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# EXPERIMENTAL INVESTIGATION ON THE EFFECT OF DIFFERENT PERFORATION GEOMETRY OF VERTICAL FINS UNDER FORCED CONVECTION HEAT TRANSFER

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***Abstract****-This experimental study is carried out to investigate the effect of the perforation shape or geometry of extended surface byforced convection heat transferto find out the heat transfer characteristics of various perforated fin to clarify the best perforation shapes for plane heat sink. According to the investigation temperature drop along the perforated fin is greater than non-perforation one. The average convective heat transfer coefficient increases for 150 W are 78.98% for triangular with respect to non-perforated fins which is more than rectangular 74.36% and 41.42 % for circular, also similarity found for 100W power input triangular perforated fins shows highest temperature difference which is 54.59% followed by rectangular 38.0%, circular 33.04%. The highest temperature difference is found for triangular shapes which is 25.76% while compare the temperature at base of the heat sink with the tip and lowest is 18.84% for non-perforated fin*

**Keywords:** Heat sink; Fins; Perforation; Heat transfer coefficient; Temperature distribution**.**

## 1 INTRODUCTION

Heat transfer is a process of energy transfer from the higher temperature region to the lower temperature region. It is also define as the exchanges of thermal energy between physical systems, depending on the temperature and pressure, by dissipating heat. In the middle of the nineteenth century the true physical understanding about the nature of heat happened due to the development of the kinetic theory which treats molecules as a tiny ball that is in motion, thus possess kinetic energy [1]. Heat is defined as the energy associated with the random motion of atoms and molecules. In 1789 Fresh Chemist Antoine Lavoisier (1743-1794) proposed fundamental heat transfer theory based on Caloric Theory. Caloric theory expresses that heat is a massless, colourless,odourless and tasteless fluid substance and when it is added to a body the temperature increase and when removed temperature decrease [2]. But in 1843, the Englishman James P. Joule carries an experiment and proved that the heat isn't a substance as a result Caloric theory is put into rest. Next time the caloric theory is combined with the law of conservation energy, the caloric theory still shows a valuable aspect on heat [3]. While any engineering system is operated, they produce heat. If this excess amount of heat is not dissipate properly they cause rapid increase in temperature which leads to failure of the system by overheating [4]. So researchers and engineers are constantly study various ways to efficiently remove this excess heat [5]. So if any system would be invented that dissipated this excessive heat then it would be better. As a result effective cooling system is needed. Aircooling is recognized as important technique for cooling thermal device because of its safe operation in hostile environment [6-7]. Fin is an extended surface which is used to enhance the heat transfer rate by increasing heat transfer area. It is used in many engineering application where excessive heat is produced. Using fins heat transfer rate is increase as a result more heat is dissipated. Fins are commonly applied in automotive, electrical and power management system to reduce overheating [8]. Along with extended surface fluid velocity, surrounding temperature around any component plays significant rolls to dissipated heat from the system [9]. Many study done on various parameters of extended surface. Walunj et al. [10] showed that heat sinks plays a vital rules to avoid electronic failure. Geometric parameters of fin like fin spacing, fin height, fin length, fin thickness, fin number significantly affect convection heat transfer. They also concludes that vertical fin array is more effective. But fins increases the total weight of system. So any system that reduce weight and increase heat transfer rate then it is better. To increase the heat transfer rate and to reduce the material weight of the fins, the fins can be perforated so that the fins are more efficient in size and weight [11]. The spacing between the fins and fin perforation has a significant effect on the heat transfer characteristics [12-13]. Various perforation shapes have been study but effective perforated shape is not fully understood. Some investigation introduce new structure through making cavities, holes, slots, grooves or channels along the fins surface to get the higher heat transfer rate and additionally the heat transfer coefficient. By applying the perforation to the fins bodies, it will extend the heat transfer [14]. According to Chaudhari et al. [15] the heat transfer rate and the heat transfer coefficient is expanded with the perforation diameter increased. The perforation shapes additionally grow to be a foremost element in accomplishing the most heat transfer coefficient and additionally the temperature distribution along the plate. For finding best perforation shape many investigation occurs day by day. Shaeri et al. [16] concluded that the heat dissipation rate is the most important for perforation dimension and lateral spacing for the perforated fin.Salimi et al. [17] numerically found that in film compound circular cooling holes increases the cooling rates than the other. According to the study of Junqi et al. [18] Perforation increase the heat transfer rate and compared the elliptic perforation with normal plate fin and find higher heat transfer rate than plate fins and additionally reduce the expenditure of the fin material. Al-Doori[19] experimentally investigated that with rectangular fins against plate fins and find perforated rectangular fins are higher than the easy plate fin, the experiment also conclude that the number of perforations have an effect on temperature distribution, the heat transfer rate and the coefficient of heat transfer. Different shape of perforation shows different effect of heat transfer coefficient, pressure drop, and also the temperature distribution. According to Qin et al. [20] fin angle have significant effect on both convection and radiation heat transfer. The number of perforations also becomes the important issue in the enhancement of the perforation to the plate fin.Ibrahim et al. [21] experimentally found that various perforation shapes of fins have significant effect on forced convection heat transfer. The result convince that perforation on fins assist to increase convective heat transfer coefficient which results increase in heat transfer rate. In this modern area the engineering becomes more complicated, size and weight becomes an important factor. So new design that requires compact size and light weight properties have been done in order to achieve maximum heat removal with minimum material exposure including a selection of material, perforated and interrupted plate. In this study the effect of three perforation shape triangular, rectangular and circular have been investigated under forced convection to find out the best perforation shape.

## 2. RELATED WORK

### 2.1 Effect of number of perforations

As fins is extended surface so using it weight is increased. There are so many researcher thinking about the best modification of fins. As a result they making cavities, holes, slots and groove and find out which is best. Perforation is the best technique that reduce the weight but increase heat transfer coefficient. Jasim et al. [22] found that heat transfer rate increase with increasing perforation area at same perforated shape. Some researcher are studying with optimal perforation number on unit area which dissipated higher heat from the source. Based on ANSIS analysis the thermal flux is higher in perforated fins with respect to non-perforated fins. According to Jassem [23] who find the lowest temperature at triangular perforated shape at natural convection.

Table 1: refers percentage of weight reduce due to number of perforation [16].

| Number of perforation | Percentage of weight reduction |
|---|---|
| 2 | 5.56 |
| 3 | 11.11 |
| 4 | 16.67 |
| 5 | 22.22 |
| 6 | 33.33 |
| 7 | 44.44 |
| 8 | 25 |
| 9 | 44.44 |
| 10 | 69.44 |

Table 2: refers heat flus obtain with respect to number of perforation [22].

| Number of perforation | Heat flux (W/m2) |
|---|---|
| Without perforation | 656 |
| 2 | 819 |
| 4 | 883.4 |
| 6 | 847.4 |
| 8 | 911 |
| 10 | 999 |
| 12 | 1040.1 |

## 3. EXPERIMENTAL SET UP

### 3.1Wind Tunnel

A wind tunnel shown in fig.1 was used to run air flow into the extended region to making velocity.The dimension of wind tunnel $890\times 160 \times 160$mm .

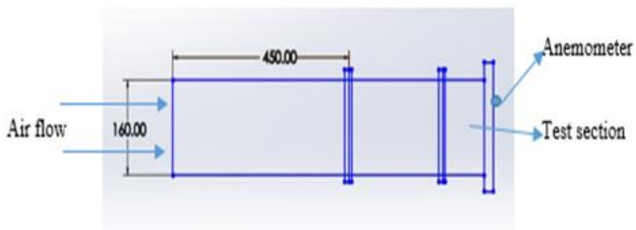


Fig.1: Schematic diagrams of the wind tunnel.

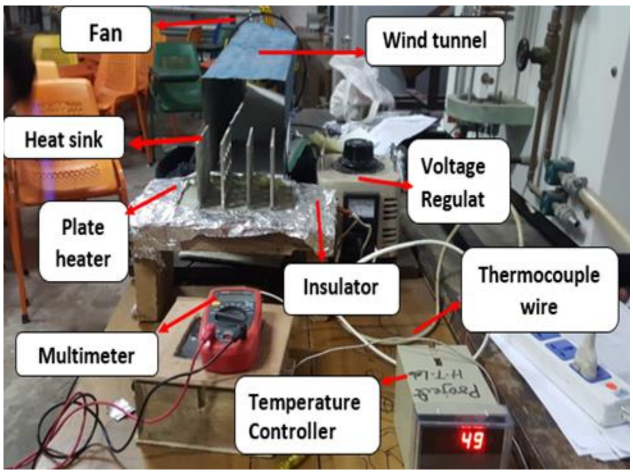


Fig.2: Experimental set up

Wind tunnel consists of fan to control speed velocity, to make flow uniform at inlet straightener is used near to inlet. Air velocity is measured using Anemometer.

### 3.2 Heat sink assembly

For heat sink a solid aluminum block of 190 mm long and 120 mm width and 7 mm thickness were taken. The fins were 120 mm long, 85 mm wide and 4 mm thick. Fig.3 show the components of the heat sink assembly. Each fins were place 38mm distance for equal heat distribution. To minimize the heat loss from the base plate and the fins plates, the fins plates were placed inside the base plate 3 mm, moreover soldering was done to base plate and fins to reduce heat loss. A 500W plate heater is used at the base of the heat sink as heat source that generate uniform heat flux at different output.

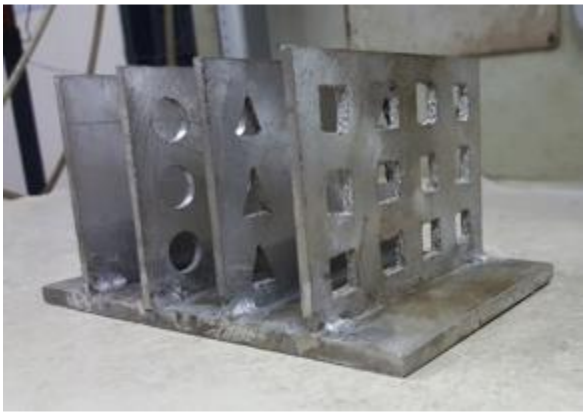

Fig.3: Heat sink design.

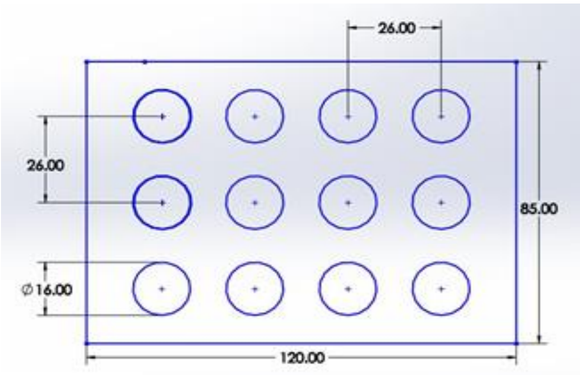


Fig.4:Dimension of circular perforated fin

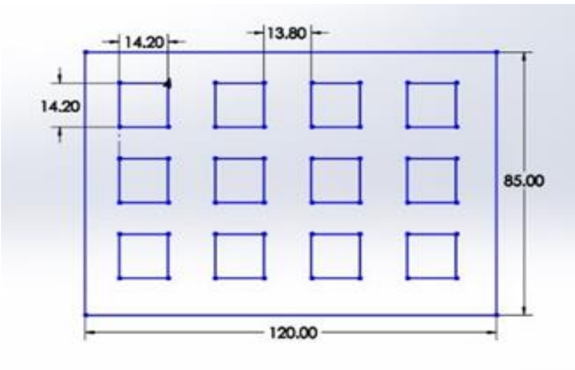


Fig.5:Dimension of rectangular perforated fin

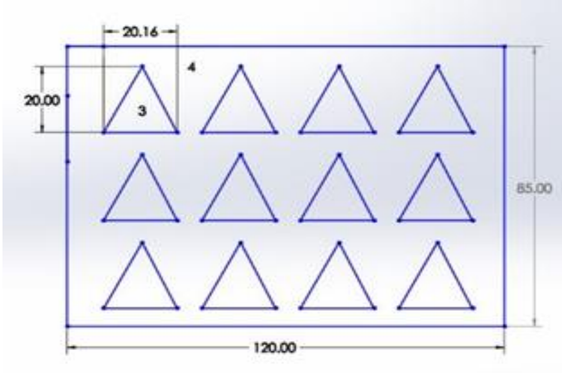


Fig.6: Dimension of triangular perforated fin

### 3.3 Data Collection

All the data have been recorded by thermocouple type-K that is calibrated and all recorded data convert this standard. A wind tunnel is used that is able to supply constant and variable velocity. A Voltage regulator is used control voltage input to the plate heater and Multimeter is used to measure the current. Input heat flux is calculated using this current and voltage. The thermocouple have been struck to plate fin (without perforation) at 8mm, 20mm, 50mm, fins tip. Two powerinput 100W and 150 W is applied at the base of the heat sink using voltage regulator and wait until temperature becomes steady. Temperature at the base of the heat sink and fins at different position are taken.This process repeat for other fins such as rectangular, triangular, circular fins. Further it done for different velocity(1.9 m/s, 2.2 m/s,2.9m/s, 3.4m/s ) at 100W and 150W input power at previous way.

### 3.4 Mathematical Analysis on Perforated fins

By given perforation to the fins, the surface area of the fins can be increased but the size of the fins can be maintained. The total surface area of the rectangular fins that touches the fluid flow with the different perforation shape can be determined by subtracting the area of fins without the perforation. In this study, the number of perforations was N assumed. For the rectangular type perforated fin, the surface area can be expressed as follows:

$A_{rec}= A_t - A_{p\,(rec)}= [(A\times B) +2(B\times C) +2(C\times A)] - [N\times a\times b]$

For the circular type perforated fin, the surface area can be expressed as follows:

$A_{cir}= A_t - A_{p(cir)} =[(A\times B)+2(B\times C)+2(C\times A)] - [N\times \pi\times r^2]$

For the triangular type perforated fin, the surface area can be expressed as follows:

$A_{tri}= A_t - A_{p\,(tri)} = [(A\times B) +2(B\times C) +2(C\times A)] - [N\times \frac{x\times y}{2}]$

### 3.5 Convective heat transfer coefficient

Convective heat transfer coefficient, h is the rate of heat transfer between a solid surface and a fluid per unit surface area per unit temperature difference [24]. Heat transfer coefficient can be obtained by:

$$h=\frac{k\left(\frac{\delta y}{\delta x}\right)S}{T_s - T_\alpha} \quad (1)$$

Where $T_S$= Surface Temperature, Tα= Ambient temperature in (°C).

### 3.6 Convective heat transfer rate

Convection heat transfer depends upon solid surface and adjacent fluid that is in motions also combine effect of conduction and fluid motion. Higher the fluid motion better the convection heat transfer. Conduction heat transfer between solid surface and adjacent fluid layer then het is carried away by convection. The convective heat transfer rate 'Q' can be expressed as Newton's second low of cooling as

$$Q = hA_c(T_S - T_\alpha) \quad (2)$$

Where $A_C$ is Surface area in $m^2$

## 4. RESULT AND DISCUSSION

### 4.1 Temperature Distribution

This experiment is done at steady condition while base plate temperature is 105.26̊ C and 133.37 °C for 100W and 150 W respectively, then fins temperature at different position have been recorded .Where $T_1$, $T_2$, $T_3$, refers the temperatures8mm, 20mm, 50mm from base plate respectively and$T_{out}$ refers the temperature at the fin tip.

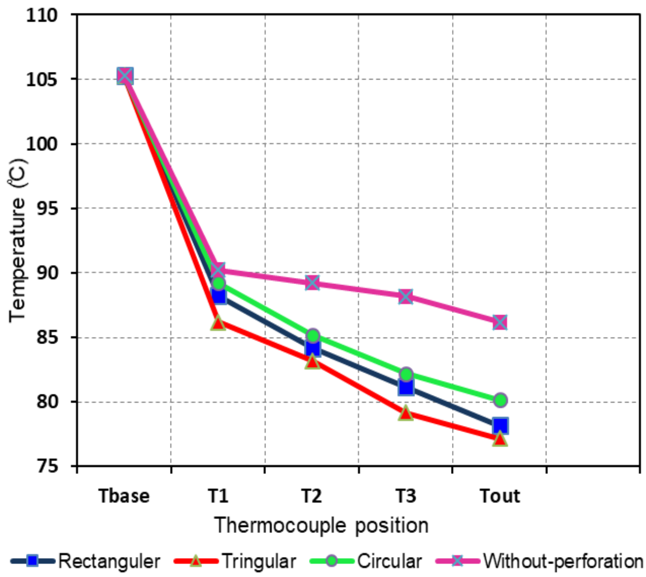


Figure.7: Temperature distribution (100W).

Fig.7 and fig.8 represent Temperature distribution sat different Thermocouple position for 100W and 150W respectively at velocity 0 m/s. From the figures it found that temperature gradually decreases from base plate to fin tip this is because heat from base plate is dissipated along the fin. Triangular perforation shows highest temperature difference between base plates and fin tip shoes in fig.7 which is 26.67% followed by 25.71% for rectangular, 23.81% for circular and 18.09% at 100W.Temperature difference between base plate and tip of the fin at 150 W shows in fig.8 24.81% for triangular, 22.56% for rectangular, 23.31% for circular, and 19.55% for non-perforated fin.

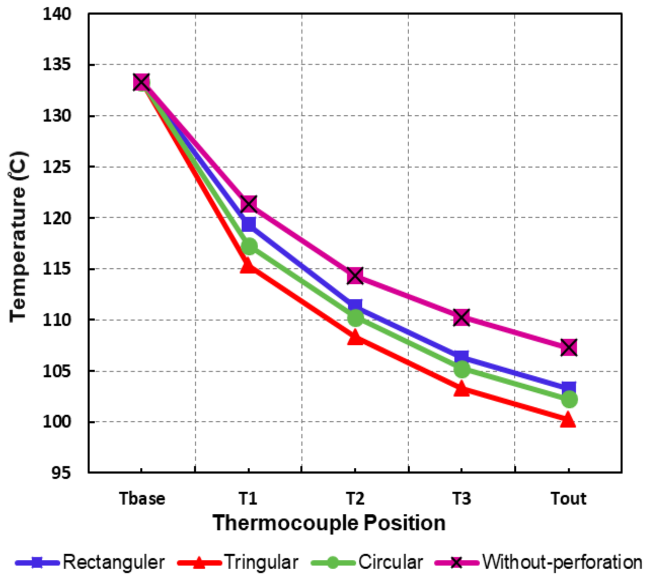


Fig.8: Temperature distribution (150W).

Different percentages found for different power input because gradation of heat and time for heating is different for different power input. In both cases triangular perforated shapes best result.So it is clear that perforation and perforation shapes of fin have significant effect on temperature distribution through the fin which effects the performance the fins. Triangular perforated shapes shows best result followed by rectangular and circular.

### 4.2 Heat transfer co-efficient

Figure 9 and fig.10 shows heat transfer coefficient h at different velocity for different perforated shapes at inlet control temperature of air 28 °C throughout the experiment. Values of heat transfer coefficient h is calculated using eqn.2 at 100W and 150W power input.

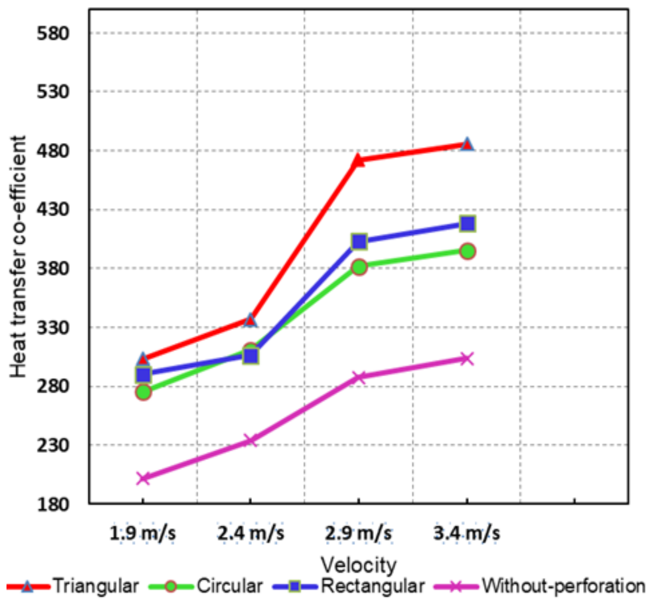


Fig.9: Heat transfer coefficient (h) at different velocity at 100W.

From the graphs it is clear heat transfer coefficient increase with the increase in velocity and heat transfer coefficient is highest for triangular perforated shapes at both power input compared with non-perforated fins. It can be also concluded that all three perforated fins shows better result than non-perforated one. This is because perforation assist to create turbulence around the perforated area which helps better heat dissipation from the heated body also geometry of the perforation shapes effects the intensity of the turbulence. Velocity of air varies from 1.9 m/s to 3.4 m/s for both power input.From fig.9 heat transfer coefficient increase 54.59% compared with non-perforated fins which is highest followed by 38% for rectangular and 33.04% for circular perforated shapes at 100W.

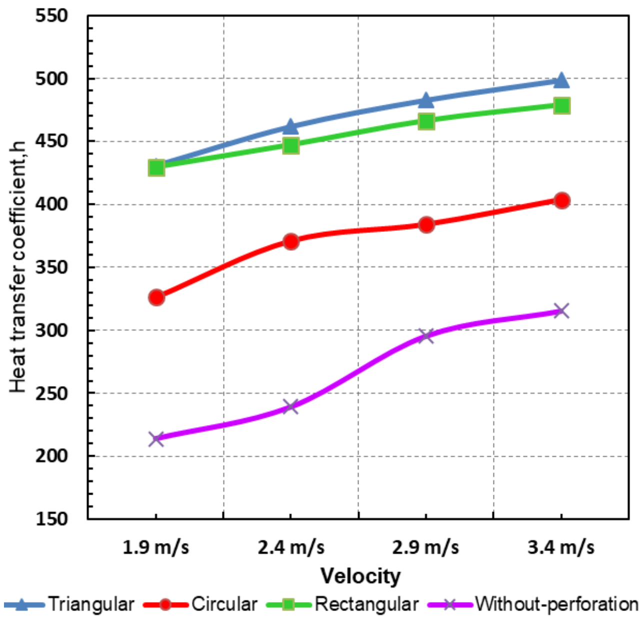


Fig.10: Heat transfer coefficient (h) at different velocity at 150W.

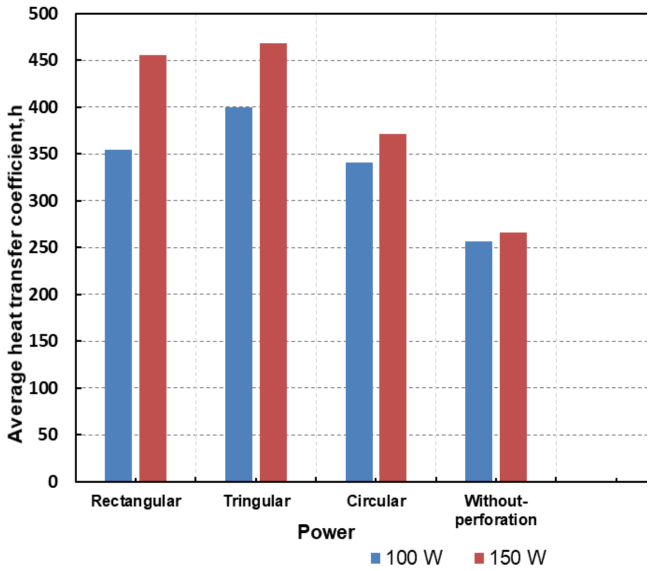


Fig.11: Heat transfer coefficient of different perforation shape against different input power

At 150W power input heat transfer coefficient increases 78.98% for triangular, 74.36% for rectangular and 41.42% for circular perforation compared with non-perforated fins showed in fig.10. So similarity found with 100W power input. Triangular shapes perform better than the other two which is 17.22% and 26.18% while compare with the circular shapes at 100W and 150W respectively. Also better than rectangular shapes which is 12.71% and 2.84% at 100W and 150W power input. In both cases heat transfer coefficient increase in perforated fins rather than non-perforated fin and triangular shapes shoed best result followed by rectangular and circular shapes.Figure 11 represent the heat transfer coefficient against different input power for three perforation shapes and non-perforated fins. In this figure it is clear that heat transfer coefficient increase with increasing power input.

But the amount of heat transfer coefficient increment totally depend on geometrical shapes of perforation. In this figure for rectangular shape increasing rate is high than other shape and for plate fin or without perforation shape.But triangular perforation shape in term of heat transfer coefficient for individual power input.

## 5. CONCLUSION

The aim of the experiment is to find out the effect of perforation and perforation shape in forced convection heat transfer at 100W and 150W power input combined with different velocities. Perforation in the fin t helps to dissipate heat more rapidly from solid and fluid interface at perforated area. Moreover narrow edge of perforated area increase turbulence intensity. From this study it can be concluded that:

- By giving perforation to the fins will increase the temperature difference which affect the temperature distribution along the fin area also heat coefficient of the heat sink.
- Perforation significantly affect the temperature distribution along the fins.
- Perforation to the fins increases heat transfer coefficient by 33.04% to 78.98% for 100 W and 41.42% to 78.98% for 150W regarding to the perforation shape or geometry at velocity 1.9 m/s to 3.4m/s.
- Heat transfer coefficient increases most for triangular perforation followed by circular, rectangular and no perforation for different power input.So in forced convection heat transfer perforation and perforation shapes of fin showed a significant effect.

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## 8. NOMENCLATURE

| Symbol | Meaning | Unit |
|---|---|---|
| Q | Input Power | (W) |
| h | Convective heat transfer coefficient | ($W/m^2K$) |
| $\frac{\delta y}{\delta x}$ | Temperature normal to the surface area and perforation | ($^0C$) |
| $A_{rec}$,$A_{tri,}$ $A_{cir}$ | Area of rectangular, Triangular and Circular perforated fins | ($m^2$) |
| A | Length of rectangular fins | (mm) |
| B | Thickness of rectangular fins | (mm) |
| C | Height of rectangular fins | (mm) |
| a,b | Length and height of rectangular perforation | |
| r | Radius of circle | (mm) |
| x,y | Base and height of triangle(mm) | (mm) |