Experimental study and heat transfer analysis of effect of various perforations on vertical heated plates in natural convection

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Abstract- This Heat transfer by natural convection is to found very important role in many engineering applications such as cooling of automotive, electronic components, nuclear reactors etc. The weight and size of equipment are always important parameter of design. Nowadays general trend is to use more compact system results higher packing density and causes higher heat generation which may affects performance and causes its failure. Continuous research is going on to improve the heat transfer rate by reducing thermal boundary layer thickness. Perforation on heat sink is one way to enhance heat transfer rate. An experimental work is presented to investigate heat transfer rate by natural convection in a vertical perforated plate. Aluminum plates (200*200*20) are used one plate is non perforated and other are perforated by introducing different shape and size (circular, triangular and square) modification. These perforations are distributed in 3 rows and 4 columns. The parameters varied for experiment is heaters input (60 – 120 watt), area of perforation (33.2 mm^2 to 176.8 mm^2). The results shows that drop in temperature as perforation size increases and also largest value of heat transfer coefficient at circular perforation and it is also observed that as perforation size increases value of convective heat transfer coefficient is increases.

Keywords: **Natural convection, perforated vertical plate, Heat transfer rate.**

I. INTRODUCTION

The performance of thermal sink can be enhancing by applying extended surfaces. The practical application is found in many industrial applications, cooling of automobile engine, electronic devices. Fins are used as extended surfaces weight and volume of the equipment and system becomes bulky. While a result, in recent years a lot progress has been made to optimize the fin geometry (elshafei et.al, 2010).

Extended surface technology is improved in recent years, new design ideas has comes in to picture, including fins made of various materials. In electronic equipment there is high demand for low weight, reduced size, and economical fins, the optimization of the fin size has great importance. Therefore fins must be designed to get maximum heat transfer with minimum material expenditure, taken into account, and also with the ease of manufacturing the fin shape. A large number of studies have been conducted on optimizing fin shapes (ali Th. et. al, 2007).

Processes for improving heat transfer classified in three families: active and passive methods and compound. Active type heat enhancement process required an external power source to increase heat transfer but passive methods do required the external power source.

One of the popular heat transfer augmentation technique involves the use of interrupted surfaces of different configurations. The interruption aims at promoting surface turbulence that is intended mainly to increase the heat transfer coefficient besides the surface area. It was noticed that the non-flat surfaces have natural convection coefficients is more than those of flat surfaces (Abdullah, H. et. al 2009).

Many other researchers reported a similar trend for interrupted, perforated and roughed surfaces, attributing the improvement to the restarting of the thermal boundary layer after each interruption, indicating that the increase in the convective heat transfer coefficient even if reduction in area (sheri,M.R. et .al 2009).

Other studies have introduced shape modifications by removing some materials from fins to make perforation, slot, grooves or the channels through the fin body to increase heat transfer rate. One popular heat transfer enhancement method involves the use of artificial rough or interrupted surfaces of different shape. The concept of heat transfer through perforated material is one method of improving the heat transfer characteristic in the natural convection. Continuous research is going on to increases heat transfer rate by reducing the thermal boundary layer thickness (Raaid R. ET. Al. 2013).

II. LITERATURE REVIEW

In recent studies Abd et al. (2007) has been done theoretical study for a natural convection heat transfer from horizontal , vertical and inclined heated square (with and without circle hole) which include the numerical study of the transient N-S equations. Alli et al. (2007) has been done experimental study for isothermal square flat plate (with and without square hole) with extended surface. The experimental work laminar region with a range of Rayleigh number of order of 10^6, and included the manufacturing of four square models of aluminum (10cm) length, (1cm) thickness and ratio of perforation (m=0.0,0.04,0.16&0.36) respectively.

Another important heat transfer enhancement technique involves the use of rough or interrupted surfaces of various patterns. The artificial surface roughness or perforation or interruption to boundary layer promotes surface turbulence which increases the heat transfer rate and reduces surface area and volume. It was observed that non-flat surfaces have free convection coefficients that near about 1.5 to 2 times greater conventional flat surfaces. Many other researchers reported a similar kind of results for rough, interrupted, perforated, and assigning the improvement in boundary thermal boundary layer thickness after each interruption, indicating that the increase in convection coefficient.

In 2007 A. M. et al. Studied the natural convection heat transfer from perforated fins. The temperature gradient across perforation was examined for an array of rectangular fins (15 fins) with uniform cross-sectional area with different vertical plate perforations. The perforations pattern on plate include 18(4*4) circular hole. The coefficient of convective heat transfer increases with hole diameter increased. Ganesh Kumar et.al. Perform experimental study on mixed convection heat transfer through perforated pin fin and he reported that perforation enhance the heat transfer rate it depends on perforation size.

AlEssaet.al. experimentally investigated the enhancement of natural convection heat transfer from a horizontal rectangular fin embedded with rectangular perforations of RAF ratio of two. The results of perforated fin compared with its equivalent non perforated one. An experimental study was carried out for geometrical dimensions of the fin and the perforations. The study investigated the gain in fin area and of heat transfer coefficients due to perforations. They observed that that, values of rectangular perforation dimension, the perforated fin enhance heat transfer. The enhancement in heat transfer rate is directly proportional to the thickness of plate and perforation ratio. Shaeriet al. Studied the laminar and turbulent fluid flow and convection heat transfer around fin array of rectangular solid with different number of perforation and different size. Experiments were conducted for the laminar region. This experiment was conducted to examining the transfer enhancement from vertical rectangular isothermal plate under natural convection. Conditions as a result of introducing modification (perforations) to the fin body. Perforated fins can be effectively used to increase the heat transfer rate and effective heat transfer area. The change in magnitude of the surface area depends on the geometry of the perforations (Abdullah et al. 2009).

Jassemet all performed an experimental study to investigate the heat transfer by natural convection in a rectangular perforated fin plates. six extended surface plate used in this experimentation out of which one fin non-perforated and others fins perforated by different shapes these fins perforation by different shapes , but these perforations ratio have same. These perforations distributed on 3 columns and 6 rows. It is observed that the drop in the temperature gradient of the non-perforated. The greater value of RAF is observed at triangular perforation and the less value occurred in circular one. Also, triangular perforation gives better values of heat transfer coefficient than circular perforation, square, hexagonal, and non-perforation respectively.

III. DESIGN AND DEVELOPMENT EXPERIMENTAL SETUP

A schematic diagram of this experimental setup is as shown in Fig. 1. The experimental setup consists of the following parts such as Teflon K type thermocouple, Temperature Indicator, cartridge heater as heat Heating element, control panel to vary the heat input, Duct to maintain natural convection, Stand and Hanger etc.

Fig 1 Experimental setup

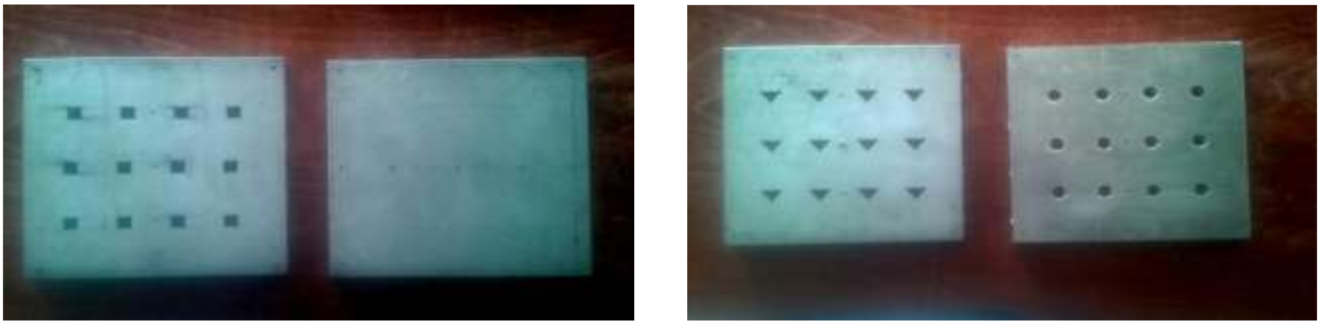

Fig. 2 Plate specimen used in experimentation

3.1 Test Plate:

In this experimental work is conducts to develop the perforated plates with triangular, circular, and square shapes with different size of perforation. Thermal performance of the perforated plates will be compared with the plain vertical heated plate and it will suggest shape modification in fin. The plain vertical plate and proposed perforated plates with variation in the size perforations are as shown in Fig.No.2. Material used for plate is aluminum. These materials are selected considering the thermal properties like thermal conductivity and production feasibility.

Table 1 plates used in experimentation

Case	Shape of Perforation	Area of perforation
solid plate		
Circular perforated plate	Circular 12(3*4)	Plate 1 (33.2mm^2) Plate 2(86.6mm^2) Plate 3 (122.7mm^2) Plate 4(176.7mm^2)
Triangular perforated plate	Triangular 12(3*4)	Plate 1 (33.2mm^2) Plate 2(86.6mm^2) Plate 3 (122.7mm^2) Plate 4(176.7mm^2)
Square perforated plate	Square 12(3*4)	Plate 1 (33.2mm^2) Plate 2(86.6mm^2) Plate 3 (122.7mm^2) Plate 4(176.7mm^2)

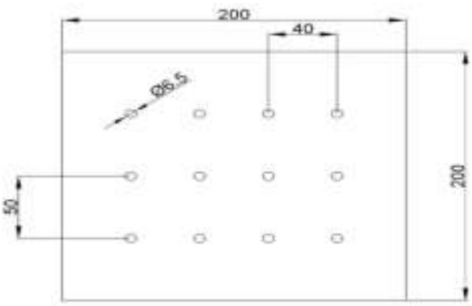

Fig .3 Circular perforation with hole dia 6.5 mm

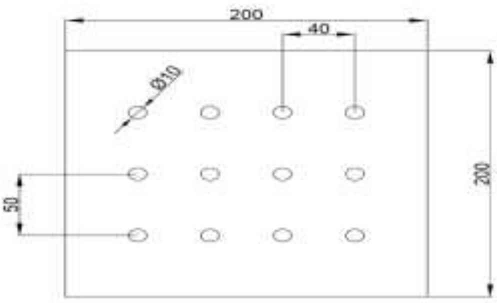

Fig .4 Circular perforation with hole dia 10 mm

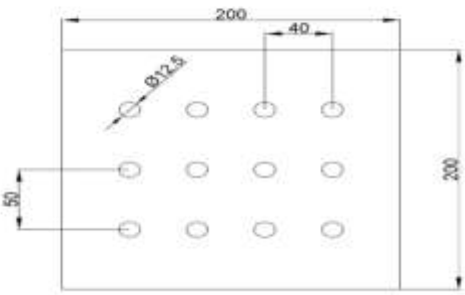

Fig .5 Circular perforation with hole dia 12mm

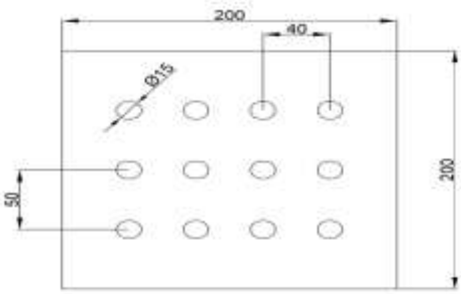

Fig .6 Circular perforation with hole dia 15 mm

3.2 Test Methodology:

In order to conduct the experimental study of Natural heat transfer coefficient through vertical heated perforated plate of aluminum is selected , it has been decided to vary the heater input from 60 W to 120 W in the step of 30 W. Readings are taken up to steady state condition . Cartridge type of heater is placed evenly in test plates for that separates hole are provided along the plates. Test set up is assembled vertically and Voltage supplied is varied (60- 120 watt) with the help of dimmer stat and temperatures are recorded with temperature indicator.

3.3 Experimental procedure

First of all the thermocouples are connected to the plate at the locations and simultaneously are connected to control panel. The power is set by the dimmer and given to the heater; the heater will heat the plate. After the steady state means at the time when there is no change temperature taking place the readings are recorded by temperature knob. The same process is carried out for all the plates. The recorded values are entered in the excel sheet for the various calculations. By using the values of various parameters the graph are plotted. The required conclusions are concluded through the various graphs.

3.4 Test Parameters and Calculations:

Experimentation was carried on the perforated and non perforated plate at heater input in watt.

Table 2 Test parameters

Parameters	Description
Heat load (W)	60W,90W,120W,
Time	Up to Steady State

All the required equipment was assembled and experimental set was developed. The necessary instruments were attached at proper location and the set up is ready for the experimentation.

IV. RESULTS AND DISCUSSION

Experimental study was conducted by using one solid (non- perforated) and others are perforated as per proposed size and shape as show in table no1. The effect of perforation size and shape are presented by heat transfer coefficient vs. watt input. The heat transfer coefficient is calculated by varying input and perforation size. The results are plotted in heat transfer coefficient vs. various parameters like heat input, variation in perforation size.

Fig.7 and fig.8 shows that value of heat transfer coefficient calculated by experimental and theoretical method are approximately similar. Experimental values are 10% varies from theoretical one because of field errors. From these graph we can say that the experimental work is validated.

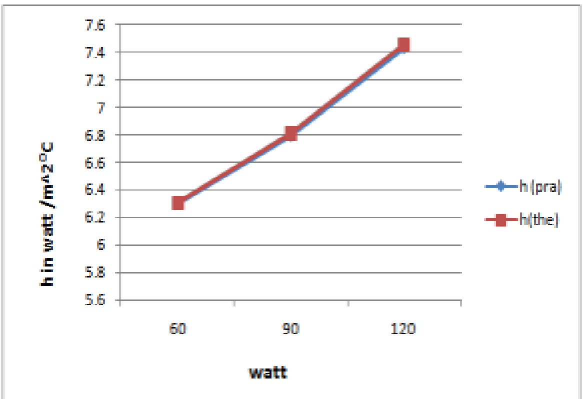

Fig.7 Comparison of heat transfer coefficient calculated experimentally and theoretically for circular perforated plate 4

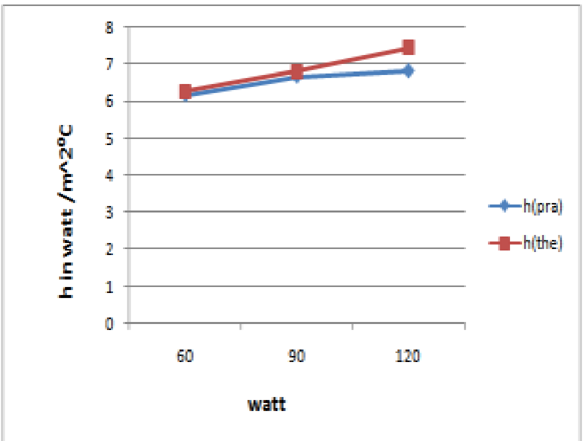

Fig.8 Comparison of heat transfer coefficient calculated experimentally and theoretically for circular perforated plate 3

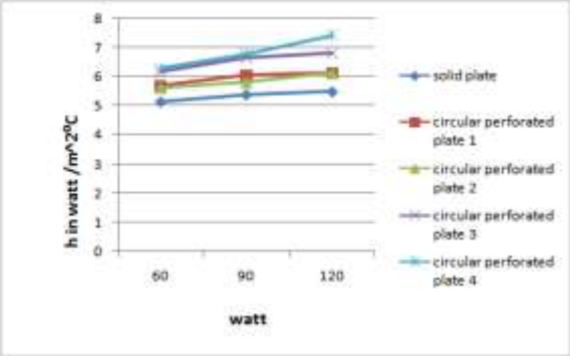

Fig.9 Variations in heat transfer coefficient with heat input for circular perforated plates.

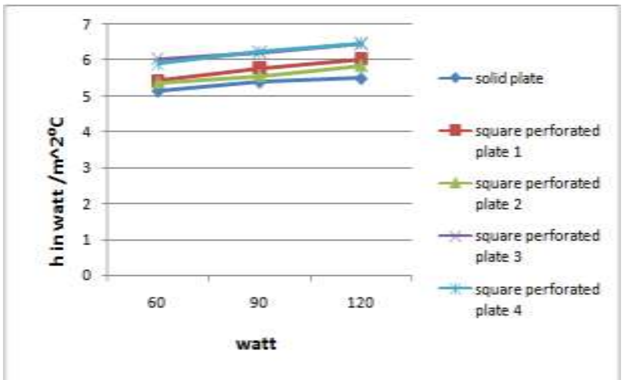

Fig .10 Variations in heat transfer coefficient with heat input for square perforated plates

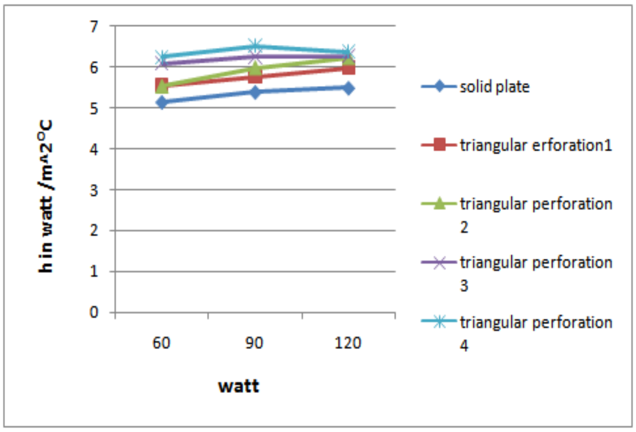

Fig .11 Variations in heat transfer coefficient with heat input for triangular perforated plates

In fig.12, fig.13, fig.114, fig15 comparison made between circular, triangular and square type of perforated plate. As circular shape having its own advantages like area to volume ratio, it is observed that circular perforated plate give better performance than square and triangular type of perforated plate.

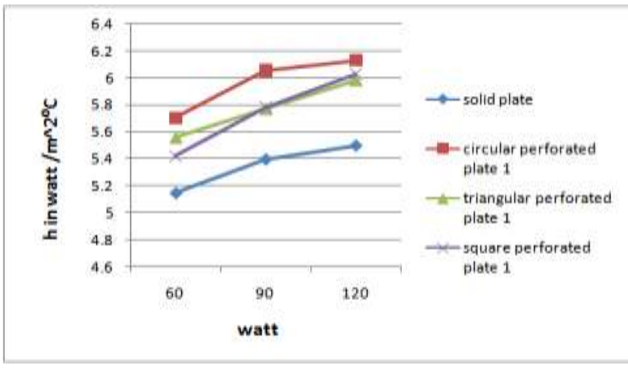

Fig.12 Comparison in variations in heat transfer coefficient with heat input for various perforated plates of same cross sectional area

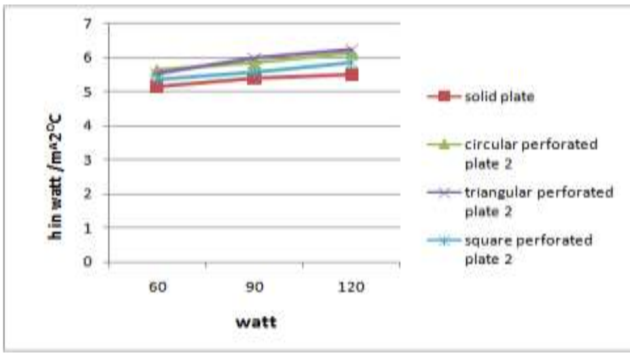

Fig.13 Comparison in variations in heat transfer coefficient with heat input for various perforated plates of same cross sectional area

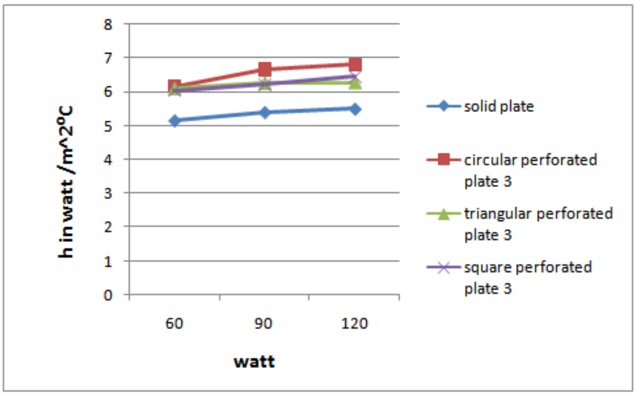

Fig.14 Comparison in variations in heat transfer coefficient with heat input for various perforated plates of same cross sectional area

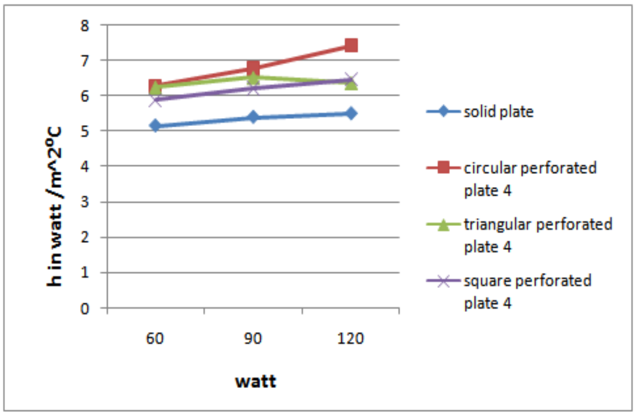

Fig.15 Comparison in variations in heat transfer coefficient with heat input for various perforated plates of same cross sectional area

V. CONCLUSIONS

Experimental study is carried out on perforated plate Based on above experiential study following conclusion can be drawn

1. Heat transfer from heated plate is strongly affected by perforations, as perforation area is increased, more boundary layer gets disturb, refuses its thickness and coefficient of heat transfer enhanced.
2. It is observed that circular perforation give better performance than triangular and square perforation.
3. At 5% perforation area heat transfer coefficient can be increased up to 20%. And weight of plate is increases.

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