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Optimization of Heat Transfer Rate by Forced Convection Process on Perforated Fin

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ABSTRACT

Present work focuses on optimization of hole diameter of porous fin to enhance heat transfer by forced convection experimentally. In porous fin holes are drilled on extended surface. For achieving highest Nusselt Number and lowest base temperature of fin, the L\d ratio should be optimal. Hence holes were drilled from 4mm dia, to 5mm and 6mm dia. Fins were subjected to Reynolds Number ranging from 7000 to 30000 and heat flux was varied from 50W to 75Watts. Orientation of fin was varied from 0deg, to 30,45,60,90 deg. Observation table of and graphs were drawn to compare the results.

Keywords: fin, heat transfer enhancement, forced convection, channel flow, vortex generator, heat transfer augmentation.

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I. INTRODUCTION

With advancement of technology and compact size of system, heat generated per unit area has gone up. Hence the conventional processes and equipment are not able to handle the amount of heat generated. As a result lot of research work is going on to enhance the heat transfer rate in natural and forced convection process. Forced convection process is adopted for handling large amount of heat. Various devices such as roughness element, turbulent promoters, interrupted fin array etc have been utilized.

In our setup, the holes are drilled on solid fin surface to enhance the heat transfer. Experiments are done to reach best value of L/d ratio, L is length of fin and d is diameter of drilled hole. With optimal value of L/s ratio the Nusselt number will be highest and fin base temperature will be minimum.

Lot of experimental and theoretical work related to natural and forced convection heat transfer past an array of fins grooved channels, perforated fins, porous sleeves, blockages with round and elongated holes, wooden porous material around staggered tube bundles, permeable fins(drilled fins) etc. is carried out by different investigators.

Yorwearthet. Al. [1] in their experimental investigation compared the heat transfer enhancement of carbon foam and aluminum fins in natural convection. The largest increase in Nusselt number was achieved by a solid carbon foam sleeve, which was about 2.5 times greater than a bare copper pipe. It was investigated that the Nusselt number increases as the diameter of HTC sleeve increases. HTC sleeve produce more heat transfer enhancement that their area would indicate as compared with HTC fins which produced less heat transfer enhancement than their surface area would indicate. But it should be noted that HTC sleeves as compared with aluminum fins have more emissive power. Hence the net enhancement is the combined effect of radiation and convection.

Bogdanet.al.[2] he studied the effect of metallic porous materials, inserted in a pipe on the rate of heat transfer. The porous media used for experiments work manufacture from commercial aluminum screen. The effect of porosity, porous material dia and thermal conductivity as well as Reynolds number on the heat transfer rate and pressure drop are investigated. The results are compared with clear flow case where no porous material was used. It was found that reasonable heat transfer enhancement can be achieved using porous inserts.

H.S.Ahn et.al.[3] experimental investigated the heat transfer enhancement for turbulent floe through blockage with ground and elongated holes in rectangular channel the results showed the blockage with smaller holes increases heat transfer on the wall segments more than those with larger holes. In all cases the heat transfer enhancement is lower when the air flow rate is higher. The blockages with larger holes in this study out performance the blockages with smaller holes.

Naga s. sarda et.al.[4] carried out cfd analysis to investigate the enhancement of heat transfer by he incorporating different wire coil inserts in the tube of length 610 mm with the inside dia of 27 mm. The analysis was performed either air as working fluid. For the plane tube and the heat transfer coefficient obtained is compared with the experimental results for the validation. It is observed that heat transfer coefficient is found obtain analytically is 10.7% more than the obtained experimentally.

NOMENCLATURE

A	heat transfer surface area, m^2	D	diameter of hole, m
H	heat transfer coefficient, W/m^2 K	Q	heat transfer rate, W
K	thermal conductivity, W/m K	Re	Reynolds number
L	length, m	T_s	Temperature, °C
$\dot{m}$	mass flow rate, kg/s	V	flow velocity, m/s
Nu	Nusselt number	W	pumping power, W
Pr	Prandlt number	Δp	pressure drop, N/m^2

II. EXPERIMENTATION

An experimental set-up for the study of fin on heat transfer enhancement is as shown in Fig. 1. Test was carried out using a rig composed three sections rectangular in cross section (275mm×248mm) joined together by flanges using nut & bolts. Asbestos gaskets were used for air tight fitting in order to avoid any loss due to leakage. The three sections of the test rigs are the diverging section connecting blower with main duct followed by honeycomb section of air duct. The last section was provided with an arrangement to hold the fin arrays. Provision was also made to rotate the fin array at desired angle with respect to air flow direction. A honeycomb section of 150 mm length was installed at the entrance of the last section i.e. air duct in order to remove eddies and a more uniform velocity profile. The ceramic electric heater is placed between two identical fin arrays facing back to back.

The heater is secured between these arrays with the help of screw and nut. The ceramic heating coil used for providing a constant heat flux to the fin arrays was given an electric supply through constant voltage transformer (CVT). Constant voltage transformer was provided to take care of fluctuations if any in the supply from mains. The magnitude of heat flux was adjusted by varying the intensity of the current measured with the ammeter.

For three dimensional turbulent fluid flow and convective heat transfer around an array of solid and permeable fins will be analyzed experimentally. Permeable fins having holes in circular cross section with various diameters i.e. 4 mm,5 mm and 6mm size are used. For holes in latter section of fin the area vector of hole is perpendicular to flow directions at $\Theta=0^0$ and becomes parallel at $\Theta=90^0$ while in most previous studies, the area vector of perforations are in same directions of flow. In present study a range of angles viz. 0^0,30^0,45^0,60^0 & 90^0 is taken into consideration to study the thermal performance of solid and permeable fins. This experiment will be conducted with different heat inputs (50W, 55W, 65W, 75W) and at different Reynolds number suited for most practical applications .The wattages selected for experimentation raise the temperature of fin base in range of 50 to 90 oC which is very common in case of heat sinks used in electronic equipments and fins used in automobiles, etc.

Fig. 1:-Actual photograph of setup.

III. RESULT AND DISCUSSION

Sr . no.	Type of fin	Heat input	Angular position	Air velocity
1	Solid	50	0 30	0.1 1.0
2	Permeable with 4mm hole	55	45	1.5
3	Permeable with 5mm hole	65	60	
4	Permeable with 6mm hole	75	90	2.0

Table 3.1 Test Matrix/Variable parameters

For current work the 4 variants of fins are studied. For each fin Reynolds number vary from 7000-30000.The heat input varies from 50W to 75W with orientation of 0,30,45,60,90 degree to the direction of fluid.

3.1 Nusselt number

The formula for Nusselt number is

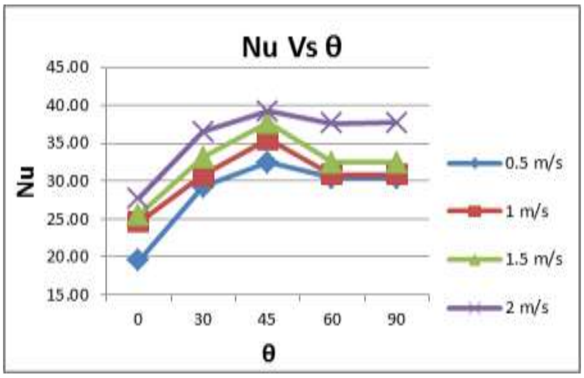

Fig. 3.1 Comparison of Nusselt number with orientation of fin for 50 watt

This is variation of Nusselt number with orientation of test piece for 50 watt. It shows that the Nusselt number increases with increase in orientation degree up to 45 degree as then it is decreases. It also show that base temperature is minimum at 45^0 .

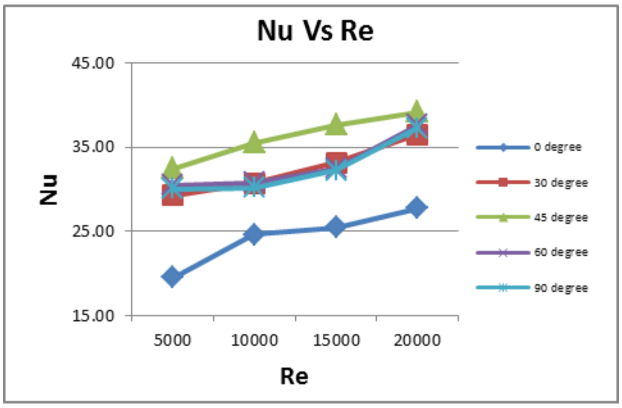

Fig. 3.2 Comparison of Nusselt number with Reynolds number for 50 watt

This is variation of Nusselt number with Reynolds number for 50 watt. It shows that the Nusselt number increases with increase in Reynolds number. It also show that base temperature is minimum at higher Reynolds number .

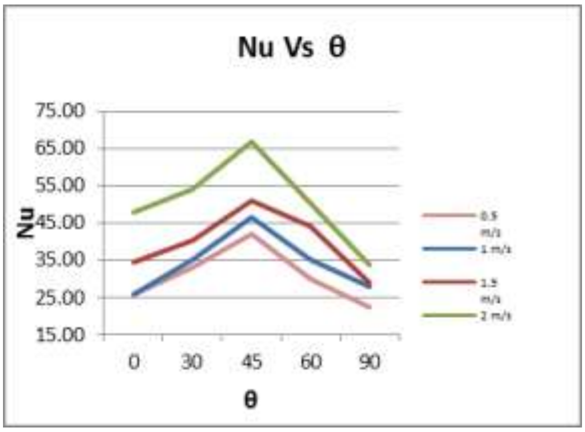

Fig. 3.2 Comparison of Nusselt number with Reynolds number for 50 watt

This is variation of Nusselt number with orientation of test piece for 50 watt. It shows that the Nusselt number increases with increase in orientation degree up to 45 degree as then it is decreases. It is observe that the Nusselt number is highest at 5 mm size of hole in porous fin. The Nusselt number will decrease if the hole size is varied to 4mm or 6mm.

VI. SUMMARY AND DISCUSSION

i. The heat transfer increases as Reynolds number increases.

ii. Porous fin (hole drilled) is more effective than solid fin.

iii. The optimal value of hole is 5 mm. If hole size is increased or decreased the Nusselt number will decrease.

iv. For the fin length of 25 mm the optimal value of L/D is 5/3.

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