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Experimental Investigation of Optimum Hole Size on Perforated Fin Under Natural Convection Heat Transfer Process

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ABSTRACT

Natural convection heat transfer through finned surfaces finds practical application in many engineering applications where high rate of heat transfer is desired with minimum expenditure of external energy. A systematic experimental investigation of a fin array with circular perforations is carried out for a horizontal fin array and heat input for free convection. The objective of this experimentation is to determine the optimum ratio of fin length to perforation diameter for which the maximum heat transfer is taking place by natural convection for different heat inputs and compare it with solid fin of same dimensions for same conditions. The fin size 72mm*25mm*2mm is used with different hole diameters of 4mm,5mm,6mm to vary the ratio of L/D. where, L is length of fin and D is the diameter of perforation. 10 such fins are attached over block of 72mm*76mm with a pitch of 6mm. The 2 series of 3 holes are punched on the fin surface to find out the maximum heat transfer rate for different heat inputs of 55W, 65W, 75W .Three L/D ratios from 6.25, 5, and 4.17 are used for experimentation. Effect of orientation of fin array is also studied to find out the best orientation for maximum heat transfer.

***Keywords*— A perforation, fin, heat transfer enhancement, Natural convection, channel flow.**

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I. INTRODUCTION

Heat transfer is the study of thermal energy transport within a medium or among neighboring media by molecular interaction, fluid motion, and electro-magnetic waves, resulting from a spatial variation in temperature. This variation in temperature is governed by the principle of energy conservation, which when applied to a control volume or a control mass, states that the sum of the flow of energy and heat across the system, the work done on the system, and the energy stored and converted within the system, is zero.

Heat transfer finds application in many important areas, namely design of thermal and nuclear power plants including heat engines, steam generators, condensers and other heat exchange equipments, catalytic convertors, heat shields for space vehicles, furnaces, electronic equipments etc. internal combustion engines, refrigeration and airE.A.M.Elshafei et al.[1] investigated study natural convection heat transfer from circular pin fin heat sinks and influence of geometry of array, heat flux and orientation on convective heat transfer. Experiments were performed on heat sinks of widely spaced solid and hollow/perforated pin fins arranged in a staggered manner on a heated base. An array of 8 cylindrical solid or hollow with single perforated pin fins screwed in to the upper surface of the base plate was used for experimentation. He found that over the tested range of Rayleigh number, $3.8 \text{ x } 106 \leqslant Ra \leqslant 1.65 \text{ x } 107$, the solid pin fin heat sink performance for upward and sideward orientation showed a competitive nature.

Raaid R. Jassem et. al.[2] investigated the effects of various types of perforations with natural convection to find out the best shape of perforations to maximize heat transfer. He used aluminum fins with circular, square, triangular and hexagonal perforations for the study and compared the heat transfer through the perforated fins and solid fin for same conditions. Decreasing the perforation dimension reduces the rate of temperature drop along the length of perforated fin, and the heat transfer coefficient for a perforated fin with large number of perforations was higher than perforated fins with smaller number of perforations.

NOMENCLATURE:-

A	heat transfer surface area, m^2	N	Number of fin
H	heat transfer coefficient, W/m^2 K	Q	heat transfer rate, W
K	thermal conductivity, W/m K	Re	Reynolds number
L_A	Length of array, m	T_s	Temperature, °C
$\dot{m}$	mass flow rate, kg/s	V	flow velocity, m/s
Nu	Nusselt number	W	Width of array, m
Pr	Prandlt number	D	diameter of dimples, m

Conditioning units, design of cooling systems for electric motors generators and transformers, heating and cooling of fluids etc. in chemical operations, construction of dams and structures, minimization of building heat losses using improved insulation techniques, thermal control of space vehicles, heat treatment of metals, dispersion of atmospheric pollutants.

A thermal system contains matter or substance and this substance may change by transformation or by exchange of mass with the surroundings. To perform a thermal analysis of a system, we need to use thermodynamics, which allows for quantitative description of the substance. This is done by defining the boundaries of the system, applying the conservation principles, and examining how the system participates in thermal energy exchange and conversion.

Wadhah Hussein Abdul et.al.[3], investigate heat transfer through natural convection in a rectangular fin with circular perforations. The diameter of perforations was kept same for all the experiments and the number of perforations was varied from 24 to 56. He observed that that the temperature distribution along the non-perforated fin was greater than that of the perforated fins and that the temperature drop between the fin base and the tip increased as the perforation diameter increased due to reduction in the thermal resistance.

II. EXPERIMENTAL SETUP

An experimental set-up for the study of fin on heat transfer enhancement is as shown in Fig. 1. Fin array is generally made up of materials with high thermal conductivity so as to reduce the thermal resistance to the flow of heat. Aluminum is most preferred material for fins because of its high conductivity, low weight and low cost compared to copper. Aluminum extruded fin arrays will be used for the purpose of study as they are easily available and suited for the study.

In this experiment the fin with base dimensions of 72mm*25mm*2mm is used .To avoid any effect of turbulent air flow around the fin array, the assembly of fn array and heater is proposed to be kept inside an enclosure of sufficient volume to allow for heat exchange between ambient air and the fins. Top of the enclosure is kept open for undisturbed natural convection. To vary the ratio of L/D different hole diameters of 4mm, 5mm, 6mm are drilled on the fins. Where, L is length of fin and D is the diameter of perforation. To get bulk effect 10 such fins are attached over block of 72mm*76mm with a pitch of 6mm.

Fig. 2.1:- Setup for natural convection

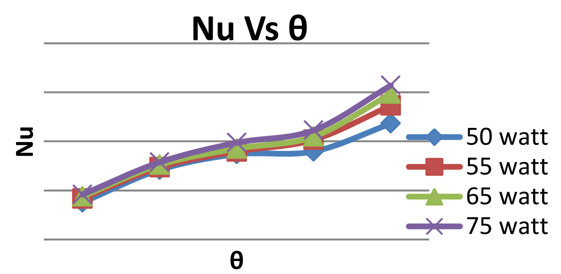
III. RESULT AND DISCUSSION

In this research work, four fin with different hole size in fin combination are used. Out of four fins three plates contain perforation.

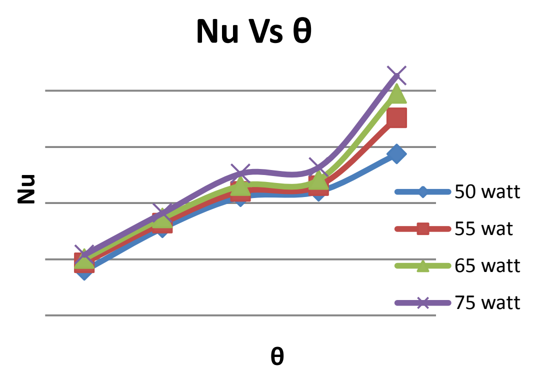
3.1 Baseline Nusselt number

The baseline Nusselt number indicates that the Nusselt number without any fin perforations. The graph indicates the variation of Nusselt number with the orientation of the fin to the flow of fluid. The angle varies as 0, 30,45,60,90 degree.

The graph shows that the Nusselt‘s number increase with the increases in angle, because it gives path to flow air easily by natural convection.



3.1 Effect of Orientation on Nusselt number.



3.2 Effect of perforations on Nusselt number.

The graph indicates the variation of Nusselt number with the orientation of the fin to the flow of fluid for 4mm perforations.
It shows that Nusselt number increase with the increases in angle,

IV. SUMMARY AND DISCUSSION

A For the experiments performed to study average heat transfer enhancement on different geometrical rectangular fins, the conclusions are as follows:

i. The perforated fin array with 3 numbers of perforations made at the center of fin with different diameters to achieve the L/D ratio of 6.25, 5, and 4.17.
ii. It is proposed to conduct experimentation for inputs of 50W, 55W, 65W and 75W.
iii. Graphs will be plotted to study the effect of L/D ratio on Convective Heat Transfer Co-efficient, Nusselt's number on Rayleigh's number, effect of Δ T on Convective Heat Transfer Co-efficient and effect of angle of inclination on heat transfer coefficient for solid and perforated fins of varying ratio of L/D.
iv. The Nusselt's number increase with the increases in angle, because it produces natural draught for smooth flow over fin.
v. The perforation fin produces more heat transfer than the solid fin.
vi. The heat transfer in optimum in case of 5 mm diameter as compare to 6 mm because as hole size increases the surface area for heat conduction decreases.
vii. The heat transfer in optimum in case of 5 mm diameter as compare to 4 mm because as hole size small because of that the air restriction for pass through it so heat transfer decreases.

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