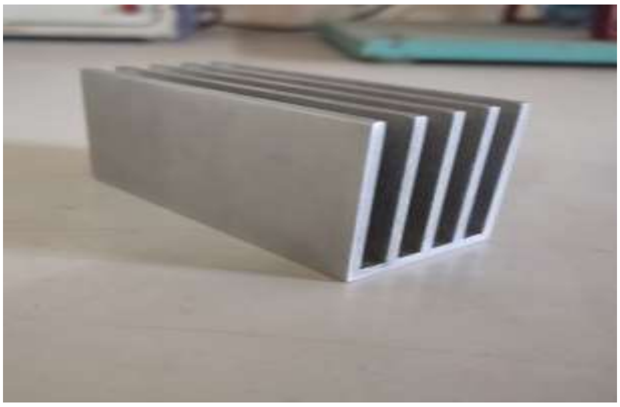

Fig. 4. Manufactured Aluminum non-perforated fin.

4. ANALYSIS OF FINS BY EXPERIMENTAL METHOD

Test is conducted in an experimental set up. Fins are placed on the aluminum based heater in the duct. The heat input given to the heater is 20 watts. Thermocouples are attached to the different surfaces of the fin. 11 thermocouples are used to measure the temperature of the different surfaces of the fins. A blower is used for the continuous circulation of air over the surface of the fin as the experiment is of forced convection type. Velocity of the air in the duct can be measured using venturi meter. Readings of temperature was measured by the thermocouples, input voltage and current will be measured by reading on control panel.

Boundary conditions

Ideal air was used as the Fluid passing through the duct and fin. For all the solid walls, no penetration and no slip boundary conditions were considered. For the inlet port of the duct, velocity and temperature boundary conditions were used. For the outlet port of the duct, average static pressure boundary condition was used.

1) Ambient temperature: 303 K
2) Fin Material: Aluminum
3) Thermal Conductivity of the material: 202.4 w/m c
4) Velocity Inlet: 0.2 m/s
5) Heat Input: 20 watts

Observation table

Table 1: Reading of non-perforated fin

Thermocouple Reading											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Duct**
53	40	42	42	42	43	44	43	44	42	43	37

Table 2: Reading of perforated fin

Thermocouple Reading											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Duct**
53	40	42	40	42	42	44	42	44	42	43	37

Formula used for the Calculation

$$\frac{T_x - T_\infty}{T_0 - T_\infty} = \frac{\mathrm{Coshm}(L - x)}{\mathrm{CoshmL}}$$

$$m = \frac{\sqrt{Ph}}{\sqrt{KA}}$$

5. ANALYSIS OF FINS BY SIMULATION

Analysis of fins are done using Ansys 17.2 software. Solid models of fins are made using Solid Works software. Solid models of fins were analyzed and simulated in Ansys 17.2 Software. Temperature on different points of fin were obtained from the software. Convective heat transfer coefficient, turbulence intensity surface heat transfer coefficient, temperature air flow also calculated using the Ansys 17.2 software.

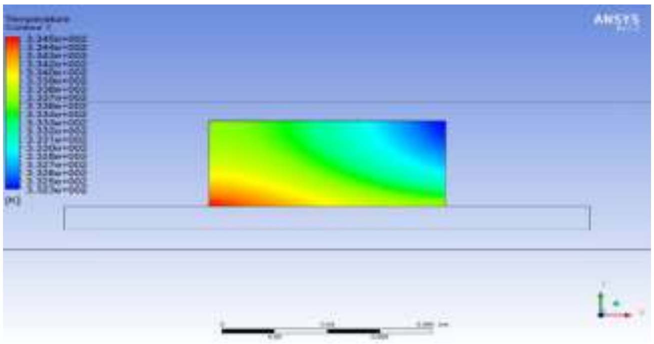

Fig. 5. Temperature profile for Solid fin.

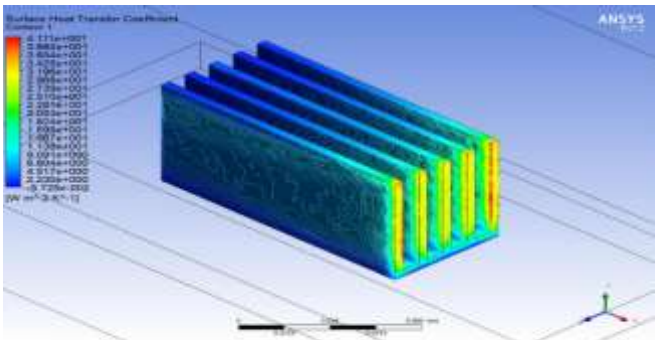

Fig. 6. Convective heat transfer coefficient profile for Solid fin.

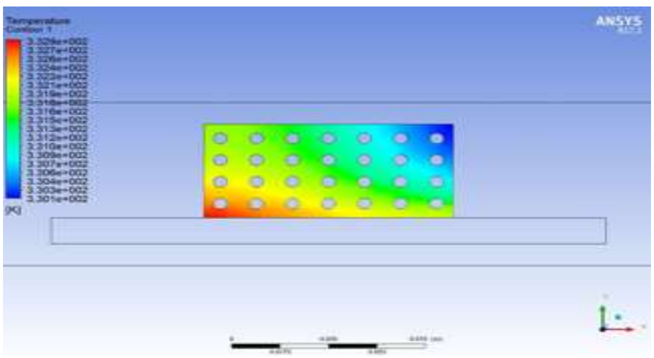

Fig. 7. Temperature profile for rectangular fin with circular perforation.

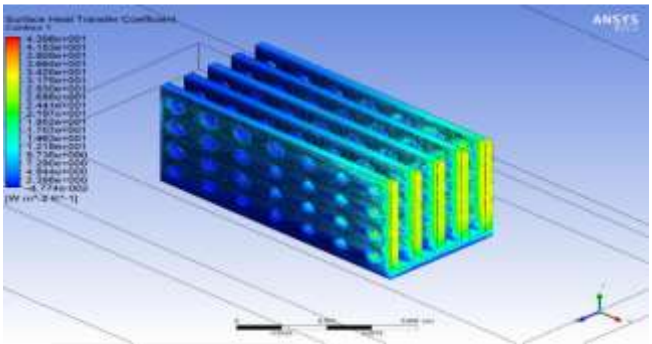

Fig. 8. Convective heat transfer coefficient profile for the rectangular fin with circular perforation

6. RESULTS

The Convective heat transfer coefficient (h) is calculated using suitable formula. Convective heat transfer coefficient is calculated from experiment and simulation for both the solid fin and solid fin with circular perforation. Due to non-uniform heating, losses, irregular surface and obstructions in duct creates the turbulence so that the value of convective heat transfer coefficient is more in experimental method as compared to simulation. The calculated result for both the cases are given in below table.

Table 3. Results

SHAPES	CONVECTIVE HEAT TRANSFER COEFFICIENT W/M^2 C	
	EXPERIMENT	***SIMULATION***
NON-PERFORATED	21.83	16.85
PERFORATED	34.18	22.56

7. CONCLUSION

Both the fins are simulated and analyzed experimentally carefully. From the above study, it is concluded that the convective heat transfer coefficient of the rectangular fin with circular perforation is maximum. Perforation creates turbulence compare to solid fin so perforated fin has 36% more convective heat transfer coefficient compared to solid rectangular fin. Due to the increase in convective heat transfer coefficient, the heat transfer is also more in perforated fin. In this study, the effect of the various parameters like geometry, Reynolds number, and friction factor on the heat transfer for the rectangular fins with circular perforation are investigated experimentally. The effects of Reynolds number and perforation on the heat transfer characteristics were determined. The Nusselt numbers of perforated fin arrays, as well as solid fin arrays, increases with an increase in Reynolds number. Make use of perforated fins not only increases heat dissipation rate but also simultaneously reduces fin weight, low weight means saving material of fin and which decreases the expenditure on the fin material and related equipment. Hence it may be utilized for cooling of air for much electronic equipment and many other industrial applications.

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