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A Review on Augmentation of Heat Transfer from Square Perforated fins in Staggered Arrangement

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Abstract

This paper gives a review on augmentation of heat transfer over a flat surface equipped with Square perforated pin fins in staggered arrangement in a rectangular channel. The Fin dimensions are 100mm in height & 25mm in width. The range of Reynolds number is fixed & about 13,500– 42,000, the clearance ratio (C/H) 0, 0.33 and 1, the inter-fin spacing ratio (Sy/D) 1.208, 1.524, 1.944 and 3.417. S_y i.e. stream wise distance is varies and S_X i.e. span wise distance is constant. The friction factor, enhancement efficiency and heat transfer correlate in equations with each other. Here we are comparing Square pin fins with cylindrical pin fins. Staggered arrangement and perforation will enhance the heat transfer rate. Clearance ratio and inter-fin spacing ratio affect on Enhancement efficiency. Both lower clearance ratio and lower inter-fin spacing ratio and comparatively lower Reynolds number give higher thermal performance. Friction factor & Nusselt number are Key parameter which relates with efficiency enhancement and heat transfer rate.

Keywords: *Heat transfer enhancement; perforated pin fins; Performance analysis; Staggered arrangement.*

1. Introduction

There are numerous situations where heat is to be transferred between a fluid and a surface. In such cases the heat flow depends on three factors namely (*i*) area of the surface (*ii*) Temperature difference and (*iii*) the convective heat transfer coefficient. The base surface area is limited by design of the system. The temperature difference depends on the process and cannot be altered. The only choice appears to be the convection heat transfer coefficient and this also cannot be increased beyond a certain value. Any such increase will be at the expense of power for fans or pumps. Thus the possible option is to increase the base area by the so called extended surfaces or fins. The fins extend form the base surface and provide additional convection area for the heat conducted into the fin at the base. Fins are thus used whenever the available surface area is found insufficient 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. 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. Pin fins having a height-to-diameter ratio, H/D, between 0.5 and 4 are accepted as short fins, whereas long pin fins have a pin height-to-diameter ratio, H/D, exceeding 4. The various important parameters in the analysis of fins are, (1).Heat transfer coefficient,(2).Length of the fin, (3). Cross sectional area of the fin,(4). Thermal conductivity of fin,(5). Efficiency and Effectiveness of fin. The use of extended surfaces is of practical importance for numerous applications such as cooling the Air-cooled engine cylinder head, Economizers for steam power plants, Radiators of automobiles, Small capacity compressors, Transformers, Electronic equipment.

In this experimental analysis we are using the same parameters and setup as that of the work done on the cylindrical pin fins but here only aim is to prove that the Square cross section pin fins are having influencing Effectiveness (ε_f) and efficiency (η) on the cylindrical pin fins.

2. Square Fins

2.1 Amol B. Dhumne and Hemant Farkade

In this paper the heat transfer of analysis on cylindrical perforated fins in staggered arrangement, in this type of

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arrangement and shape have analysis that heat transfer on cylindrical fin more heat transfer rate. In which the Reynolds number taken as fixed range but it have to change in shape of the fin and give staggered arrangement it has same as the reference paper [1] change is only shape. In this paper they have analysis on both staggered and in line arrangement of fin the after the result obtain the cylindrical and also this solid and perforated pin fins. In staggered arrangement better heat transfer enhancement than the solid cylindrical fins the result obtain of compared to in line staggered arrangement and perforated with solid fins and also given to lower Reynolds numbers are suggested for higher thermal performance. Enhancement efficiencies vary depending on the clearance ratio and inter-fin spacing ratio.

2.2 G.J.Vanfossen and B.A.Brigham

The paper reported that this paper describes the analysis of the heat transfer by short pin-fins in staggered arrangements. By short pin-fins the heat transfers in staggered arrangements. According to results, more heat transfer is longer pin-fins having (H/d = 4) but shorter pin-fins having (H/d = ½ and 2) less heat transfer as compare to the above ratio and the slightly exceeds that with only four rows when array-averaged heat transfer with eight rows of pin-fins. The another point in as results is the average heat transfer coefficient on the pin surface is around 35% more than that on the end walls is established.

2.3 Bayram Sahin, Alparslan Demir

In this paper studies the Performance of a heat exchanger having perforated square fins in this paper the condition is take square fins having different in numbers of Fins that is depend of inter fin distance and in this paper give the perforation due to the perforated internal surface is take outer air which come from atmosphere through the tunnel and Fin molecules will be donated heat energy to air molecule by convectively. There have been many investigation regarding heat transfer and pressure drop of channels with pin fins, which are restricted to pin fins with circular or few different cross sections. The Heat transfer through the solid to the surface of the solid by conduction is major heat transfer mode and also the major heat transfer by conduction followed by convection whereas from the surface to the surroundings takes place by convection. Many investigations have been done regarding pressure drop and heat transfer true the channel with different cross section of fins that is circular or other shape. The conductive heat transfer means solid to solid surface from one end to another end in which major heat transfer rate in pin fin and the conduction followed by convection also major heat transfer, where as in surrounding take place of surface by convection the attaching of extended surface over the flat plate by increasing surface area is called Fins . The material of fin takes highly conductive like Aluminum, copper, etc. The cooling of electronic equipment and stationery engine for this specially designed fin surface called heat sink. The minimum material and maximum heat transfer give of this type of design In this paper the experimental range of some parameter fixed like inter fin distance ratio (Sy/D) 1.208, 1.524, 1.944 and 3.417, clearance ratio (C/H) 0, 0.33 and 1 and Reynolds number 13,500–42,000. Enhancement efficiencies depending on the clearance ratio and inter- fin spacing ratio and it's varied between 1.1 and 1.9. The effects of the flow and geometrical parameters on the heat transfer and friction factors were determined, and the enhancement efficiency correlations have been obtained. [1] Bayram Sahin, Alparslan Demir analysis that the maximum heat transfer rate was observed at 42,000 Reynolds number, 3.417 Sy/D and 50 mm fin height.

3. Experimental Plan

The all above references are used in this experiment and we arrange the Square fins. In this experiment we have taken the Square shape structure. Square with perforation as well as staggered arrangement is done .The improvement in the flow (thus the enhancement in the heat transfer) is brought about by the multiple jet-like flows through the perforations [7] and the staggered arrangement creates more turbulence due to that all molecule present in air which collides with the Fins gives the heat energy to the air molecule by force convection. In this Experiment same parameter are taken into consideration as in reference papers [4] [1] like Reynolds numbers 13,500–42,000. As the Reynolds number increases the Nussult Number is also increases.

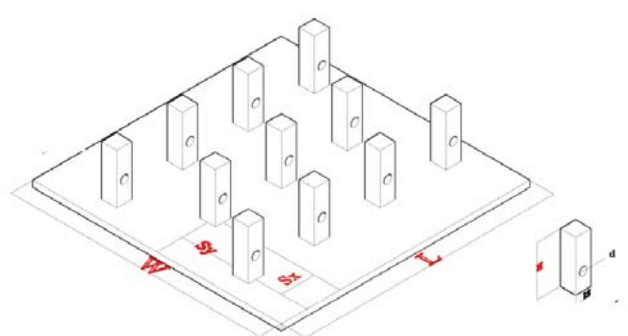

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Fig. 1 Base Plate with Square fins in staggered arrangement.

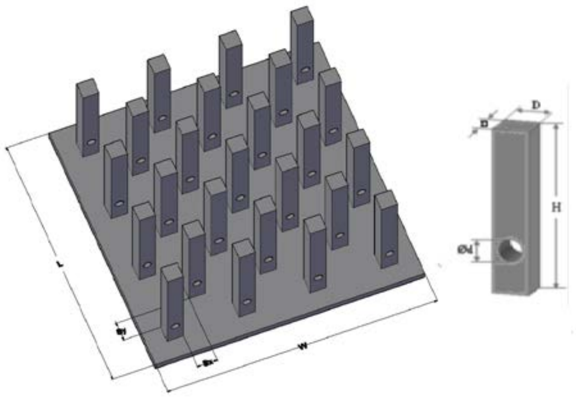

Fig. 2 Base plate having Sy/D=1.208. No. of fins 25.

The base plate having square fins in staggered fashion are shown in fig.1 in which base plate used is also having a square shape. The arrangement as per the inter fin distance is shown in fig.2, which is having the inter fin spacing i.e. Sy/D=1.208 and for this spacing the number of fins on the base plate having dimensions 250mm x 250mm is 25 in number.

4. Performance Parameters

4.1 Input Parameters

1) *Base plate temperature:* The base plate temperature is maintaint constant temperature At 100 ^{o}C with the help of temperature controller of RTD sensors. Switch on the heater, as soon as base plate temperature reached upto 100˚C, the temperature controller of RTD sensors comes in operation and it will cut off the power supply of heater.

2) *Area:* It consist of square plate at base having the dimension 250mm x 250 mm, thickness is 6mm and fin is parpendicullar set on the base plate of cylinderical square compound shape fin. Number of on base plate is 25,21,18 and 11 with its different in S_y/D ratio and different in lengths, corresponding to C/H (Clearance ratio) values of 0, 0.333 and 1 they have to give different in hieght i.e.100,75,50 [1].

3) *Voltage,Current and Resistance:*Voltage,Current(I), Resistance(R) Input electric system is $Q_{elect.}=I^2 \times R$ [4].

4) *Air Velocity :* The effects of air movement upon sensible heat loss from individual birds at ambient temperatures. The air velocity is about 2 m/s to 5 m/s.

4.2 Output Parameters

1) *Temperature*: The output and input temperature differences are affected the heat transfer coefficient.

2) *Nussult Number*: In heat transfer at a boundary (surface) within a fluid, the Nussult number is the ratio of convective to conductive heat transfer across (normal to) the boundary. In this context, convection includes both advection 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 [4].

$$Nu_L = \frac{hL}{k_f}$$

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 [10].

$$Re = \frac{\rho v L}{\mu} = \frac{v L}{\nu}$$

5. Set up Facility

The range of Reynolds number used in this experiment 13,500–42,000, the average velocity (U) and hydraulic diameter of the channel over the test section (Dh) these two parameter are use to calculate the Reynolds number. The inlet and outlet temperature of the air stream will be measured RTD Sensors which mounted in wind tunnel. One RTD Sensors for the outer surface temperature of the heating section and one for the ambient temperature is employed The pressure drop across the test model is measured using two pressure transducers that can take measurements between 0 and 150 Kg/cm² which mounted in wind tunnel.

Tunnel constructed of wood of 20 mm thickness, had an internal cross-section of area 250 mm × 250 mm and 100 mm the total height of tunnel the length channel is 1030 mm. The air supplied into the tunnel over Fin with the of blower, which have adjustable speed i.e. 1,2,3,4,5,6 m/s and range of rotation 0 to 16000 rpm and it is fitted at entry of tunnel i.e. at convergent part of tunnel and positioned horizontally. It has a convergent and divergent section at both ends having the inclination of 30°. A anemometer measured the average inlet velocities of the air flow entering to the test section the anemometer is mounted at the inlet of the tunnel the range of this anemometer is 0 to 15 m/sec.

6. Experimental Procedure

1. First of all attached all the measuring instruments on their specific positions i.e. RTD sensors, Display control panel, Heater etc.
2. Put the aluminum base plate on heater.
3. Move the heater unit and base plate upward with the help of screw jack.
4. The base plate touches the RTD sensor and check the positions of two other sensor i.e. inlet outlet RTD sensor.
5. Then Switch on the main supply, the heater gets ON , As the temperature raised up to 100˚C, the controller of RTD sensors is get activated & it will cut off the power supply.
6. Next step is to start the blower and by using digital anemometer measure the velocity of inlet air and maintain inlet air velocity constant as per specified (i.e.2, 3, 4,5 and 6 m/s) with the help of blower regulator.
7. Now through tunnel air will flow over heated Fin plate.
8. Measure the outgoing warm air with the help of RTD outlet temperature sensor.
9. As soon as the temperature of base plate decreases, due to forced convection,.so that heater gets start to achieve constant temperature of 100˚C.
10. Apply the same procedure for velocities 3m/s, 4m/s, 5m/s, and 6m/s and take down the readings.

7. Data Processing

7.1 Heat Transfer

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

Where: Q_{conv}, Qelect, $Q_{cond,}$ 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.[1][4]

$$Q_{elect.} = I^2 \times R \quad (2)$$

Total area = Projected area + Total surface area contribution from the blocks [2][4]

$$A_S = W \times L + Np \times HD + Np \times (\pi Dd - 0.5\pi d^2) \quad (3)$$

Where W&L are the width & length of the base plate, H is the height of the fin, D is the side of the fin, Np is the number of pin fins & d is the diameter of the perforated hole.

The heat transfer from the test section by convection can be expressed as [9][10]

$$Q_{conv.} = h_{av} A_s \left[T_s - \left(\frac{T_{out} + T_{in}}{2} \right) \right] \quad (4)$$

Reynolds Number: [10]

$$R_e = \frac{D_h U}{\nu} \quad (5)$$

Nussult number smooth surface (Nu_s) For without Fin:[4][1]

$$Nu_s = 0.077 Re^{0.716} Pr^{1/3} \quad (6)$$

Nussult number: [1][4]

$$Nu_{p2} = 45.99 Re^{0.396} \left(1 + {C}/{H}\right)^{-0.608} \left({S_y}/{D}\right)^{-0.522} Pr^{1/3} \quad (7)$$

7.2 Friction Factor

The Pressure drop calculated by experiment this pressure drop is finding 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.[4]

$$F = 2.4 Re^{-0.0836} (1 + C/H)^{-0.0836} (S_y/D)^{-0.0814} \quad (8)$$

7.3 Enhancement Efficiency

The effectiveness of the heat transfer for a constant pumping power, it is useful to determine enhancement of a heat transfer. The enhancement efficiency is the ratio of heat transfer coefficient with Fins to without Fins. [4][1]

$$\eta = \frac{ha}{hs} = 51.09\, Re^{-0.358}\left(1 + {}^{C}/_{H}\right)^{0.1028}\left({}^{S_y}/_{D}\right)^{0.0812} \quad (9)$$

Where h_a= convective heat transfer coefficient with Fins and h_s= convective heat transfer coefficient without fins.

8. Conclusions

In this Experiment, we studied the square Shape of Fin. The square area is more than that of the other due to that the effect of the various parameters, i.e. overall heat transfer and friction factor on the heat transfer. The square fins cover more flue gases therefore more heat transfer by convection will takes place. And here we are using staggered arrangement therefore turbulence will me more & the perforation will give the jet like flows of air which will be very much helpful for the enhancement of the heat transfer. The geometrical factor which enhances enhancement efficiency by heat transfer rate increase and friction characteristics will determine and enhancement efficiency & the correlations have been obtained.

The inter-fin distance ratio and clearance ratio is decreases due to that friction factor will increase. The projected area is helpful for calculating average Nusselt number and decreasing clearance ratio, and as inter-fin distance decreases the number of the fins on the base plate increases.

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