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HEAT TRANSFER ANALYSIS OF PIN FIN ARRAY

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Abstract- *This paper emphasizes on the performance of pin fin based on the heat transfer analysis and it also describes the fabrication of pin fin array. For the fabrication of pin fin arrangement, aluminum metal was used as fin material and base plate was also aluminum. In this case seven fins were used. The fins of diameter 8.2 mm and length 70 mm were arranged in-line manner. The experiments were conducted for various mass flow rate of air. In the experimental investigation, the heat transfer coefficient for free convection h=31.6, 35.39, 38* W/m^2 ℃ *and for force convection h=54.14, 58.85, 64.78*W/m^2 ℃ *were investigated. The fin efficiency for pin fin shapes for free convection* η*=52.87, 60.16, 55.88% and for force convection* η*= 23.6, 20.84, 16.17% were also investigated. Pin fin become helpful to enhance heat transfer within a suitable performance. It was also cause to increase pumping power.*

Keywords: Pin fin, Free convection, Force convection, Convective heat transfer coefficient, Fin performance, Fin efficiency.

1. INTRUDUCTION

Heat transfer by convection between a surface and the surrounding fluid can be increased by attaching an extended thin strip of metal called fin. When heat transfer takes place by convection from both interior and exterior surfaces of a plate, generally fins are used on the surface where the heat transfer coefficient is low. The selection of fin depends on different parameters like geometrical shape, fin spacing, fin height, base thickness, kind of material, surface finish etc. There have been many investigations restricted on the heat transfer and pressure drop in channels with pin-fins of circular cross-section [1-7]. Sparrow et *al.* [1] were among the first to investigate the heat transfer performance of inline and staggered wall attached arrays of cylindrical fins. Metzger et *al.* [3] investigated the heat transfer characteristics of staggered arrays of cylindrical pin-fins. Simoneau and Vanfossen [4] also studied the heat transfer from a staggered array of cylindrical pin- fins. A review of staggered array pin-fin heat transfer for turbine cooling applications was presented by Armstrong and Winstanley [5]. The end wall heat transfer in the presence of inline and staggered adiabatic circular pin-fins were studied by Matsumoto et *al*. [6]The pin height-to-diameter ratios of typical heat sink used for such applications are between 1/2 and 4 [7]. Damerow et al. [8] measured pressure drops in channels with arrays of pin fins having *H*/*D* from 2 to 4 with various pin spacing geometries and found no *H*/*D* effect on the friction factor. A similar trend has been reported by Metzger et *al.* [9], who also obtained friction factors data, which agreed well with the long tube correlations proposed by Jacob [10]. Armstrong and Winstan-ley [11] compared the experimental data obtained by Peng [12], Metzger et *al*. [9], Damerow et *al*. [8], and Jacob [10]. The correlation proposed by Metzger et al. [9] provided the best fit for the data (within ±15%), while Damerow's [8] correlation did not match the experimental results. Although Jacob's [10] correlation was originally developed for long fins, it predicted the experimental data fairly well. An interesting result that might explain the similar pressure drop trends for long and intermediate size tubes was obtained by Sparrow et *al*. [13]. Heat transfer and pressure drop of flow across tube bundles/pin fins have been a subject of extensive research over the last century [14]. The Nusselt number and friction factor correlations obtained primarily through experimental studies have been developed for circular [15–19], rectangular [20, 21], oval [22], elliptical [23], diamond [24], hexagonal [25] and Lenticular [26] configurations, among others. Dimensional analysis suggests that the convective heat transfer across long cylinders in cross flows varies with the Reynolds and Prandtl numbers. Flows over intermediate size pin fin banks have been commonly used in turbine cooling systems to increase the internal heat transfer characteristics. The pin height-to-diameter, *H*/*d*, ratios of typical heat sinks used for such applications were between ½ and 4 [27]. Rahman [28] analyzed parabolic shape of fin [28]. Yusuf [29] showed rectangular shape of fin more efficient than parabolic shape [29]. The pin-fins with various cross-sections have different heat transfer and flow resistance characteristics, and that circular pin-fins are often used for applications because of their relative simplicity in fabrication. Therefore, it is essential to investigate various pin-fin geometries with different cross-sections in order to enhance the heat transfer and decrease the flow resistance. It is the aim of this study to investigate the heat transfer and performance characteristics for the pin-fin arrays attached on a flat surface in a rectangular box in case of free and force convection.

2. EXPERIMENTAL METHOD

Here pin fin is selected for heat transfer enhancement. Following parameters were selected: Determination of the size of fin, selection of fin material, Design fin with respect to my project job, Collection of the raw material, Construction of fin array as required size and shapes, Construction of a fin box as equal to the box of heat laboratory and fin shown in Table 1 and Fig. 1. Then experimental set up was performed with a heater and a thermocouple in the box. And finally we have taken the experimental data by doing experiment in several times and calculate the efficiencies from the data.

2.1. Experimental procedure

- **a)** Sufficient time was allowed to reach steady state operation before noting the heated wall temperature (t_H).
- **b)** The air temperature and the temperature at each of three points along the fin (t_F) were noted.
- **c)** For the force convection switch on the fan and select a low speed whilst maintaining the input power constant.
- **d)** After allowing sufficient time to reach steady state operation the reading rate are taken with the air velocity (U_A).
- e) Data should be repeated for a range of increasing fan speed.

2.2. Materials selection

At first aluminum metal were selected for fin array & plate box. Then a voltage regulator was used for measuring voltage. T-type thermocouple was used to measure the temperature. Heater was used for heating purpose. Asbestos and heat insulating cloth were selected for heat insulating purposes. Multi-meter was used for current measuring through the heater. Fan was used for supply air and Anemometer was used for measuring this supply air velocity. Selection of G.I sheet for fin box and screws due to attach fin into the fin plate.

3. GOVERNING EQUATION

The rate of convection heat transfer from the extended surface

$$Q = hA_H(t_H - t_A) + hA_F(t_{FAv} - t_A) \qquad (1)$$

Where,

h = convection heat transfer coefficient (assumed constant)

A_H = area of heated wall only

A_F = summed area of all fins

t_{FAv} = average temperature along the length of fins which may be approximated as mean temperature of three temperature measured along length.

The fin efficiency η is the ratio of the actual heat transfer from the surface to heat which would be transferred if the entire area were at base temperature.

Where $$\eta = \frac{t_{FAv} - t_A}{t_H - t_A} \times 100 \qquad (2)$$

Table 1: Specifications of the pin fin

Type	Dimension (mm)
Box length	172
Box width	123
Box height	54
Plate length	165
Plate width	118
Plate thickness	6
Fin length	70
Fin diameter	8.20

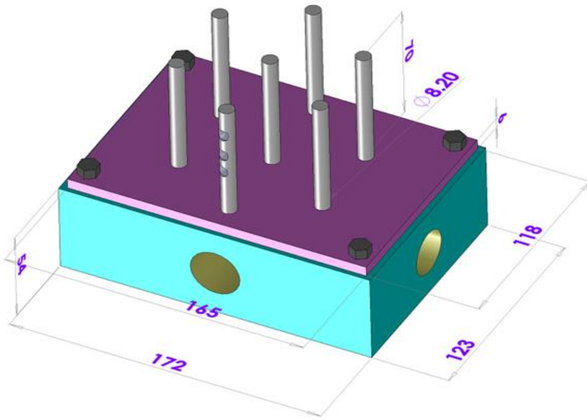

Fig. 1: Pin fin array

4. EXPERIMENTAL SETUP

In case of free convection (shown in Fig. 2) supply power first passes to the voltage regulator where we get supply voltage. The power supply then passes to the multi-meter . In this case we use multi-meter for the measurement of supply current. Finally it passes to the heater and the heater become heated. The heated wall tempereture were measured by thermocouple monitor and it was also used to measure the fin tempereture. From this data we calculated the fin efficiency. But during foece convection (shown in Fig. 3) an air duct were used to supply the flowing air to the fin and a fan were used to supply this air. The velocity of supply air were measured by anemometer. Fin efficiency for force convection is lower than that of free convection shown in Table 2.

Fig. 2: Assemble of fin for free convection.

Fig. 3: Assemble of fin for force convection.

Table 2: Heat transfer coefficient and fin efficiency.

Test no	Free convection		Force convection	
	h W/m^2 °C	η%	h W/m^2 °C	η%
1	31.61	52.87	54.14	23.6
2	35.39	60.16	58.85	20.84
3	38	63	64.78	16.17

5. RESULTS AND DISCUSSION

From Figure 4 it is observed that the heat transfer is increase rapidly with the fan speed. With the increase of fan speed the heat transfer coefficient is increase. It is also observed that efficiency of fin will decrease if velocity of fan is increase because increase in fan velocity occurs less time of contact between fin and air. As a result decrease actual heat transfer from fin and consequently decrease fin efficiency in case of force convection.

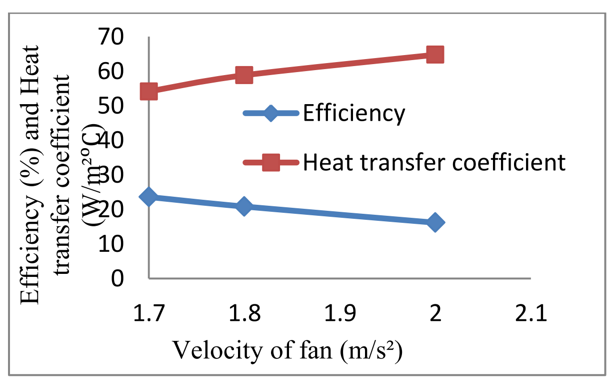

Fig. 4: Variation of efficiency & heat transfer coefficient with velocity of fan. (Force convection)

From Fig. 5: it is observed that the efficiency of fin decrease with the increase of heat transfer coefficient for forced convection. It is also observed that efficiency will increase if the heat transfer coefficient will increase for free convection.

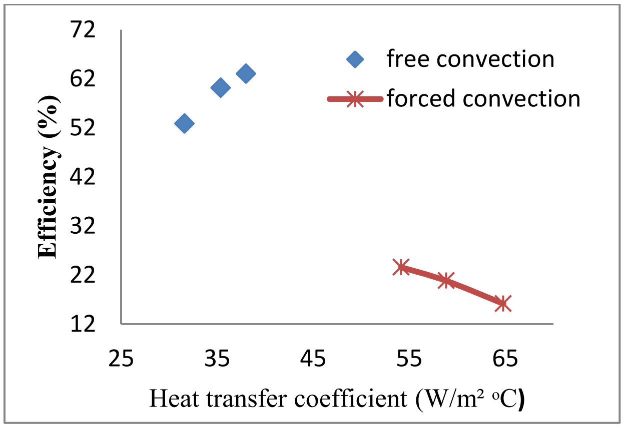

Fig. 5: Variation of fin efficiency with heat transfer coefficient

6. CONCLUSIONS

Fin is used in many type of application for heat transfer from the surface. We examine heat transfer in a fin as a way of some criteria design. Design of fin may be easy but it fabrication is not easy. In my project I design and constructed of pin fin array. I have to design the component by trail and error as there is no other way. During experiment I used a cylindrical heater, so uniform heat transfer may not occur through the base of fin. Fin surface were rebated to the base plate, some air resistance may be present due to poor rebating. In my project I assumed the heat loss is negligible but some heat loss during experiment. Overcoming all such problem, some error were still remains. But I was trying to best to complete my project.

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