Comparison of Forced convective heat transfer coefficient between solid pin fin and perforated pin fin

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ABSTRACT – The rapid growth in high speed multi-functional miniaturized electronics demands more stringent thermal management. The present work numerically investigates the use of perforated pin fins to enhance the rate of heat transfer. In particular, the numbers of horizontal perforations, horizontal diameters of perforation on each pin-fin are studied. Results show that heat transfer in perforated pin fin is greater than solid pin fin. Pressure drop with perforated pins is reduced as compared with that in solid fins and more surface area get available which enhance the convective heat transfer.

Keywords: Heat Transfer, Extended Surface, Forced convection, Perforated Fin.

1. Introduction

Extended Surface (Fin) is used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats with it. The high thermal conductivity allowing increased heat being conducted from the wall through the fin. Fins are used to enhance convective heat transfer in a wide range of engineering applications, and offer practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. Other applications include IC engine cooling, such as Fins in a car radiator.

Heat sinks are employed to dissipate thermal energy generated by electronic components to maintain a stable operation temperature. A compact, efficient and easily fabricated heat sink is required. However, the design of heat sink device is strongly dependent upon the need to balance thermal dissipation and pressure drop across the system such that the overall cost and efficiency may be optimized. An example of a familiar solution is to apply pin fin into a heat sink design.

The thermal dissipation performance of pin fin and pin fin heat sinks when subject to a horizontal impinging flow.

We concluded that the heat transfer and pressure coefficients for cylindrical attach perforated pin fin are higher than those of solid pin fin. Fins are widely used in the trailing edges of gas-turbine blades, in electronic cooling and in the aerospace industry. The relative fin height (H/d) affects the heat transfer of pin-fins, and other affecting factors include the velocity of fluid flow, the thermal properties of the fluid, the cross-sectional area of fluid flow.

2. Experimentation set-up

The experimental set-up consisting of the following parts

A. Main Duct (cylindrical)

B. Heater Unit

C. Base Plate

D. Data Unit

A. Main Duct (cylindrical): A cylindrical channel constructed by using galvanizing steel of 1 mm thickness and has a diameter of 150mm and length of 1200mm . at the middle there is attach the perforated pin fin .It will be operated in force draught mode by the blower of 0.5 H.P. 13000 rpm.

B. Heater Unit: Heater Unit (test section) has a diameter of 160mm and width of 20mm which is wound on the cylindrical fin portion the heating unit mainly consisted of an electrical heater The heater output has a power of 200 W at 220V and a current of 10 amp.

C .Central portion: On the central portion of the cylindrical duct there is pin fin attach and to heat that pin fin on the central portion of cylindrical duct band heater is wound to heat the pin fin.

D. Data Unit: It consists of various indicating devices which indicate the reading taken by the various components like sensors, voltmeter, manometer. There are temperature indicator which shows reading taken by the seven sensors in the range 0°c to 450 °c among this, two gives inlet and out temperature of air, three gives temperature at base, middle, and tip of the fin.

There is one sensor which shows temperature above the fin. One sensor gives reading at outlet.

Inlet flow rate of air is indicated by velocity indicator using manometer.

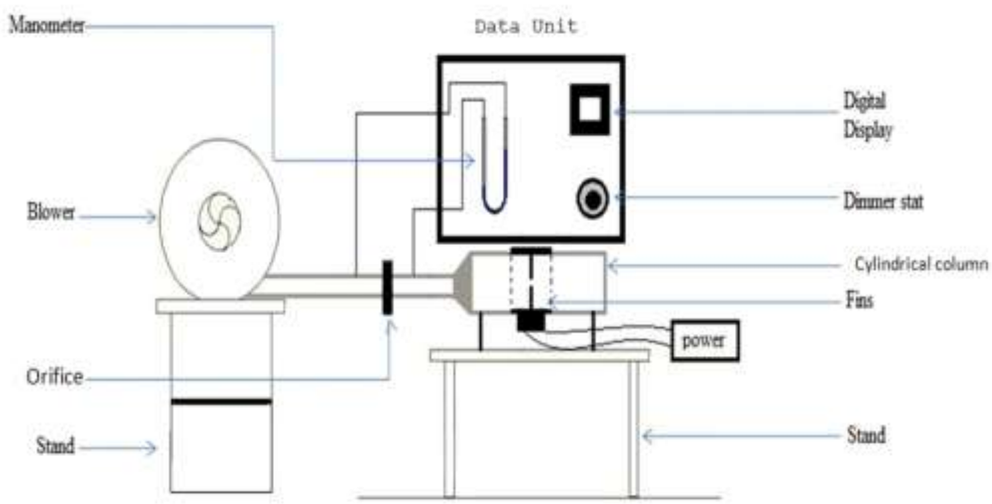


Fig1: pictorial view of experiment

3. Experimentation Procedure

1) First blower and heater are started simultaneously.
2) After starting the blower pressure difference due to the fins employed using manometer are noted.
3) Reading of atmospheric temperature is also taken.
4) Voltage is set to different values like 90v, 100v, 120v, 130v, 140v etc. and readings are taken for solid pin fin, single hole pin fin, double hole pin fin, three hole pin fins .
5) The voltage, current and temperatures at different points where thermocouples are attached are noted down.

Similarly readings at same voltage for the different pin fin sets. (i.e. solid, single hole, double hole, three holes are observed and noted)

4. Nomenclature

Q heat transfer
Q_{con} heat transfer due to convection
Q_{rad} heat transfer due to radiation
h heat transfer coefficient
A_s Surface area of fin
T_m mean temperature
I current (amp)
D diameter of duct
R resistance

5. Governing Equations

The Convective heat transfer rate electrically heated test surface is calculated by using

$$Q_{conv.} = Q_e - Q_{cond} - Q_{rad} \qquad (1)$$

where ,
Q_{conv} is the heat transfer rate by convection
Q_e is the heat transfer rate of electrical
Q_{cond} is the heat transfer rate by conduction
Q_{rad}. is the heat transfer rate by radiation,
Q_e is calculated using following equation

$$Q_e = I^2 \times R \qquad (2)$$

Where,
I is current flowing through heater and R is resistance.

In similar studies, investigators reported that total heat loss through radiation from a similar test surface would be about 0.5% of the total electrical heat input. The conductive heat losses through the sidewalls can be neglected in comparison to those through the bottom surface of the test section. Using these findings, together with the fact that wall of the test section are well insulated and readings of the thermocouple placed at the inlet of tunnel should be nearly equal to ambient temperature, one could assume with some confidence that the last two terms of Eq. (1) may be ignored.

The heat transfer from the test section by convection can be expressed as

$$Q_{conv.} = h_{avg}\ A_s\ [T_{m1} - T_{m2}] \qquad (3)$$

Hence, the average convective heat transfer coefficient have could be deduced using

$$h_{avg} = \frac{Qconv}{As[Tm1 - Tm2]} \qquad (4)$$

where
A_s is the surface area of fin.
T_{m1} is the mean temperature over surface.
T_{m2} is the temperature outside the fins.

Friction factor to measure amount of friction using pressure drop is calculated by equation below

$$f = \frac{\Delta P}{\left(\frac{L}{D_h}\right)\rho\frac{V^2}{2}} \qquad (5)$$

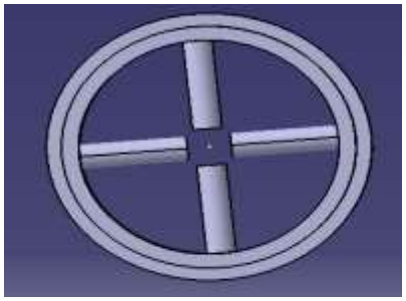


Fig2: Solid Fins

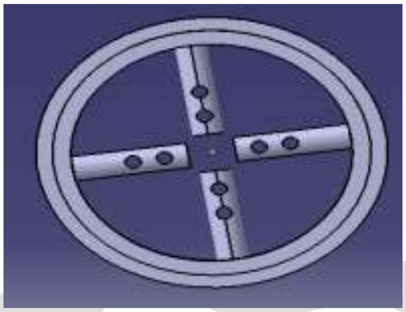


Fig4: 2 holes fins

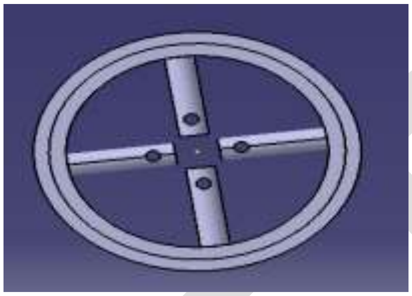


Fig3: 1 hole fins

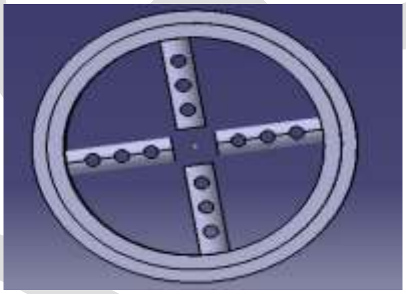


Fig5: 3 holes fins

6. Observations

The various observation like heat input "Q" in Watt, mean temperature over the fins T_{m1} in ^oC, mean outside temperature T_{m2} in ^oC, temperature difference "ΔT" in ^oC and "h" heat transfer rate in $W/mm^2\,^oC$ and "ΔP" pressure drop in mm of water for solid pin fin , 1 hole pin fin, 2 holes pin fin, and 3 holes pin fins are made and calculated.

7.Result

Result stated that heat transfer increases with increasing number of parforation on fins .

7.1. Pressure Drop Effect

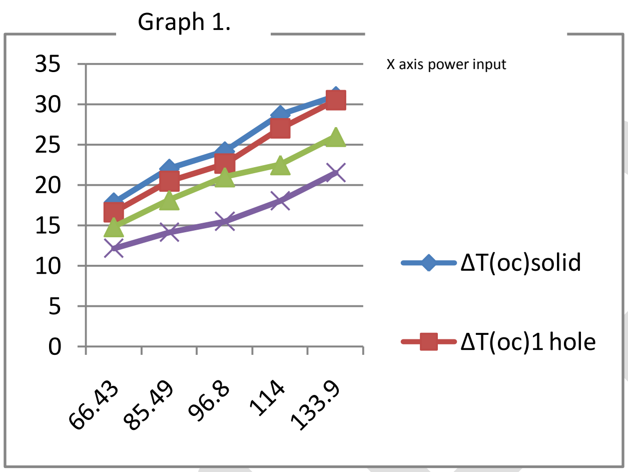
Fig.2, Fig.3, Fig.4 & Fig.5 shows how the fins are arranged in circular duct. *"f" i.e.* Friction Factor decreases with increasing number of perforation as the perforations decrease the blockage effect. Since the number of perforation is restricted on a given pin, *f* may be further reduced by increasing the perforation diameter. It is important to note that vertically perforated pins are critical for heat sinks subject to impinging flow. As shown in Fig., pins with horizontal and vertical perforations have lower *f* than pins without, and pins with vertical perforations have the lowest *f*.

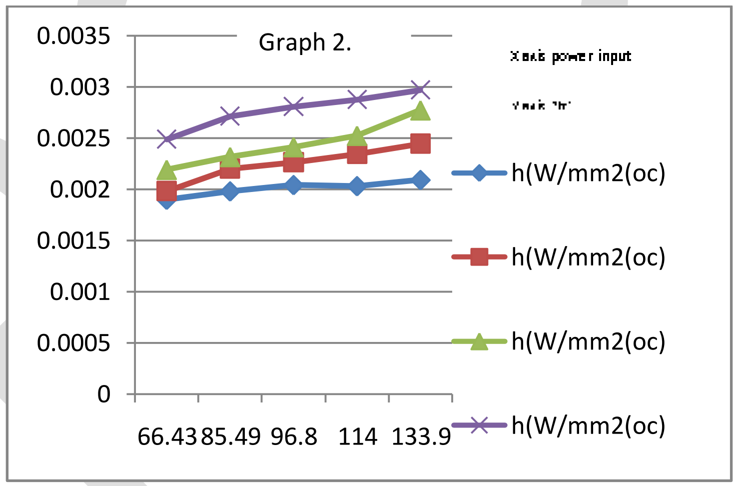
7.2. Heat Transfer Performance

More importantly, thermal dissipation is higher with perforated pin fins than with solid pins. It is found that the larger the number of perforation on each pin fin However, further increasing the perforation diameter reduces heat transfer from base to tip of the fin. This is due to the decrease in the cross sectional area of the pin for heat conduction along the pins.

7.3.Heat Transfer Efficiency

It is found that the perforated pin fins have higher efficiency than the solid pin fins. The result shows that heat transfer increases with number of perforations, when solid fins are compared with 3 holes pin fin it is find out that h increases with increasing number of hole from no hole to 3 hole obtained successfully. Also the temperature difference decreases with increase of number of perforation. This shows that low temperature difference leads to high heat transfer. The efficiency of the perforated pin fins are 15 to 17 % more than solid pin fins.





7.4. Conclusions

In this study, the overall heat transfer and friction factor for the heat exchanger equipped with cylindrical cross-sectional perforated pin fins were investigated experimentally. The effects of the flow and geometrical parameters on the heat transfer and friction characteristics were determined:

a) ΔP across the pin fins are smaller with increasing number of perforation and perforation diameter. In all cases, perforated pin fin array performs better than the solid pins. Hence, perforated pin fins require less pumping power than the solid pins for the same thermal performance.

b) Maximum “h” is obtained from pin fin with 3 perforations, 3mm horizontal perforation diameter, It is approximately 10% higher than that for the solid pins at $R_{ep}=11\times10^3$. More importantly, the thermal energy is dissipated at a smaller pressure drop.

c) Further increasing the perforation diameters will lead to a reduction in thermal dissipation. This is due to the decrease in vertical heat conduction along the perforated pin fins, as well as the perforations induces reshaping of wakes behind the pins.

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