Int. J. Mech. Eng. & Rob. Res. 2014

International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 2, April, 2014

Research Paper

CONVECTIVE HEAT TRANSFER COMPARISON BETWEEN SOLID AND PERFORATED PIN FINS

Ashok Fule[1]*, A M Salwe[1], A Zahir Sheikh[1], Nikhil Wasnik[1]

Corresponding Author: **Ashok Fule, ✉ ashokrfule@gmail.com*

The forced convective heat transfer between perforated pin fin and solid pin fin in cylindrical channel is numerically studied in this paper. Air is employed as the cold fluid and the effect of different number of perforation and hence the heat transfer is studied in detail. In the present work heat transfer is compared between solid and perforated pin fin in cylindrical column. The cylindrical column has diameter of 150 mm and length of 1200 mm. The result shows that the perforated pin fins have higher heat transfer as compared to solid pin fins. Results also show that there is significant increase in convective heat transfer with increase in number of perforation when comparison between single, two, and three holes perforation is done.

Keywords: Heat transfer, Forced convection, Perforated pin fin

INTRODUCTION

It is well known that, to increase the heat transfer by convection, extended surfaces i.e. fins are used. Due to surface contact area heat transfer increases. 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. Fins are widely used in the trailing edges of gas-turbine blades, in electronic cooling and in the aerospace industry. The purpose of this paper is to compare the heat transfer between solid fin and perforated fin. If we will use perforated pin fin more surface area explore, leads to more fin surface area contact with the working fluid. This will leads to more heat transfer as compared to solid fin.

There have been many investigations regarding heat transfer and pressure drop of channels with pin fins has been done by the following researchers considering the different factors for heat transfer. Jian Yang (2010) studied the forced convective heat transfer in three-dimensional porous pin fin channels. The Forchheimer-Brinkman extended Darcy model and two-equation energy model are adopted to describe the flow and heat transfer in porous media. Air

[1] Manoharbhai Patel Institute of Engineering and Technology, Shahapur, Bhandara, Maharashtra, India

and water are employed as the cold fluids and the effects of Reynolds number (Re), pore density (PPI) and pin fin form are studied in detail. The results show that, with proper selection of physical parameters, significant heat transfer enhancements and pressure drop reductions can be achieved simultaneously with porous pin fins and the overall heat transfer performances in porous pin fin channels are much better than those in traditional solid pin fin channels.

Ji-Jinn Foo(2012), studied the use of staggered perforated pin fins to enhance the rate of heat transfer while subject to a vertical impinging flow.Results show that the Nusselt number of pins with horizontal and vertical perforations is about 9% higher than that for the solid pins and it increases with the number of horizontal perforations. Pressure drop with perforated pins is reduced by about 10% compared with that in solid pins. Perforation produces smaller but larger number of vortices downstream of the pins which increases convective heat transfer but reduces pressure losses. However, further increasing the perforation diameters leads to a significant drop in thermal dissipation.

HadiNiknamiEsfahani(2012), studied the forced convection heat transfer in high porosity metal-foam filled tube heat exchangers. He obtained temperature and velocity distributions by solving the equations numerically with constant heat flux boundary condition. After inspecting the effects of different parameters on the heat transfer, the governing equations have been simplified with neglecting the parameters with lesser impacts. The results show that using metal foams can enhance heat transfer performance significantly.

PHYSICAL MODEL AND COMPUTATIONAL METHOD

A) Physical Model

The physical model consist of following parts

a) Main Circular Cylindrical Duct

b) Heating Unit

c) Pin fins Unit

d) Data Unit

A) Main Duct: Cylindrical duct constructed of galvanize sheet of 1 mm thickness, had an internal diameter 150 mm. The total length of the channel is 1000 mm. It will be operated in force draught mode by the blower of 0.5 H.P., 0 to 13000 rpm, 220W, 1.8Kg.The Reynolds number range for this experiment was 13,000 to 42,000.

B) Heating Unit: Heating unit is "Band Heater".Band heater is used for test section and is of circular shape of 150 mm diameter and length 20mm.There are fins mounted inside the duct over which heater is wrapped. The heater output has a power of 200 W at 220V and a current of 10 amp.

C) Pin Fin Unit: In this experiment we used four types of fins, which are fixed inside the four changeable parts, these are

a) Solid Fin (No hole fin)

b) Single hole Fin

c) Two holes Fin

d) Three holes Fin

The fins are in 10mm diameter and 60mm in length. There are four units of each kind of fins, which are mounted inside cylinder at equal distance in a circular fashion. Fins are made of Aluminium since it's thermal conductivity is high. The holes are at equal distance over each fin.

D) Data Unit: Data Unit consists of switches like main switch and blower switch, Digital Indicator for displaying voltage and current, Digital temperature indicator to display different temperatures using thermocouples, dimmerstat to vary the supply of current and voltage. Thermocouples are placed inside the cylinder, over the fin and after the fin section.

Figure 1: Experimental Setup

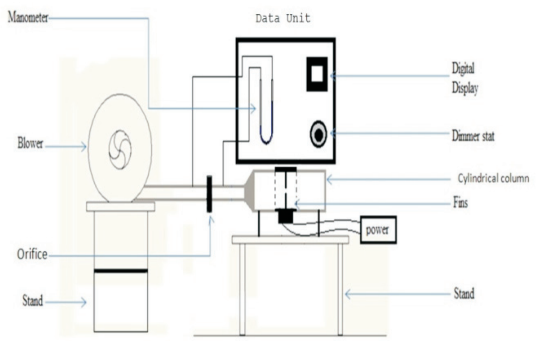
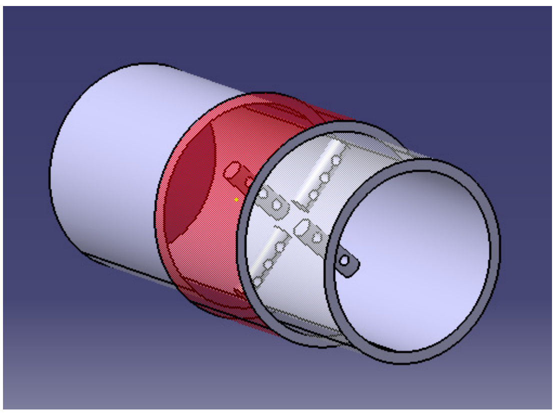


Figure 2: Actual Experimental Set-up

Figure 3: Main Duct (Cylindrical Coloumn)



B) Experimental Methodology:

Procedure: After Assembling the whole apparatus the blower and heater is started, the readings are taken for each set of pin fins for various voltages like 91 volts, 103 volts, 110 volts, 120 volts & 130 volts and current like 0.74 amp, 0.83 amp, 0.88 amp, 0.96 amp & 1.03 amp respectively. Also the readings of temperatures over the fins and outside the fins are noted down.

Governing Equations: The convective heat transfer rate of electrically heated test surface is calculated by using

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

Where, Q_{conv} is the heat transfer rate by convection

Q_e is the electrical heat transfer rate

Q_{cond} is the heat transfer rate by conduction

Q_{rad}. is the heat transfer rate by radiation

The Value of Q_e is calculated using following equation

$$Q_e = I^2 \times R \quad ....(2)$$

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

In similar studies, investigators reported that total radiative heat loss 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

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

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

$$h_{av} = \frac{Qconv}{As[Tm1-Tm2]} \quad ....(4)$$

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

Figure 4: Solid Fins

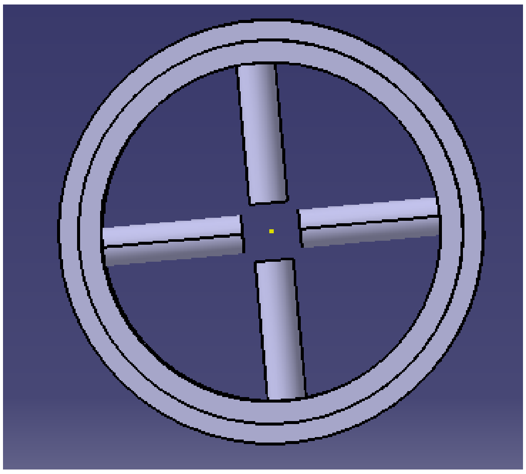


Figure 5: 1 Hole Fins

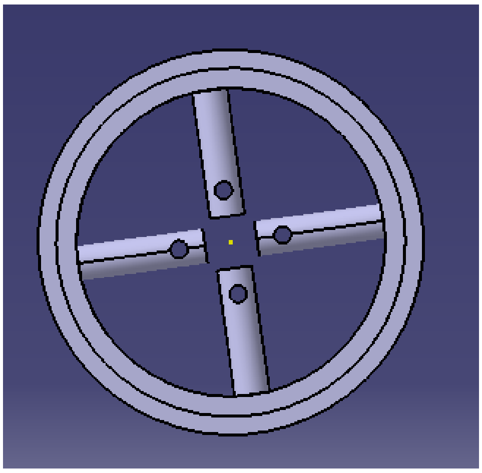


Figure 6: 2 Holes Fins

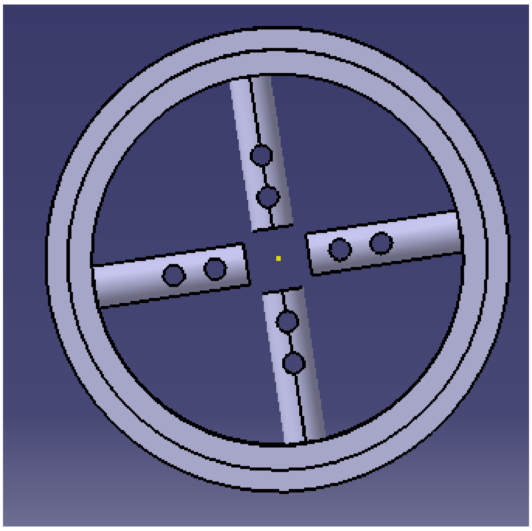
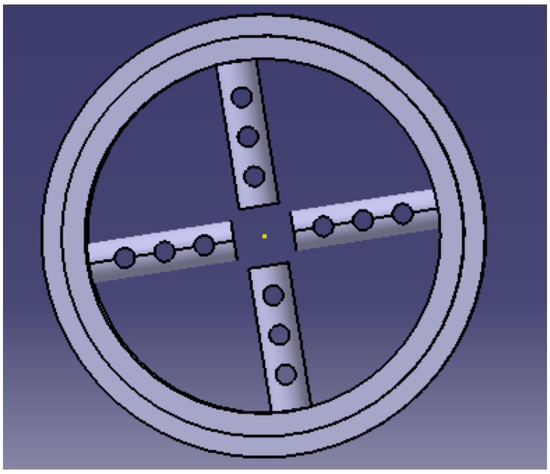


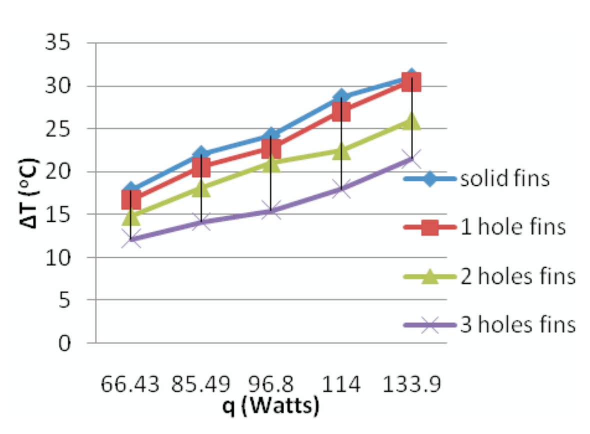
Figure 7: 3 Holes Fins



RESULT AND DISCUSSION

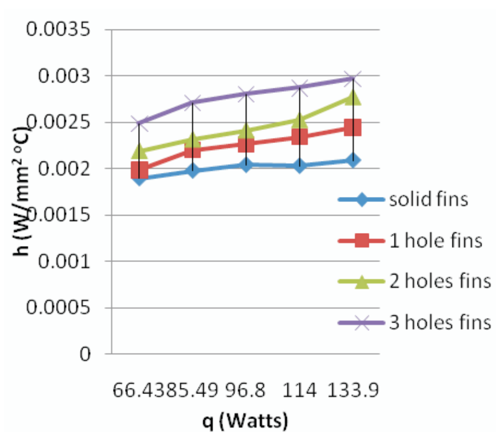
The various observation are made like heat input q i.e., Qconv. in W, mean temperature over the fins T_{m1} in °C mean outside temperature T_{m2} in °C, temperature difference ΔT in °C and h heat transfer rate in W/mm2 °C for solid pin fin , 1 hole pin fin, 2 holes pin fin, and 3 holes pin fins and the 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 about 30 to 40%. Also the temperature difference decreases with increase of number of perforation. This shows that low temperature difference leads to high heat transfer.

Figure 8: Graph Between 'q' on X-axis and Temperature Difference 'ΔT' on Y-axis



Above graph shows that difference between the temperatures for different types of fins used in this experiment. The value of temperature difference is less for 3 holes fins as compared to other fins. Hence that will be the reason for more convective heat transfer

Figure 9: Graph Between 'q' on X-axis and 'h' on Y-axis



Above graph shows the variation of the h with respect to q i.e., Qconv. for all types of fins. Here the value of h varies from 0.00189748 W/mm2oC to maximum of 0.00297 W/mm2oC. Which shows that with increase of perforation value of h increases.

CONCLUSION

The Conclusion of this experiment is that,

a) Convective heat transfer is more in perforated pin fin as compared to solid pin fin. Hence we can use the perforated fins over various applications where solid fins are used. The value of temperature difference increases with number of perforations and also the surface area increases.

b) In this project, we used 4 types of fins, hence 3hole fin is more efficient than other fins used in experiment. The value of convective heat transfer increase by 30 to 40%. The temperature difference vary from 17 to 31oC for solid fins,16 to 30 oC for 1 hole fins, 14 to 26 oC for 2 holes fins, 12 to 21 oC for 3hole fins for various values of q.

REFERENCES

1. Jian Yang, Min Zeng, Qiuwang Wang, (2010), "Forced Convection Heat Transfer Enhancement by Porous Pin Fins in Rectangular Channels" *Int. J. Heat Mass Transfer* (3).

2. Sahiti, N, Durst, F., and Dewan, A, (2005), "Heat Transfer Enhancement by Pin Elements," *Int. J Heat Mass Transfer*, No. 48, pp. 4738-4747.

3. Hadi Niknami Esfahani ,Hosse in Shokouhmand, Fahim Faraji, (2012) "Improvement of Energy Efficiency using Porous Fins in heat Exchangers" *Int. J. Heat Mass Transfer*.

4. Ji-Jinn Foo, Shung-YuhPui, Yin-Ling Lai, Swee-Boon Chin, (2012) "Forced Convective Heat Transfer Enhancement With Perforated Pin Fins Subject To An Impinging Flow".

5. Huang, P C, and Vafai, K, (1994), "Analysis of Forced Convection Enhancement in a Channel Using Porous Blocks," *J Thermophys. Heat Transfer*, No. 8, pp. 563-573.