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Experimental Investigation of Heat Transfer by Natural Convection with Perforated Pin Fin Array

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Abstract

The main objective of this experimental study is to quantify and compare the natural convection heat transfer enhancement of perforated fin array with various fin spacing, perforation angle, perforation diameter, pitch of perforation and heater inputs. The variables for this natural convection cooling with the help of finned surfaces are orientation and geometry. In this study, the steady state heat transfer from the solid fin and perforated fin arrays are measured. The present study establishes optimized fin setup for various parameters of fin geometry and its effect on heat transfer results. The results obtained are matched well and showed similar trend and satisfactory agreement for heat transfer under natural convection. From all results it is concluded that the heat transfer rate for the fins of perforation with constant pitch and 4 mm diameter with 45^{o} geometry of perforation is optimum fin and the array of this fin with 10 mm spacing is best suited horizontal rectangular fin array.

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Keywords: Experiment; Convection; Array; Temperaure

1. Introduction

Convection is the mode of heat transfer between a surface and a fluid moving over it. The energy transfer in convection is predominantly due to the bulk motion of the fluid particles, though the molecular conduction within the fluid itself also contributes to some extent. If this motion is mainly due to the density variations associated with temperature gradient within the fluid, the mode of heat transfer is said to be due to free or natural convection. On the other hand fluid motion is principally produced by some superimposed velocity field (like a fan, blower or a pump),

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the energy transport is said to be due to forced convection [1-3]. Mainly there are two ways to increase the rate of heat transfer either by increasing convection heat transfer coefficient or by increasing the surface area. Increasing heat transfer coefficient may require the installation of a pump or fan, or replacing the existing one with a larger one, but this approach may or may not be practical. Besides, it may not be adequate [3]. The alternative is to increase the surface area by attaching to the surface extended surfaces called fins made of highly conductive materials such as aluminium. Such finned surfaces are commonly used in practice to enhance heat transfer, and they often increase the rate of heat transfer from a surface several fold [4.5].

2. Literature Review

Heat conduction is the mode of heat transfer accomplished via two mechanisms, by molecular interaction where energy exchange takes place by kinetic motion or by direct impact of molecule, or by the drift of free electrons as in case of metallic solids. Convection is the mode of heat transfer between a surface and a fluid moving over it [3, 6]. A large number of studies have been conducted on shape modifications by cutting some material from fins to make holes, cavities, slots, grooves or channels through the fin body to increase the heat transfer area and/or the heat transfer coefficient. Bassam and Abu [1, 2] conducted the numerical analysis and found that the heat transfer through permeable fins resulted in significant enhancement over solid fins. They stated that increase of number of permeable fins always resulted in increase in Nusselt number unlike in solid fins. They used certain assumptions to make the analysis simple that the fins are made up of highly conducting material. They did not validate their results with experimental work. Ridouane and Campo [3] in their study showed the enhancement in heat transfer using grooved channels. They found that the grooves enhance the local heat transfer relative to flat passage. Jamin and Mohamad [4] quantified and compared the steady state heat transfer from a heated vertical pipe with and without porous medium. They found that the largest increase in Nusselt number was achieved by high thermal conductivity solid carbon foam sleeve, which was about 2.5 times greater than a bare copper pipe. Ahn et al. [5] in their experiment compared the heat transfer rates with rounded and elongated holes in rectangular plate. They showed that elongated holes enhance heat transfer rate more than rounded holes but at the cost of pressure drop. Layeghi [6] in his numerical analysis also showed that heat transfer can be enhanced using porous media, but there is an increasing in pressure drop. Abdullatif Ben-Nakhi et al [7] studied the natural convection in open cavity. They found that the heat transfer rate increases with the thin fins attached to the hot surface. Zhnegguo et al., [8] used three-dimensional petal shaped finned tubes to enhance the heat transfer. Povel and Mohamad [9] in their experimental and numerical study, investigated the effect of metallic porous material, inserted in a pipe, on rate of heat transfer. Effects of porosity, porous material diameter, thermal conductivity as well as Reynolds number on heat transfer rate and pressure drop were investigated. Awasarmol et al. [11, 12, 13, 14] studied the effect of permeability of fins on natural and forced convection heat transfer. On the basis of temperature profile they experimentally and numerically found out that the permeable fins perform better than the solid fins.

The objective of present study is to experimentally quantify and compare natural convection heat transfer enhancement in perforated aluminum fin array with various perforation configurations, different perforation diameters, different heat inputs and at different angles of inclination, consequently to check the suitability of perforated fins (as opposed to solid fins) for industrial applications as far as the heat transfer enhancement is concerned. The study investigates the steady state heat transfer from the vertical plate with solid and perforated fins in natural convection environment and compares heat transfer performance results of perforated fin array to solid fin array.

3. Experimental Setup

An experimental setup is designed and developed to carry out the investigation on Horizontal Rectangular Fin Array under mixed convection. The length and height of fin flats is kept same as in case of natural convection. Insulating siporex block was also used to reduce the leakage of heat from bottom and sides of fin array. Thus side and bottom heat losses from the siporex block were measured an accounted for. Experiments are performed with natural and mixed convection to get better idea about the relative performance of same fin array. The main objective