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Forced Convective Heat Transfer Improvement Through Perforated Fins

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Abstract: Fins are useful way to increase heat transfer with minimal increase in volume. There is evidence suggesting that even dinosaurs used fins for heat transfer. Fins transfer heat either through free or forced convection. As the extended surface technology continues to grow, new design ideas emerge, including fins made of anisotropic composites, porous media and perforated and interrupted plates. The requirements of lightweight fins and economical, so the optimization of fin size is very important in fins design. Therefore, fins must be designed to achieve maximum heat removal with minimum material expenditure, taking into account, however, the ease of manufacturing of the fin shape. Large number of studies has been conducted on optimizing fin shapes. Other studies have introduced shape modifications by cutting some material from fins to make cavities, holes, slots, grooves and channels through the fin body to increase the heat transfer area and the heat transfer coefficient. The purpose of this study is to investigate the effects of lateral perforation shapes on the thermal performance of fins in comparison with the regular solid fins. Finding the best perforation shape among different types of perforations on fins. Lower inter-fin spacing ratio and comparatively lower Reynolds numbers are suggested for higher thermal performance. The major role maintained by Nusselt number and friction factor for enhancement of heat transfer through perforatedfins.

Keywords: Heat Transfer, Perforated Fins, Nusselt Number, Friction Factor

I.INTRODUCTION

Whenever the available surface area is found in sufficient to transfer the required quantity of heat with the available temperature difference and heat transfer coefficient. In the case of fins the direction of heat transfer by convection is perpendicular to the direction of conduction flow ([3]-[5]). Various types of heat exchanger fins, ranging from relatively simple shapes, such as rectangular, square, cylindrical, annular, tapered or pin fins, to a combination of different geometries, have been used. These fins may protrude from either a rectangular or cylindrical base. One of the commonly used heat exchanger fins is the pin fin. A pin fin is a cylinder, square or other shaped element attached perpendicular to a wall with the transfer fluid passing in cross flow over the element. In designing or selecting appropriate fins that satisfies the required thermal and geometric criteria, one needs to examine various parameters that affect not only the fin performance itself, but also the overall performance of the system. Option of choosing a particular type of fin depends largely on the thermal budget allowed for the fin and external conditions surrounding the fin ([6]-[8]).To indicates the effectiveness of a fin in transferring a given quantity of heat, a new parameter called fin efficiency. Fin efficiency is defined as the ratio of actual heat transferred by fin to the maximum heat transferable by fin, if entire fin area were at base temperature. The maximum heat transfer would occur if the temperature of the extended surface was equal to the base temperature. The effectiveness of fin is defined as the ratio of heat transfer rate from a surface with fin to heat transfer rate from a surface without fin. Extended surfaces, which are popularly known as fins, are extensively used in air-cooled automobile engines and in air-cooled aircraft engines. Fins are also used for the cooling of computer processors, and other electronic devices. Fins are used in the cooling of oil carrying pipe line which runs several hundreds of miles. In various applications heat from the fins is dissipated by natural as well as forced convection and radiation.

II.EXPERIMENTALSET-UP

The experimental set up for perforated fins ([4]-[5]) as shown in Fig.1.It consists of main parts of experimental set-up are :(A) Main Duct (Tunnel) (B) Heater Unit (C) Base Plate (D) Data Unit

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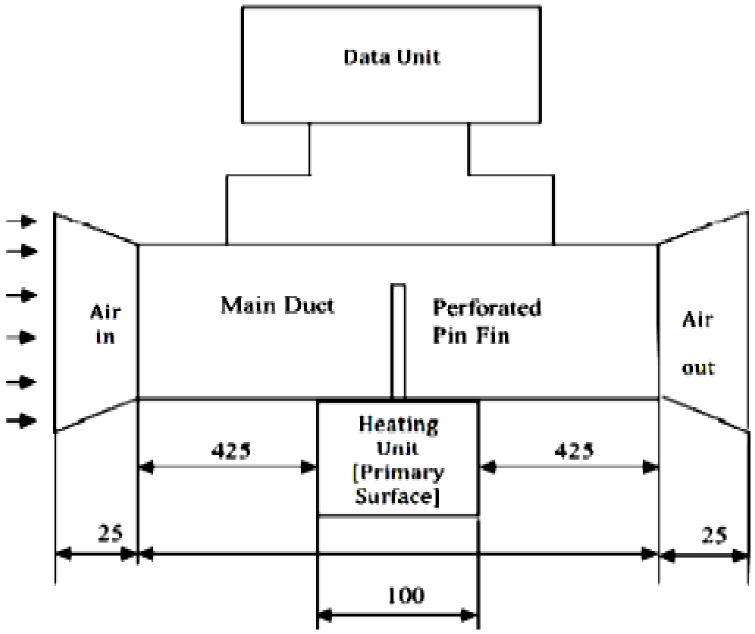

Fig.1. Experimental set-up for Perforated Fin

A. Main Duct (Tunnel):

Main duct or Tunnel made up of wood having 20 mm thickness, tunnel had an internal cross-section of 250 mm width and 100 mm. The total length of the tunnel is 1000 mm. It has a convergent and divergent section at both ends having the inclination of 30°. A Matrix anemometer is mounted in a tunnel to measure the mean inlet velocities of the air flow entering to the test section the range of this anemometer is 0-40m/sec.

B. HeaterUnit:

Heater Unit (test section) having a cross-section of 250 mm x 250 mm square; the heating unit mainly consisted of an electrical heater, a two firebrick of 250x 220 mm, glass wool and the dimensions of the electrical heater placed on the firebrick are 250 mm x 250 mm. The heater output has a power of 2000 W at 230V and a current of 10amps.

C. BasePlate:

It consists of square plate at base having the dimension 250mm x 250 mm and thickness is 6mm. The pin fins and base plate made of the same material i.e. Aluminum because of considerations of conductivity, machinability and cost. The temperature of the base plate is measured by RTD Sensor which can sense the temperature from 0°c to 450°c and it is inserted into groove in the base plate the readings of the RTD Sensors will be shown on dataunit.

D. Data Unit:

It consists of various indicating devices which show the reading taken by the various components like RTD sensors, pressure gauges andAnemometer.

1. PROCEDURE

a) First of all attach all the measuring instruments on their specific positions i.e. RTD sensors, Display control panel, Heateretc.
b) Put the base plate onheater.
c) Move the heater unit and base plate upward with the help of screwjack.
d) The base plate touches the RTD sensor and check the positions of two other sensor i.e. inlet outlet RTDsensor.
e) Then Switch on the main supply, the heater gets ON , As the temperature raised up to T˚C,
f) As soon as the temperature of base plate decreases, due to forced convection, than heater gets start to achieve constant temperature ofT˚C.
g) Apply the same procedure for velocities 3m/s, 4m/s, 5m/s, and 6m/s and take down thereadings.

2. RESULTS ANDDISCUSSIONS

A. InputParameters

1) Base Plate Temperature: The base plate temperature is maintaining constant temperature At T0C with the help of temperature controller of Resistance Temperature Detector (RTD) sensors. Switch on the heater, as soon as base plate temperature reached up to T0C, the temperature controller of RTD sensors comes in operation and it will cut off the power supply of heater.

2) Area: It consists of square plate at base having the some dimensions (Area), thickness and fin is perpendicularly set on the base plate. Number of Fins on base plate is N_p with different in S_y/D ratio and different lengths, corresponding to C/H (Clearance ratio) values they have to give different inheight.

3) Electrical Input: Input to electrical system is $Q_{elect.}$ =I2R.

4) Air Velocity: The air velocity is about 2 m/s to5 m/s.

B. OutputParameters

1) Temperature: The output and input temperature differences affect the heat transfercoefficient.
2) Nusselt Number: In heat transfer at a boundary (surface) within a fluid, the Nusselt number is the ratio of convective to conductive heat transfer across (normal to) the boundary. In this context, convection includes both convection and conduction. Named after Wilhelm Nusselt, it is dimensionless number. The conductive component is measured under the same conditions as the heat convection but with a (hypothetically) stagnant (or motionless)fluid.
3) Reynolds Number: Reynolds number can be defined for a number of different situations where a fluid is in relative motion to a surface. These definitions generally include the fluid properties of density and viscosity, plus a velocity and a characteristic length or characteristic dimension.

C. Formula Correlations

$$\text{Heat transfer } Q_{conv.} = Q_{elect.} - Q_{cond.} - Q_{rad}$$

Where Qconv, Q_{elect}, Q_{cond}, Q_{rad} indicates the heat transfer rate by convection, electrical, conduction and radiation. The electrical heat input is calculated from the electrical potential and current supplied to the surface. $Q_{elect.} = IR$

The Pressure drop is found out in duct with manometer or measured under the heated flow conditions. The experimental pressure drops will be converted to the friction factor F using the experimental results. Friction factor was correlated as a function of the duct Reynolds number Re, and geometrical parameters. The pressure drops in the tunnel without fins is so small that they could not be measured by the Manometer

A. Rectangular Fins with Perforations

The purpose of this study is to investigate the effects of lateral perforation shapes [4] on the thermal performance of fins in comparison with the regular solid fins. The rectangular fin with different types of perforations as shown inFig.2.

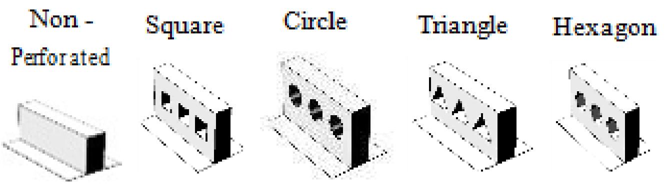

Fig.2. Rectangular Fins with different types of perforations

1) Non-Perforated, 2) Circle, 3)Square, 4) Triangle 5) Hexagon

Table.1. Efficiency Percentage improvement of perforated fin arrays over solid fin arrays

Size of Perforation	**Percentage Efficiency (E_f %) Circular**	**Percentage Efficiency (E_f %) Square**
8 mm	9.90	10.28
10 mm	12.22	12.54
12 mm	14.35	14.64

The Nusselt numbers of perforated fin arrays as well as solid fin arrays increases with increase in Reynolds number. Percentage improvement in Nu of perforated fin arrays over solid fin array is found. Result shows that average of percentage improvement of square perforated fin arrays is more than fin arrays of circulated perforated fin of same size. Friction factor slightly increases with increase in the size of perforation. Utilization of perforated fins increases heat dissipation rate, simultaneously reduction in fins weight, low weight means saving material of fin and which decreases the expenditure on the fin material and related equipment.

The study on to investigate the heat transfer by natural convection in a rectangular perforated fin plates [5]. Five fins used in this work first fin non-perforated and others fins perforated by different shapes these fins perforation by different shapes circle, square, triangle, and hexagon but these perforations have the same cross section area(113 mm^2). These perforations distributed on 3 columns and 6 rows. The results show that the drop in the temperature of the non-perforated fin from 72 to 57^0C while the temperature drop in perforated fins, at the same power supplied (126 W) was (72-52^0C), (72-51.5^0C),(72-50^0C) and (72-48^0C) for shapes hexagonal, square, circular and triangular. The largest value of RAF at triangular perforation and the smaller value occurred in circular perforation. Also, triangular perforation gives best values of heat transfer coefficient and then the circular, square, hexagonal, and non-perforation respectively. The gain in heat dissipation rate for the perforated fin is a strong function of the perforation dimension and lateral spacing. Decreasing the perforation dimension reduces the rate of temperature drop along the perforated fin. Heat transfer coefficient for perforated fin that contained a larger number of perforations higher than the perforated fin that contained a small number of perforations. The numerical study [4] has been performed to investigate the turbulent convection heat transfer on a rectangular plate mounted over a flat surface. Thermal and fluid dynamic performances of extended surfaces having various types of lateral perforations with square, circular, triangular and hexagonal cross sections are investigated. RANS based k– ω turbulence model is used to calculate the fluid flow and heat transfer parameters. By introducing different shapes of perforations (having equal fin volume), better fin effectiveness and higher HTPE values for turbulent flow condition has been observed in this study. The purpose of this study is to investigate the effects of lateral perforation shapes on the thermal performance of heat sinks in comparison with the regular solid fins under turbulent flow condition. (1) Shape of lateral perforation has significant effects on the thermal performance of heat sinks under turbulent flow conditions. (2) Triangular perforated fins have the lowest and solid fins have the highest Nusselt number values. (3) Hexagonal perforated fins show the highest fin effectiveness and the highest HTPE values. (4) Perforation shape is also an important factor for the better fluid dynamic performance. It is found that triangular perforated fins have lowest skin friction coefficient value than the other types of fins considered here.

III.CONCLUSION

Extended Perforations in the fins one way that used to improve its effectiveness, Heat dissipation rate for the perforated fin is a strong function of the perforation dimension. The most important parameters affecting the heat transfer are the Reynolds number, fin spaces (pitch) and fin height. Enhancement efficiencies increased with decreasing Reynolds number. Therefore, relatively lower Reynolds number led to an improvement in the heat transfer performance. Heat transfer coefficient for perforated fin that contained a larger number of perforations higher than the perforated fin that contained a small number of perforations. For a particular size of the perforations in the fins, higher efficiency occurred in square perforations and lowest in circular perforations. Hexagonal perforated fins show the highest fin effectiveness and the highest HTPE values. It is found that triangular perforated fins have lowest skin friction coefficient value than the other types of fins considered here Triangular perforated fins have the highest Nusselt number values. The largest value of RAF at triangular perforation and the smaller value occurred in circular perforation. Also, triangular perforation gives best values of heat transfer coefficient and then the circular, square, hexagonal, and non-perforation respectively

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