Experimental Investigation of Fins With Different Geometric Profile

Mr.Nalkande S.A
M.E. Student, Mechanical Engg.
DPES Wagholi, Pune.

Prof. Shiriramshasri
ME Co-ordinator, Mechanical Engg. Department
DPES Wagholi, Pune.

Abstract: Remove the heat from heated surface and reducing cost and material weight become a major task for design of exchanger equipment's like electronic instrument, refrigeration and air condition, electronic power plant ,chemical industry and I C engines. Develop of super heat exchangers to transfer heat from heated surface and to increase efficient techniques to exchange the maximum amount of heat from extended surface to the ambient fluid. Ambient fluid may be force convection or natural convection. The research summarized in this paper presents the experimental investigation of fins with different geometric profile and analysis of temperature profile .The experiment was carried out in the laboratory using a test rig for attaching rectangular fins with and without circular perforation and triangular fins to a flat base plate. The number of circular perforation done in a rectangular fins. The experiment is conducted for different fin geometry (rectangular and circular) settings.

Keywords: Heat transfer rate, Perforated fins, natural convection, Forced convection

1. INTRODUCTION

Extended surfaces that are well known as a fin are commonly used to enhance heat transfer in many applications. Therefore, various types of fins like rectangular plate fins, square pin-fins and circular pin-fins are commonly used for both natural and forced convection heat transfers. Extended surface heat transfer plays a very important role in heat exchangers involving a gas as one of the fluids. A heat exchanger is a device which is used to transfer thermal energy between two or more fluid, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. Not only are heat exchangers often used in the process, power, petroleum, air-conditioning, refrigeration, cryogenic, heat recovery, alternative fuel, and manufacturing industries, they also serve as key components of many industrial products available in the market. The heat exchangers can be classified in several ways such as, according to the transfer process, number of fluids and heat transfer mechanism. Plate type extended surface heat exchangers have corrugated fins mostly of triangular or rectangular cross-sections sandwiched between the parallel plates. These are widely used in automobile, aerospace, cryogenic and chemical industries, electric power plants, propulsive power plants, systems with thermodynamic cycles i.e. heat pump, refrigeration etc. and in electronic, gas- liquefaction, air-conditioning, waste heat recovery systems etc. They are characterized by high effectiveness, compactness (high surface area density), low weight and moderate cost. The next category is Tube-Fin Heat Exchangers, These heat exchangers may further be classified as (a) conventional and (b) specialized tube-fin exchangers. Tube-fin exchangers are employed when one fluid stream is at a high pressure and or has a significantly higher heat transfer coefficient than that of the other fluid stream. In a conventional tube-fin heat exchanger, the transfer of heat takes place by conduction through the tube surface. Kadir Bilen et al. [1] carried out experimental study on the heat and friction loss characteristics of a surface with cylindrical fins in a channel having rectangular cross section with larger fin diameter and different channel geometry, employing a finned heating surface kept at a constant temperature of 45^{o}C for two-fin arrangement inline and staggered. Regarding studies about perforated fins Sparrow and

Carranco Ortiz [2] experimentally determined heat transfer coefficient on an upstream facing surface and how they are related to diameter ratio and Reynolds number. Wadhah Hussein Abdul Razzaq Al Doori [3] discuss enhancement of natural convection heat transfer from the rectangular fins by circular perforations. K. H. Dhanawade et al [4] discuss enhancement of forced convection heat transfer from fin arrays with circular perforation. The results of perforated fin arrays have been compared with its external dimensionally equivalent solid fin arrays. It shows that enhancement in heat transfer of perforated fin arrays than solid fin arrays. D. Abdullah H. AlEssa [5] determined augmentation of heat transfer of a fin by rectangular perforations with aspect ratio of three. The magnitude of heat dissipation enhancement depends upon the fin thickness, its thermal conductivity, the perforation dimension, lateral and longitudinal spacing. Finally, the study showed that, the perforating of the fins enhances heat dissipation rates and at the same time decreases the weight of the fin. M.R. Shaeri et al. [6-8] three- dimensional array of rectangular perforated fins with square windows was arranged in lateral surface of fins. Three –dimensional incompressible laminar and steady fluid flow with constant properties, and heat transfer of a heated array of rectangular perforated and solid fins attached on the flat surface, perforations with rectangular cross section was along the length of bluff plates was studied numerically. Abdullah H. AIEssa et al. [9-12] found that numerically enhancement of natural convection heat transfer from a fin by triangular perforations, square perforation, and rectangular perforation by using finite technique. Bayram Sahin et al. [13, 14] experimentally investigated overall heat transfer, friction factor and the effect of various design parameters on heat transfer and friction factor for heat exchanger equipped with square and circular cross sectional perforated pin fins in a rectangular channel. Torii and Yang [15] studied two dimensional, incompressible thermal-fluid flows over both sides of a slot – perforated flat surface, which was placed in a pulsating free stream. The object of the present study is to determine thermal performance of a new design of perforated fins with circular perforations and without perforations. Thus, turbulent fluid flow and convective heat transfer around arrays of solid and perforated fins are studied experimentally. In this experiment two types of perforated fin arrays are compared with solid fin arrays. The external dimensions (L×H×t) of all fins were kept constant. Heat transfer is a thermal energy which occurs in transits due to temperature difference**.** The modes of heat transfer are conduction, convection and radiation. Fin is a thin component or appendage attached to larger body or structure. Based upon the cross sectional area type, straight fins are of different types such as rectangular fin**,** triangular fin, trapezoidal fin parabolic fin or cylindrical fin. Fin performance can be measured by using the effectiveness of fin, thermal resistance and efficiency. Triangular fins have applications on cylinders of air cooled cylinders and compressors, outer space radiators and air conditioned systems in space craft. Several authors paid attention in analyzing the performance of fins. Thirumaleshwar [1] in his book provided an introduction to modes of heat transfer. He had given detailed information of extended surfaces such as boundary conditions and analysis. Arora et al.[2] in their book provided an introduction to triangular fins and they had given detailed information of triangular fins its boundary conditions and analysis. Incropera [3] in his book proposed a correlation for triangular fins. He discussed two dimensional fin analysis participating in heat transfer

Fin Analysis Methodology

The rate of heat transfer from the fin

$$Qo = [PhkA]^{\frac{1}{2}} \left[\frac{\frac{h}{mk}+\tanh(ml)}{1+\frac{h}{mk}\tanh(ml)}\right] (Ts - T\infty).$$

The energy balance for experimental set-up is

$$P_{input} = qu + n \times Q_o,$$

where P_{input} =Power input to the base plate.

$$Pin = h[A_u\,(T_s - T_\infty)] + \sqrt[n]{PhkA}\,\left[\frac{\frac{h}{mk}+\tanh(ml)}{1+\frac{h}{mk}\tanh(ml)}\right](Ts - T\infty)$$

where

qu is the heat lost by uncovered area of base plate,

Qo is heat lost by one fin,

n is the number of fins used,

Au is the uncovered area of base plate.

The above equation is used for calculating the heat transfer coefficient in the experimental investigation. The pitch distance between two fins is fixed.. Three plain plate type fins were used. The power input will be constant.

For Perforated fin-

$Q = h_{pf} A_s (T_{s(av)} - T_\infty)$.

Where,

A_S =Total heat transfer area for plate type circular perforated fins.

h_{pf}= Heat transfer coefficient for plate type circular perforated fins.

$T_{s(av)}$ = Average base temperature.

T_∞= Ambient temperature.

Total heat transfer area (A_s) = Open area of base + total surface area contribution from the fins.

Triangular fin

For a triangular fin representing length of fin L, thickness, and width of fin, W and assuming the heat flow is unidirectional and it is along length and the heat transfer coefficient (h) on the surface of the fin is constant.

Heat lost by triangular fin,

$$Q = 2W\theta\sqrt{hk\delta}\left[\frac{\mathrm{I}(2\mathrm{B}\sqrt{L})}{\mathrm{Io}(2\mathrm{B}\sqrt{L})}\right]$$

where,

θ= temperature difference, K.

k=thermal conductivity.(W/mK)

B= fin parameter,

I= Bessel function of first kind

I0=Bessel function of first kind

The mass of triangular fin,

$$M_t = \frac{1}{2} * 2\delta L W \rho$$

ρ =Density of fluid kg/m^3

Rate of heat flow per unit mass ,

$$q = \frac{\text{heat flow through fin}}{\text{mass of fin}}$$

$$q = \frac{2W\sqrt{hko\theta o}\,\frac{\mathrm{I}(2\mathrm{B}\sqrt{L})}{\mathrm{Io}(2\mathrm{B}\sqrt{L})}}{\frac{1}{2} * 2\delta * L * W * \rho}$$

Efficiency of triangular fin,

$$= \frac{2W\sqrt{hko\theta o}\,\frac{\mathrm{I}(2\mathrm{B}\sqrt{L})}{\mathrm{Io}(2\mathrm{B}\sqrt{L})}}{2WLh\theta}$$

Effectiveness of triangular fin,

$$\epsilon = \frac{\text{heat lost with fins}}{\text{heat lost without fins}}$$

$$\epsilon = \frac{2W\sqrt{hko\theta o}\,\frac{\mathrm{I}(2\mathrm{B}\sqrt{L})}{\mathrm{Io}(2\mathrm{B}\sqrt{L})}}{\mathrm{hAb\theta o}}$$

Experimental Setup

It consist of a vertical rectangular duct supported by a bench mounted stand .A test section which consist of a base plate, pinned and plate type fin may be installed in the duct and secured by a quick release catch on each side. An electric heating element is fitted at the back side of the base plate. With thermostatic protection of overheating, the temperature at the base is monitored by a thermocouple sensor with connecting lead. A fan is situated at the top of the duct provides the air stream in the duct with variable speed. Air velocity in the duct, whether natural or forced, is indicated on a portable anemometer. The anemometer probe is inserted through the wall of the duct.

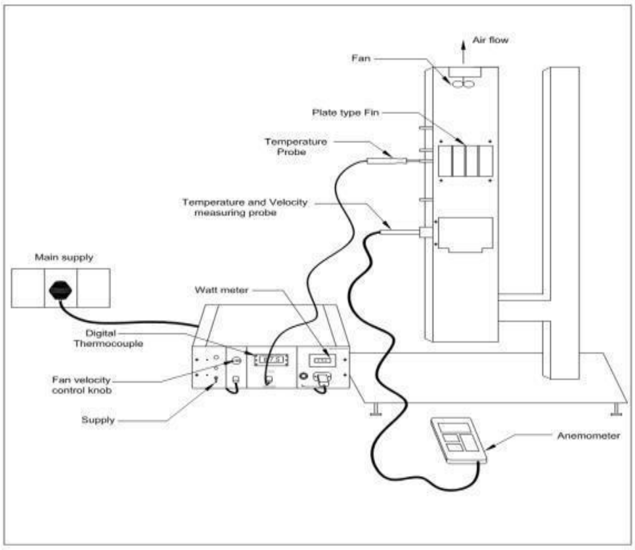

Figure1. Schematic diagram for the experimental setup.

A thermocouple probe permits measurement of air temperature, together with surface temperature of pins and fins. These temperatures are determined by inserting the probe through access holes in the duct wall. An independent bench mounted-console contains temperature measurement, power control, and fan speed control circuit with appropriate instrumentation. Temperature measurement, to a resolution of 0.1°C, is affected using thermocouple sensor with direct digital read- out in °C. An electric console incorporates a solid state power regulator with a digital read-out to control and indicate power supply to exchanger on test. The exchanger is connected to the console via the supply lead. Power is supplied to the equipment via a supply lead connected to the rear of the electric console. The power control circuit provides a continuously variable, electrical output of with a direct read-out in Watts.

Figure 2. Photograph of test section.

Table 1. Details of fin

Aluminum fin size in (mm)(L*H*T)	Perforation of diameter in (mm)	Numbers of holes.
100*68*2	Solid	-
100*68*2	7	15

Base plate dimension -100*100*20mm(L*W*T).
Box dimension-120*120*500(squire box).

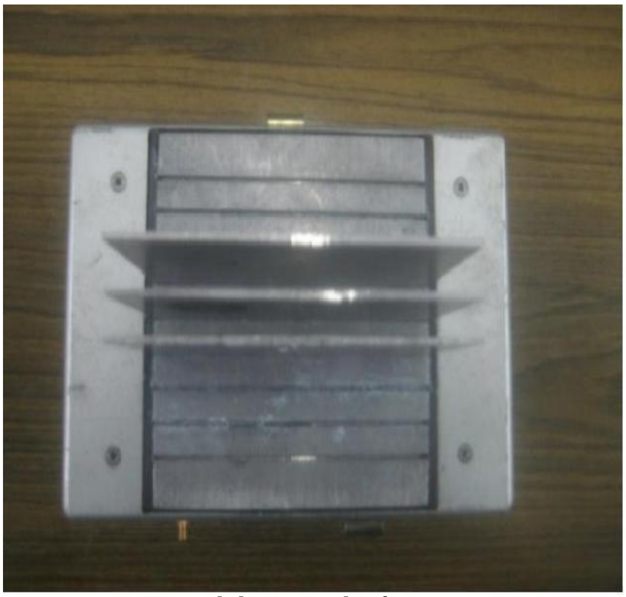

Figure 3. Solid rectangular fins.

Figure 4. Perforated rectangular fins.

4. Result and Discussion

In this section, the experimental results of solid plate fins and circular perforated fins on temperature and distance are presented. The experiments were carried out by varying the fin pitch and blower fan speed. Figures 5. show the variations in temperature with distance from base plate at different sold fin pitches. Fig 5 shows the results when the solid fin pitch was kept 1cm. The experimental results at five settings of blower fan speed are plotted in the Fig 5. It can be seen from the figure that when the fan is switched off (fan velocity zero), which corresponds to the case of free convection, the temperature at the solid fin base and at different locations is highest. After switching on the blower fan, i.e. under forced convection conditions the temperature of the fin reduces. The experiments were performed for four different settings of fan speed under forced convection. From the Fig 5, It is observed that as the fan velocity increases the fin temperatures at different locations reduced progressively as can been seen. It is obvious from the Figures 5 that a trend of temperature variations is observed. However, the absolute values of temperatures recorded are different. It is observed that when the blower fan velocity is zero, the temperature recorded for the different fin pitch settings are nearly the same. No perceptible change in the fin base temperature or temperature at different locations along the length of the fin is observed. When the blower fan speed increases the temperature of the fin is observed to be less when the fin pitch distance is increased. The reduction in the temperature with the increase in fin pitch is more pronounced when the higher blower fan speed is selected.

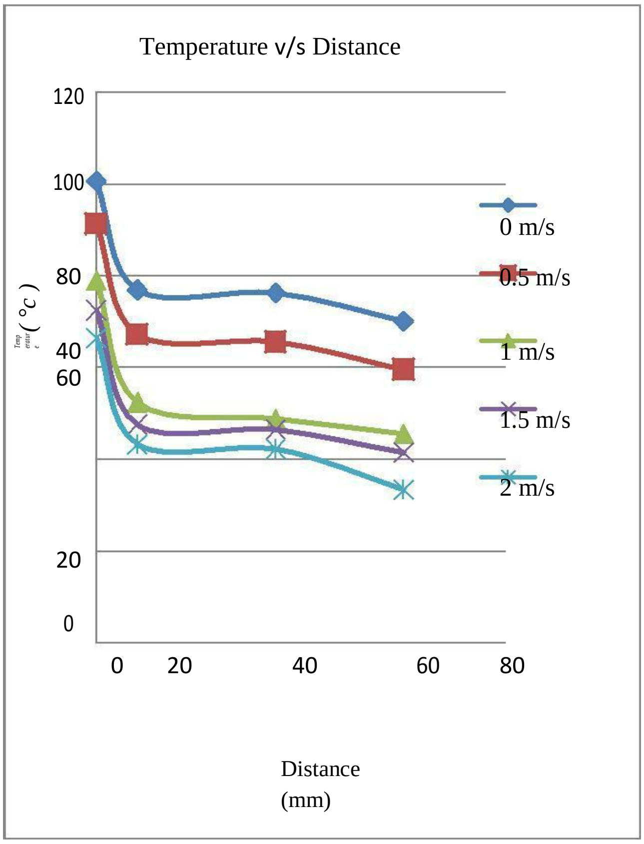

Figure 5. Variation of temperature with distance solid plate

Similarly we find out the variations in temperature with distance from base plate at different circular perforated fin pitches. Figure 6 shows the variations in temperature with distance from base plate at different circular perforated fin pitches. No perceptible change in the fin base temperature or temperature at different locations along the length of the fin is observed. When the blower fan speed increases the temperature of the fin is observed to be less but when the fin pitch distance is increased the temperature of the fin is shows small increment at higher blower fan speed. The reduction in the temperature with the increase in fin pitch is more pronounced when the higher blower fan speed is selected but after sometime with the increase in fin pitch at higher blower fan speed it shows the small increment in temperature.

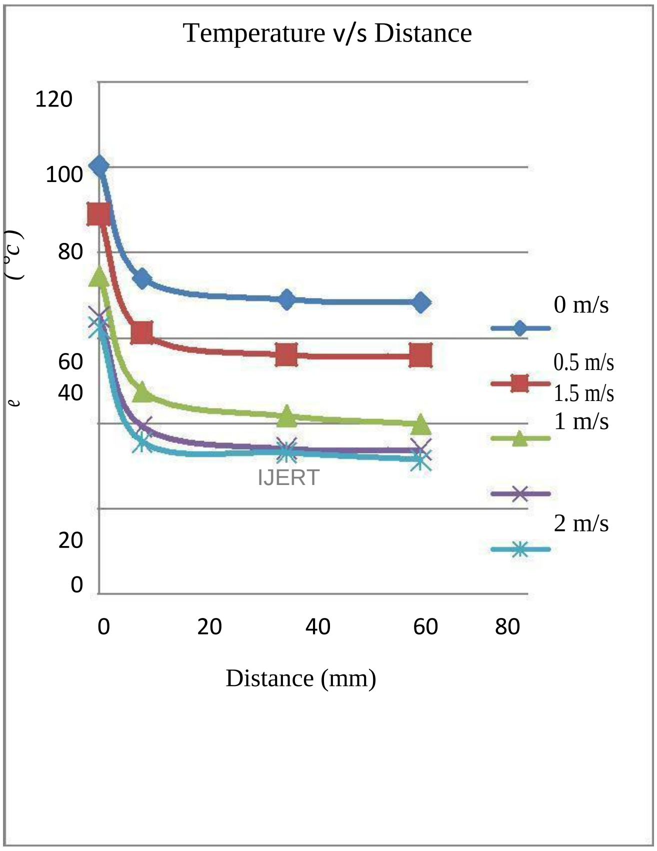

Figure 6. Variation of temperature with distance from base plate for circular perforated fin .

It is observed that from the figure 5 and 6 of perforated fins that, there is a decrement in the temperature at different locations along the fin length compared to the same case when no circular perforation was done but after sometime for circular perforated fin as we increase the blower fan speed we observe the small increment in temperature as the fin pitch increases.

5.Conclusion

1. The experiments were carried out for different fins geometry settings under different conditions solid and circular perforated fins. The experiments were performed for four flow conditions, four forced heat transfer conditions. The flow was both laminar and turbulent in all the experiments.

2. For solid fin, under forced convection heat transfer condition, the effect of change in velocity of air to change the heat transfer rate. There was no noticeable change in the fin base temperature and convection heat transfer coefficient.

3. For perforated fin, under forced convection to draw temperature profile at different velocity and also similar to triangular fins.

4. In order to study the effect of changed air flow pattern on the fin performance, circular perforation was done in a solid fin. The performance of three rectangular solid plate fins were compared with three rectangular circular perforated fins under free and forced convection heat transfer conditions. The circular perforated fin arrangement in free convection case showed about 22.26 to 32.48 percent increase in the convection heat transfer coefficient, while in forced convection condition the increase ranged from about 36.66 percent to 81.86 percent in comparison to solid fin.

6.References.

[1] Kadir Bilen, Ugur Akyol,Sinan Yapici, *"Heat transfer and friction correlations and thermal performance analysis for a finned surface",* Energy Conversion and Management vol.42, pp. 1071-1083, 2001.

[2] E.M. Sparrow, M. Carranco Ortiz, 1982. *"Heat transfer coefficients for the upstream face of a perforated plate positioned normal to an oncoming flow".* Int. J. Heat Mass Transfer 25 (1), 127–135.

[3] Wadhah Hussein Abdul Razzaq Al- Doori, 2011. *"Enhancement of natural convection heat transfer from the rectangular fins by circular perforations"*, International Journal of Automotive and Mechanical Engineering, Volume 4, Pages 428-436.

[4] K. H. Dhanawade and H. S. Dhanawade , 2010. *"Enhancement of Forced Convection Heat Transfer Fin Arrays with Circular Perforation"* IEEE, Volume 10, Pages 192-196 [5] D. Abdullah H. AlEssa, 2012. *"Augmentation of heat transfer of a fin by rectangular perforations with aspect ratio of three"*. International Journal of Mechanics and Applications Volume 2, pages 7-11

[6] M.R. Shaeri, M.Yaghoubi, K Jafarpur *"Heat transfer analysis of lateral perforated fin heat sinks"*, Applied Energy vol. 86, pp. 2019-2029, 2009.

[7] M.R. Shaeri, M.Yaghoubi, *"Thermal enhancement from heat sinks by using perforated fins"*, Energy conversion and Management, vol.50, pp. 1264-1270, 2009.

[8] M.R. Shaeri, M.Yaghoubi, *"Numerical analysis of turbulent convection heat transfer from an array of perforated fins"*, International journal of heat and fluid flow, vol.30, pp. 218-228, 2009.

[9] Abdullah H. AIEssa, Ayman M.Maqableh and Shatha Ammourah,*"Enhancement of natural convection heat transfer from a fin by rectangular perforations with aspect ratio of two"*, International journal of Physical Sciences, vol.4, 10, pp.540-547, October 2009.

[10] Abdullah H. AIEssa and Mohmmed Q. Al-Odat, *"Enhancement of natural convection heat transfer from a fin by triangular perforations of bases parallel and toward its base,"* The Arbian Journal for Science and Engineering, vol.34 2B, October 2009.

[11] Abdullah H. AIEssa and Mohmmed I. Al-Widyan, *"Enhancement of natural convection heat transfer from a fin by triangular perforations of bases parallel and toward its tip",* Applied Mathematics and Mechanicsvol.29, no 8, pp. 1033- 1044, 2008.

[12] Abdullah H. AIEssa and Fayez M.S. Al-Hussien, on topic *"The effect of orientation of square perforations on the heat transfer enhancement from a fin subjected to natural convection"*, Heat and Mass Transfer vol.40, pp. 509-515, 2004.

[13] Bayram Sahin, Alparslan Demir, *"Performance analysis of a heat exchanger having*

perforated square fins", Applied Thermal Engineering, vol.28, pp. 621-632, 2008.

[14] Bayram Sahin, Alparslan Demir, "Thermal performance analysis and optimum design parameters of heat exchanger having perforated pin fins", Energy Conversion and Management, vol.49, 2008, pp. 1684-1695. ``

[15] Shuichi Torii, Wen-jei Yang, *"Thermal Transport phenomena over slot perforated flat fins with heat sink in forced convection environment"*, ASME Heat Transfer.

[16] M. Thirumaleshwar, *Fundamentals of Heat and Mass Transfer,* Dorling Kindersely, 2011.

[17] *S.C.Arora, S.Domkundwar and Anand V.Domlundwar,* A Course in Heat and Mass Transfer, Dhanapati Rai and Co. (P) Ltd, 2004.

[18] F.P.Incropera, *Fundamentals of Heat and Mass Transfer,* John Wiley and Sons