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# Design and Analysis On Effects of Different Fin Perforations

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***Abstract***

*In many engineering applications extended surfaces known as fins, are used to enhance convective heat transfer. The problem of natural convection heat transfer for perforated fins was investigated in this work. An experimental study was conducted to investigate the natural convection heat transfer in a rectangular fin plate with no perforations ,square perforations, triangular perforation and circular perforations. The investigation is conducted to compare heat transfer rate of different fins embedded with different types of perforations. Experimental results shows the temperatures distribution and heat transfer coefficient calculated using Ansys Workbench 19.2 and Furthermore, for different perforation , the heat transfer rate and the coefficient of heat transfer also varied giving better results. The work done on various types of fins, effect of perforation shape or geometry on the heat transfer was simulated in ANSYS to determine best type of fin to be used.The comparison between experimental result and software result between the types of fins perforation was analysed for the heat transfer coefficient to clarify the best perforation shape for the required application.The experimental was reported for temperature distributions when the heat supplied are respectively. The overall conclusion shows different perforations analysed and their results are tabulated.*

*Keywords – perforations, Ansys workbench, Temperature distribution, Natural convection etc.*

## I. LITERATURE SURVEY

Thamir K. Ibrahim.[2] Heat sink with perforated and non-perforated fins were investigated. Perforated fins increase the heat coefficient of the heat sink by 35.82–51.29%.The difference between experimental and numerical results was about 8% and 9% for temperature distributions when the power supplied are 150 W and 100 W respectively. The fluid and heat transfer properties of heat sink were studied experimentally and numerically using CFD. Heat sink with perforated fins showed significant effect on the performance of forced convection heat transfer.

L.Prabhu[3].Heat transfer performance of fin is analysed by ANSYS workbench for the design of fin with various design configuration such as cylindrical , square and rectangular configuration. The heat transfer performance of fin with same base temperature is compared. In this thermal analysis, Aluminium was used as the base metal for the fin material. Fins are design with the help of CATIA V5R16. Analysis of fin performance done through the software ANSYS 15.0.

M.Sabri Sidik[4].An analysis was conducted to study the heat transfer of in-wheel electric motor cooling fin for light electric vehicle application. This study focuses on motor housing design and heat transfer analysis of different cooling fins arrangement for motor housing. Three types of cooling fin

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arrangement on the motor housing has been selected and modelled in CATIA software. There were straight fin, slanting fin and transverse fin. Then, all models were exported to ANSYS for heat transfer analysis purpose. This suggests that the straight fin arrangement has the highest efficiency of heat dissipation and distribution compare to the slanting and transverse fin arrangement

Zan WU[5]. Natural convection heat transfer enhancement of perforated fin array with different perforation diameter 4-12mm and a different Angles of inclination (0-90) increase in the heat transfer coefficient was achieved with perforated fins of 12mm perforation diameter of the Angle of orientation 45 degree which shows about 32% enhanced heat transfer coefficient with saving 30% material.

Pardeep Singh[6] In this research, the heat transfer performance of fin is analysed by design of fin with various extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions. The heat transfer performance of fin with same geometry having various extensions and without extensions is compared. Near about ranging 5% to 13% more heat transfer can be achieved with these various extensions on fin as compare to same geometry of fin without these extensions. Fin with various extensions design with the help of software AutoCAD. Analysis of fin performance done through the software Autodesk Simulation Multiphysics. In this thermal analysis, temperature variations w.r.t. distance at which heat flow occur through the fin is analysed. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it.So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it. On comparison, rectangular extensions provide on fin gives the greatest heat transfer than that of other extensions having the same length and width attached to finned surface

## II. INTRODUCTION

Fins are a useful way to increase heat transfer with minimal increase in volume • Fins transfer heat either through free or forced convection • Convection: Heat transfer between a solid surface and a moving fluid. Therefore, to increase the convective heat transfer, one can • Increase the temperature difference (Ts-Ta) between the surface and the fluid. • Increase the convection coefficient h. This can be accomplished by increasing the fluid flow over the surface since h is a function of the flow velocity and the higher the velocity, the higher the h. Example: a cooling fan. • Increase the contact surface area A. Heat exchangers are widely used in various, transportation, industrial, or domestic applications such as thermal power plants, means of heating, transporting and air conditioning systems, electronic equipment and space vehicles. In all these applications improvement in the efficiency of the heat exchangers can lead to substantial cost, space and material savings. Hence considerable research work has been done in the past to seek effective ways to improve the efficiency of heat exchangers.

According to Moore"s law the number of transistors mounted on a chip gets doubled for every two years. As the number of transistors increase with development of chip integration technology increases the power draw and heat load to disperse during operation increases. With the development of chip integrated circuits gradual decrease in size of the components has resulted severe increase in the amount of heat generation per unit volume. Unless they are properly designed and controlled high rates of heat generation result in the failure of electronic component due to high operating temperature. Heat sinks are the most common thermal management hardware used in electronics. They improve the thermal control of electronic components, assemblies, and modules by enhancing

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their surface area through the use of fins. Applications utilizing fin heat sinks for cooling of electronics have increased significantly during the last few decades due to an increase in heat flux densities and product miniaturization. Today"s advanced electronic circuits disperse substantially heavier loads of heat than ever before. At the same time, the premium associated with miniaturized applications has never been greater, and space allocated for cooling purposes is on the decline. These factors have forced design engineers to seek more efficient heat sink technologies. Air-cooling also is accepted as an important technique in the thermal design of electronic packages, because besides its availability, it is safe, does not contaminate the air and does not add Vibrations, noise and humidity to the system in which it is used. Such features of Forced convection stimulated considerable research on the development of optimized finned heat sinks and enclosures. Using fins is one of the most inexpensive and common ways to dissipate unwanted heat and it has been successfully used for many engineering applications. Rectangular fins are the most popular fin type because of their low production costs and high thermal effectiveness

The major heat transfer enhancement techniques that have found widely spread commercial application are those which possess heat transfer enhancement elements. All passive techniques aim for the same, namely to achieve higher values of product of the heat transfer coefficient and heat transfer surface area. A distinguish between the way how the heat transfer enhancement is achieved, is common in the heat transfer community. Here in the present work, a terminology similar to the literature is followed although for practical applications are irrelevant how the heat transfer enhancement is achieved.

### *A. Heat Sink.*

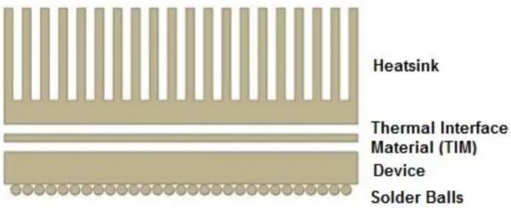


Fig 1. Basic Heat sink

A heatsink is a passive heat exchanger that transfers heat. The heatsink is typically a metallic part which can be attached to a device releasing energy in the form of heat, with the aim of dissipating that heat to a surrounding fluid in order to prevent the device overheating.

In many applications, the device is an electronic component (e.g. CPU, GPU, ASIC, FET etc.) and the surrounding fluid is air. The device transfers heat to the heatsink by conduction. The primary mechanism of heat transfer from the heatsink is convection, although radiation also has a minor influence.

## III. PROBLEM DEFINATION.

- It is observed from the fins of the literature survey are more demanding to cool electronic equipment, stationary engines and many engineering applications, so we need the optimized designs with minimum material and the maximum rate of heat transfer.

- But due to many factors such as material, fluid velocity, cross section, the climatic condition affects the heat transfer rate of the fin, the main control variable generally available to the designer is geometry of fin.

## IV. OBJECTIVES

- To construct a setup to allow experimental data to be obtained under different fin profiles (Non perforated, Square perforated and circular perforated fin) & conditions.
- To investigate the heat transfer rate of various fins
- To find out the effect of geometrical parameters of fins.
- To perform Finite Element based heat transfer analysis on the fin structures to check its heat conduction capabilities.
- The fins are made of Aluminium.
- Different geometries of the fins are considered to study the heat transfer parameters.

## V. METHODOLOGY

*1) Material selection*

- The material which is selected for farbrication of fins plates is aluminum (6061) .It is an hardened aluminum alloy ,containing magnesium and silicon as its major alloying elements.It is used commonly for manufacturing fins materials.

*2) Machine tool used*

- We have used different types of machine tools such as Hand cutting machine to cut aluminium plate into required size
- Then we have used drilling machine to drill holes of 8.5mm/9.5mm/10mm onthe plate.
- Then we used hand Grinding machine to polish the surface of thematerial.

*3) Design*

We have Designed 4 types of plates which are

- Non perforated plate:-The cross sectional area of fin is (100 x 55mm).
- square perforated plate:-The cross sectional area of fin is (100 x 55mm).There are 10 square holes is drilled at the surface of the plate with equidistance(45mm) between two holes vertical and the horizontal distance. And the bottom space is left for the heater arrangement.
- circular perforated plate:-The cross sectional area of fin is (100x 55mm).There are 10 circle holes is drilled at the surface of the plate with equidistance(45mm) between two holes vertical and the horizontal distance.

- Triangular perforated plate:-The cross sectional area of fin is (100x 55mm).There are 10 Triangular hole is drilled at the surface of the plate with equidistance vertical and the horizontal distance. we have design the fin plates model by CATIA V5 R21

*4) Analysis*

- we have analyze on cases of fins in ansys software .we had got different results through which we get which one has better heat coefficient rate.

## VI. FEM OF A HEAT SINK

In the present work, the software ANSYS 15.0 has been used to model and simulate Heat transfer and CFD analysis of heat sink with different perforations in the fins.

*A. Preparation of the Design model*

The designs of heat Sink with perforated fins is done in CATIA V5 R21 in STEP format. The 3D model are shown in Figures respectively.

A flat platform of 100 X 100 X 5 mm is common in all designs. Fin height for all models is 50 mm. There are a total number 10 fins in line arrangement with fin spacing of 10 mm between them. And thickness of each fin is 3mm.

- Non perforated plate:-The cross sectional area of fin is (100 x 50mm).

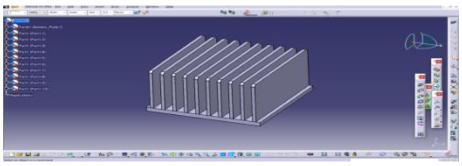

Fig 2. Non perforated plate.

- square perforated plate:-The cross sectional area of fin is (100 x 50mm).

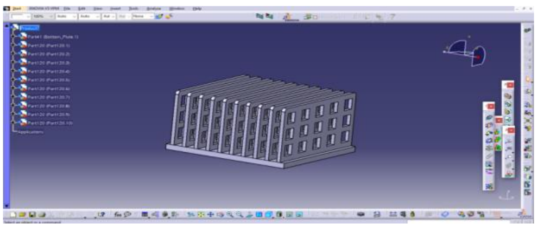

Fig 3. Square perforated plate

- circular perforated plate:-The cross sectional area of fin is (100 x 50mm).

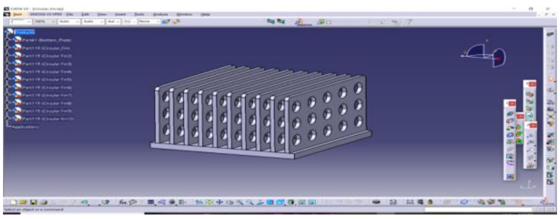

Fig 4. Circular perforated plate

- Triangular perforated plate:-The cross sectional area of fin is (100 x 50mm)

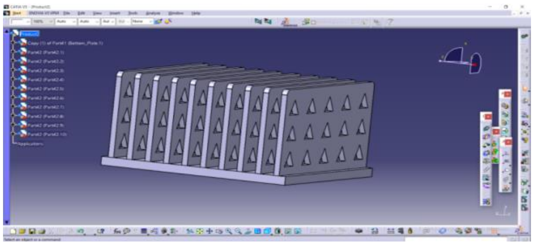

Fig 5. Triangular perforated plate

*B. Geometry*

The detailed specifications of the heat sink design are shown in the below table 3.1. The material properties for modeling of the heat sink with perforated fin are shown in the Table and properties of air are tabulated

- Material : Aluminium
- Material Properties required for Analysis
    - Density : 2.7 g/cc
    - Youngs Modulus : 68.3 GPa
    - Poisson's Ratio : 0.3
    - Shear Modulus : 30 GPa

| | A | B | C |
|---|---|---|---|
| 1 | Property | Value | Unit |
| 2 | Density | 2770 | kg m^-3 |
| 3 | Isotropic Secant Coefficient of Thermal Expansion | | |
| 4 | Coefficient of Thermal Expansion | 2.3E-05 | C^-1 |
| 5 | Isotropic Elasticity | | |
| 6 | Derive from | Young's Modulus and Poisson's Ratio | |
| 7 | Young's Modulus | 7.1E+10 | Pa |
| 8 | Poisson's Ratio | 0.33 | |
| 9 | Bulk Modulus | 6.9608E+10 | Pa |
| 10 | Shear Modulus | 2.6692E+10 | Pa |
| 11 | S-N Curve | Tabular | |
| 15 | Tensile Yield Strength | 2.8E+08 | Pa |
| 16 | Compressive Yield Strength | 2.8E+08 | Pa |
| 17 | Tensile Ultimate Strength | 3.1E+08 | Pa |
| 18 | Compressive Ultimate Strength | 0 | Pa |
| 19 | Isotropic Thermal Conductivity | Tabular | |
| 20 | Scale | 1 | |
| 21 | Offset | 0 | W m^-1 C^-1 |
| 22 | Specific Heat, $C_p$ | 875 | J kg^-1 C^-1 |
| 23 | Isotropic Relative Permeability | 1 | |
| 24 | Isotropic Resistivity | Tabular | |

Fig 6. Material properties for analysis

*C. Mesh Generation & Simulation*

The heat sink model is imported in to the work bench design modeler and meshed with a four node three dimensional tetrahedron element SOLID72the meshed model of the heat sink is as shown in the below figure-3.4 and the mechanical APDL (ANSYS Parametric Design Language) solver is used to mesh the heat sink.

- Meshing Properties
    - Type of Element : Tetrahedrons
    - Minimum Element Size : 3mm
    - Software Used : Ansys

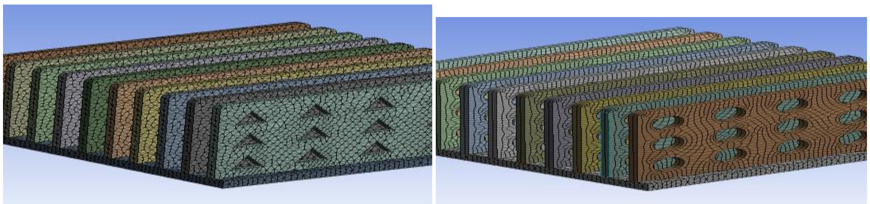

Fig 7. Mesh generation

*D. Finite Element Model – Thermal Boundary Conditions*

- Analysis Settings
- Temperature Load of 450 degrees Celsius.
- Convective Boundary condition of 5 W/m$^2$ heat transfer coefficient.

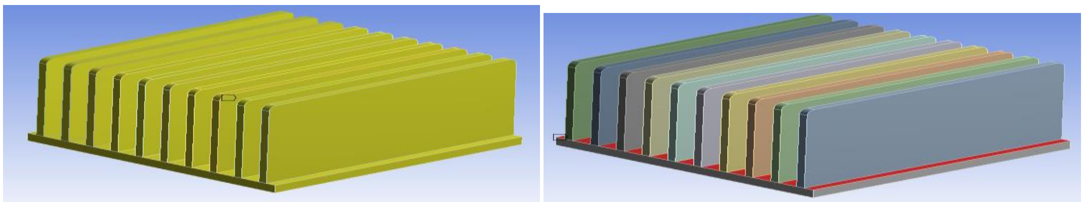

Fig 8. Finite element model

## VII. RESULT AND DISCUSSION

*1) Normal Fin*

- Results – Temperature Gradient – Normal Fin

The temperature gradient is observed to be between 251 degrees and 450 degrees Celsius.

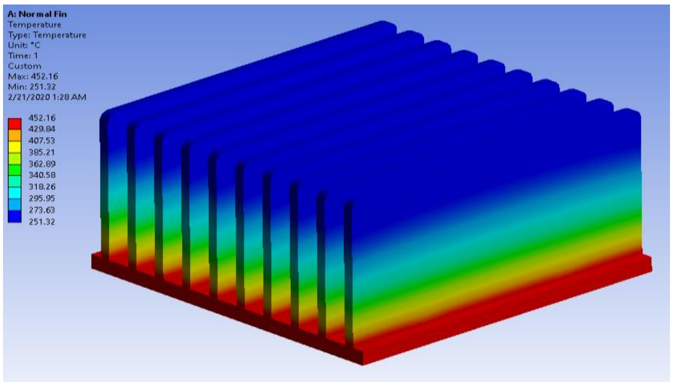


Fig 9. Temperature gradient of normal fin

- Results – Heat Flux Dissipation – Normal Fin

The heat flux dissipation through the structure is observed to be 1.34 W/mm$^2$.

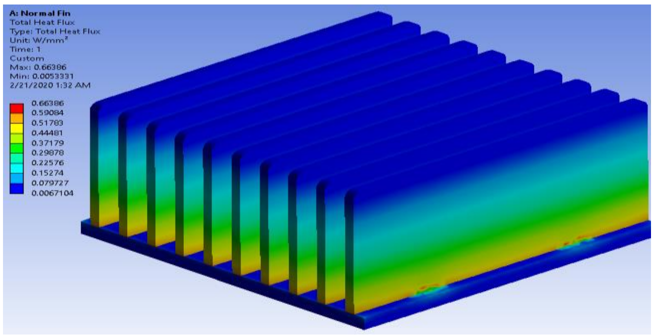


Fig 10. Heat flux dissipation of normal fin

*2) Circular Fin*

- Results – Temperature Gradient – Circular Fin

The temperature gradient is observed to be between 327.06 degrees and 450 degrees Celsius.

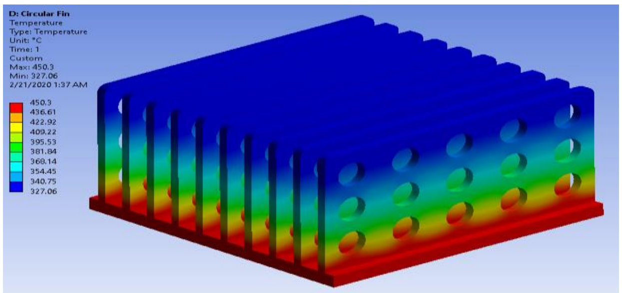


Fig 11. Temperature gradient of circular perforated fin

- Results – Heat Flux Dissipation – Circular Fin

The heat flux dissipation through the structure is observed to be 1.14 W/mm$^2$.

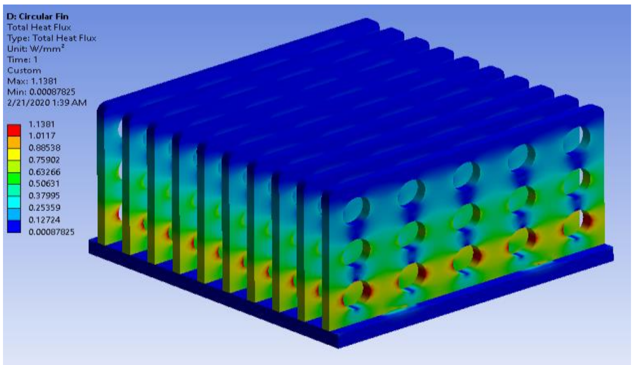


Fig 13. Heat flux dissipation of circular perforated fin

*3) Square Fin*

- Results – Temperature Gradient – Square Fin

The temperature gradient is observed to be between 315.01 degrees and 450 degrees Celsius.

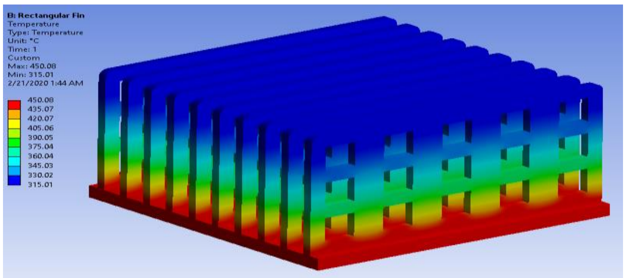


Fig 14. Temperature gradient of square perforated fin

- Results – Heat Flux Dissipation – Square Fin

The heat flux dissipation through the structure is observed to be 1.34 W/mm$^2$

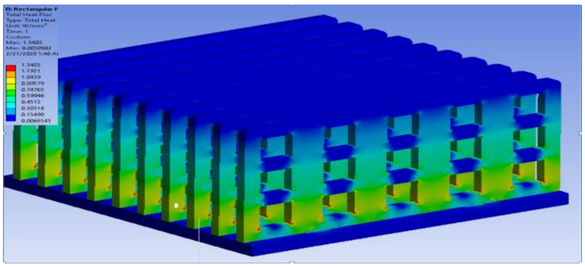

Fig 15. Heat flux dissipation of square perforated fin

*4) 4. Triangular Fin*

- Results – Temperature Gradient – Triangular Fin

The temperature gradient is observed to be between 328.5 degrees and 450 degrees Celsius.

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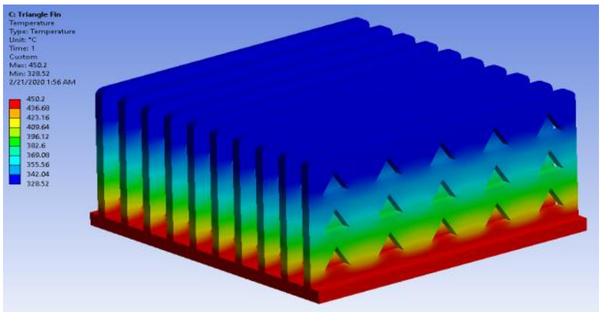


Fig 16. Temperature gradient of triangular perforated fin

- Results – Heat Flux Dissipation – Triangular Fin

The heat flux dissipation through the structure is observed to be 1.68 W/mm$^2$.

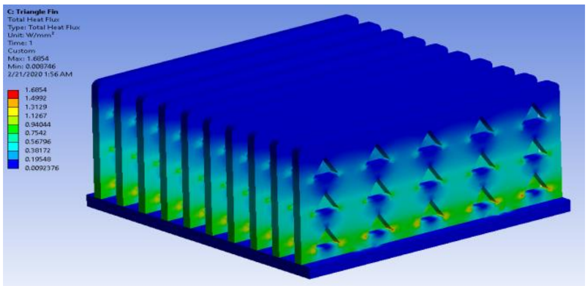


Fig 17. Heat flux dissipation of triangular perforated fin

## VIII. ADVANTAGE

- Without intermediate impedance, thermal conductivity is good because the cutting tooth density is big, so the unit volume heat dissipation area is bigger.
- Standard in size, and can be put into mass production.
- Light in weight.
- Solderable
- Customize relative easy in vary of shapes

## IX. DISADVANTAGES

- more bad rate , and low production efficiency
- The distance between FIN is smaller and the flow resistance is relatively larger
- Negative in cooling, if not accompany installed DC Fan.
- Tooling and tooling fee, it's hard to satisfy small quantity order

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## X. APPLICATIONS

- Economizers of steam power plants
- Heat exchangers of a wide variety, used in different industries
- Cooling of electric motors, transformers
- Cooling of electronic equipments, chips,I.C boards etc.
- Radiators for automobiles
- Air-cooling of cylinder heads of Internal
- Combustion engines (e.g. scooters, motor cycles, aircraft engines etc.), air compressors

## XI. COMPARISON

- The overall heat flux is generated more in triangular cross section fins. Hence, it is expected to be dissipating more heat from the surface.
- Hence, the best case scenario for the design of fins are either the triangular or rectangular cut-outs and the least case scenario is the solid normal fins
- The comparison between triangular perforation shapes with the rectangular show that the increment 5.099% which is a show that the triangular shape is better than rectangular in term of heat transfer coefficient. As the result, the heat transfer coefficient for triangular perforation shape is better compared to the non-perforation and also to the other perforation shape. In the same way, when comparing the circular perforation shape with the non-perforation and with the other perforation shape, the heat transfer coefficient has increased simultaneously by 5.239–7.194% compared to non-perforated and with the rectangular perforation fins. In comparison, the heat transfer coefficient of circular perforation with the triangular perforation shape has decreased significantly by 0.14%. As a result, the circular perforation shape is better in term of performance compared to non-perforated and rectangular shape but it not as good as the triangular perforation shape. Also, when comparing the rectangular shape with the non- perforated and another perforation shape, the rectangular perforation shape has increment of 2.25% compared to the non perforated but when doing comparison between rectangular perforations with the circular perforation the heat transfer coefficient of rectangular shape has decrement about 5.099% which is can be stated that the circular perforation shape is better than the rectangular perforation shape. This trend also can be seen when comparing the rectangular shape with the triangular shape which has decrement about 5.239%. This result will be stated that the rectangular perforation shape is the on the third place when comparing the rectangular perforation shape with non-perforation and also with the other perforation shape.

## XII. CONCLUSION

The presence of perforation and especially many perforations cause an increase in heat transfer area and also temperature difference dropped more between fin base and fin tip. The larger value of surface area and smaller temperature difference between fin and ambient air have not increased heat transfer considerably. The perforation holes act like cavities and the flow is confined inside the perforations. The use of perforated fins causes reduction of fin's weight significantly. reduction of weight due to use of new perforations. Certainly reduction of weight leads to saving material in manufacturing fins as well as lighter assembly. This explains cost and energy benefit of utilization of the new perforated fins. However the increase of heat transfer by use of these kinds of perforated fins in comparison with solid fin is not considerable.

By giving perforation to the fin will resulting the higher temperature different compared to the non-perforated fins that will affect the temperature distribution of the heat generated at the heat source along the fins. By giving perforation to the fins will increase the heat coefficient of the heat sink by 35.82–51.29% regarding to the perforation shape or geometry.

Data collected from the experiment can be used for analysing the heat transfer coefficient and also the temperature distribution for each of the perforation shape or geometry conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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