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Temperature Distribution Analysis of Sandwich Type Fins on Different Configuration Using ANSYS

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***Abstract:**Heat sink is an electronic component or a device of an electronic circuit which disperses heat from other components (mainly from the power transistors) of a circuit into the surrounding medium and cools them for improving their performance, reliability and also avoids the premature failure of the components. For the cooling purpose, it incorporates a fan or cooling device. Fins are widely used in heat exchanging devices in automobile radiators, industrial sectors, power plants, newer technology like fuel cells. Generally, the material used for the application of fins are Aluminium alloys. In this work Thermal Properties of fin are numerically investigated using ANSYS Software for different shapes like Circular, Square, Triangular, Hexagonal using Aluminium and Copper composites. Steady state analysis is carried out for different types of fins under the convection and a specified base temperature condition. The length, base thickness, and end thickness of the fins are specified. Thermal conductivity of the fin material is specified. A constant temperature condition is applied at the base of the fin convective boundary conditions applied at the tip of the fin. Comparative study is being done among the fin shapes to find out the best shape under the conditions. Total Heat Flux, steady state temperature distribution is investigated and compared.*

***Keywords:**Fin, Conduction, Natural Convection, Finite element technique, Total Heat Flux.*

I. Introduction:

Heat Transfer

Heat transfer is defined as the energy transformation from one place to another due to temperature difference and flow from high temperature region to low temperature region without any applied external force. The modes of heat transfer are conduction, convection and radiation. A steady state is a condition where the temperature at each point of a body remains constant in a period of time.

Thermal conductivity is defined as the amount of energy conducted through the body of unit area and unit thickness in unit time. The thermal conductivities of different material is varies which depends upon its molecules structure, specific gravity, moisture content temperature at base level etc. Heat transfer in composites materials plays an important role in the life span of composite materials. Due to temperature increase in the composite materials it affects the total materials that are combined in the composite. But due to uneven properties of different materials present in the composite material, they react in different manner in terms of thermal expansion which depends on thermal conductivity of materials.

Fins

Fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature gradient between the object and the environment,

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increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer.
Sometimes it is not feasible or economical to change the first two options. Thus, adding a fin to an object increases the surface area and can sometimes be an economical solution to heat transfer problems.
Heat trade through the solid to the surface of the solid happens through conduction whereas from the surface to the surroundings happens by convection. Further warmth trade may be by normal convection or by obliged convection. Fins are most commonly used in heat exchanging devices such as radiators in cars, computer CPU heat sinks, and heat exchangers in power plants. They are also used in newer technology such as hydrogen fuel cells. Nature has also taken advantage of the phenomena of fins.

Performance of a Fin

The performance of a fin can be expressed in different ways. They are
1. Fin Effectiveness
It's the ratio of heat transfer rate with fin to the heat transfer rate of the object if it had no fin. It's given by,

$$\epsilon = Q_f/(h\theta_b A_c)$$

2. Fin efficiency
It's the ratio of the fin heat transfer rate to the heat transfer rate of the fin if the entire fin were at the base temperature. It's given by,

$$\eta = Q_f/ (hA_f\, \theta_b)$$

A_f in this equation is equal to the surface area of the fin. The fin efficiency will always be less than one, as assuming the temperature throughout the fin is at the base temperature would increase the heat transfer rate.

3. Overall Surface efficiency

$$\eta_b = (Q_t) / (hA_t\theta_b)$$

Where, A_t – total area and Q_t - is the sum of the heat transfer from the unfinned base area and all of the fins. This is the efficiency for an array of fins.
Assumptions made in analyzing fins are,

- Constant material properties
- No internal heat generation
- One-dimensional conduction
- Uniform cross-sectional area
- Uniform convection across the surface area
- Steady state

II. Composite

A composite is a material made by mixing of two different materials which provides a stronger material than the parent materials. The two materials are called, one is reinforcing material and the other is matrix material. In these materials the former is mixed in the form of flakes, slices etc. and these are continuous. The practical example which is a concrete mixture used for building slabs. The natural composites which in nature are wood from trees contain lignin and cellulose fibers. Artificial composites are those used in industries like aircraft, automobile etc., which they show high strength, stiffness and durability with minimum thickness and reduces overall weight and gives much life to the component. Examples for these are epoxy and aluminium, graphite with epoxy and boron with aluminium composites. These composite materials show most advantageous properties than conventional materials which include improved strength, stiffness, fatigue, impact resistance, thermal conductivity and corrosion resistance etc. The main drawback of composite materials is its manufacturing cost is more than that of conventional materials.

Finite element analysis:

Finite Element Method is a powerful numerical tool used to find out stress analysis and deformations occurred in beams, trusses, planes and in automotive machine components. If component is felt difficulty in analysing then it is considered as a small parts called elements. Then these elements are joined with the help of nodes. By providing a serial numbers these all elements are joined to make a global system of component. Finally, the boundary conditions are applied and we solve the equations and find out the unknown quantities. But these solutions give the approximate values but not exact solution. To solve the bigger matrices, we depend on the software packages that solves the problems easily like as ANSYS

III. Methodology:

In ANSYS methodology, the thermal analysis is selected in preferences. Next we select the proper and in material properties isentropic analysis the material conductivity (k) (in W/m-K) is entered. In modelling stage the solid cylinder is made out of a rectangular base with provided radius (mm) for both inner and outer circle and extruded to its normal direction to attain its length.

Meshing is considered as discretization of the specimen into elements of finite number and each element is solved and added to obtain results. The element shape is polygonal. In meshing stage, a fine shape of 5 is selected and made the meshing for a solid cylinder and apply thermal loads in terms of temperature at base level of fin and convection heat transfer coefficient (h) value is provided on selected outer surfaces or areas and Bulk temperature is provided as ambient temperature which it acts as medium for pin fin. By selecting the steady state heat transfer analysis and solving the problem the results are obtained.

In post processing, the plot results temperature distribution level is known through images and in list results the nodal temperatures are listed out. Here four different shapes are identified and analysis is done by keeping their base area constant. FOUR different shapes are listed below:

1.Circular
2.Square
3.Triangular
4.Hexagon

Considering all of these shapes, the percentage variation o of Copper is done with 40% and 60%.

Boundary conditions applied

1.Thermal conductivity of material (K)
2.Convective heat transfer coefficient (h)
3.Ambient temperature of air
4.Fin base temperature

Steps involved in analysis

1.3D modelling of fin using the required specifications
The fin is designed using ANSYS with the required dimensions and 50 mm length for the composite pin fin. It is done using the GEOMETRY tab on ANSYS workbench.
2.Selection of materials
The material selection is done by using ENGINEERING DATA tab on ANSYS workbench. The material selected is Aluminium and Copper as composite materials.
3.Meshing
Meshing is done by selecting suitable node conditions. The meshing of the created CAD model can be made by giving the element size. The smaller the element size the greater is the accuracy in the results.
4.Applying boundary conditions
The required boundary conditions are applied through MODELLING tab. Boundary conditions like ambient temperature, base temperature and convective heat transfer coefficient are applied.
5.Generation of results
The results are generated by clicking the SOLVE button on the MODEL window. Thus the results are obtained.
6.Evaluation of results
The required results are combined and analysed for different materials

Design of parameters

The first step of designing parameters is to construct a base having dimensions,
Length, l = 150 mm.
Breadth, b = 150 mm.
Thickness, t = 2 mm.
After that Fins with respective shapes are extruded from the base plate by giving,
Height, h=50mm.
Total number of Fins were taken as, n= 36 according to the Base Plate Area and Fin Diameter.
Here Copper is sandwiched inside Aluminium and therefore Copper having inner diameter is taken as 'd_i' and aluminium having outside diameter will be taken as 'd_o'.
In the whole process of designing, we are keeping volume as constant and thereby finding dimensions of different shapes.

Circular shaped fin

In the process of designing parameters, we have chosen circular shape as primary. We have taken Diameter, d = 7 mm.
Therefore, Area of Circle, $A=(\pi/4)\times d^2$
$A=(\pi/4)\times 72\ mm^2$
$A=38.484\ mm^2$
50:50 Ratio of Circular Shaped Fin
Area of Circle, $A=0.5\times 38.484\ mm^2$
$A=19.242\ mm^2$
Therefore, Inner Diameter $d_i=\sqrt{(A/(\pi/4))}$
$d_i=\sqrt{(19.242/(\pi/4))}$
$\mathbf{d_i=4.94\ mm}$
40:60 Ratio of Circular Shaped Fin
Area of Circle, $A=0.6\times 38.484\ mm^2$
$A=23.0904\ mm^2$

Therefore, Inner Diameter $d_i=\sqrt{(A/(\pi/4))}$
$d_i=\sqrt{(23.0904/(\pi/4))}$
d_i=5.42mm.
60:40Ratio of Circular Shaped Fin
Area of Circle, A=0.4 × 38.484 mm2
A=15.3936 mm2
Therefore, Inner Diameter $d_i=\sqrt{(A/(\pi/4))}$
$d_i=\sqrt{(15.3936/(\pi/4))}$
d_i=4.427mm.
Square shaped fin
By keeping the volume of fin as constant, sides of Squares are found.
Area of Square, $A=a^2$.
50:50 Ratio of Square Shaped Fin
Area of Square, A=0.5 × 38.484 mm^2
A=19.242 mm^2
Therefore, Inner Side $a_i=\sqrt{A}$
$a_i=\sqrt{19.242}$
a_i=4.38 mm
40:60 Ratio of Square Shaped Fin
Area of Square, A=0.6 × 38.484 mm^2
A=23.0904 mm^2
Therefore, Inner Side $a_i=\sqrt{A}$
$a_i=\sqrt{23.0904}$
a_i=4.805 mm
60:40Ratio of Square Shaped Fin
Area of Square, A=0.4 × 38.484 mm^2
A=15.3936 mm^2
Therefore, Inner Side $a_i=\sqrt{A}$
$a_i=\sqrt{15.3936}$
a_i=3.923 mm.

Hexagonal shaped fin

By keeping the volume of fin as constant, sides of Hexagon are found.
Area of Hexagon, $A= (3\sqrt{3}\times a^2)/2$
50:50 Ratio of Hexagonal Shaped Fin
Area of Hexagon, A=0.5 × 38.484 mm^2
A=19.242 mm^2
Therefore, Inner Side $a_i=\sqrt{((2\times A)/3\sqrt{3})}$
$a_i=\sqrt{((2\times 19.242)/3\sqrt{3})}$
a_i=2.72 mm
40:60 Ratio of Hexagonal Shaped Fin
Area of Hexagon, A=0.6 × 38.484 mm^2
A=23.0904 mm^2
Therefore, Inner Side $a_i=\sqrt{((2\times A)/3\sqrt{3})}$
$a_i=\sqrt{((2\times 23.0904)/3\sqrt{3})}$
a_i=2.98 mm
60:40 Ratio of Hexagonal Shaped Fin
Area of Hexagon, A=0.4 × 38.484 mm2
A=15.3936 mm2
Therefore, Inner Side $a_i=\sqrt{((2\times A)/3\sqrt{3})}$
$a_i=\sqrt{((2\times 15.3936)/3\sqrt{3})}$

a_i=2.434 mm

Triangular shaped fin

By keeping the volume of fin as constant, sides of Triangle are found.
Area of Triangle, A= (√3/4) *a^2)
50:50 Ratio of Triangular Shaped Fin
Area of Triangle, A=0.5 × 38.484 mm^2
A=19.242 mm^2
Therefore, Inner Side a_i=√((4×A)/√3)
a_i=√ ((4×19.242)/√3)
a_i=6.66 mm
40:60 Ratio of Triangular Shaped Fin
Area of Triangle, A=0.6 × 38.484 mm^2
A=23.0904 mm^2
Therefore, Inner Side a_i=√((4×A)/√3)
a_i=√ ((4×23.0904)/√3)
a_i=7.302 mm
60:40 Ratio of Triangular Shaped Fin
Area of Triangle, A=0.4 × 38.484 mm^2
A=15.3936 mm^2
Therefore, Inner Side a_i=√((4×A)/√3)
a_i=√ ((4×15.3936)/√3)
a_i=5.962 mm

Temperature distribution analysis:

Circular fins 50:50

By analysing the specimen in ANSYS Software, the following images are obtained for selected shape i.e., circular. The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°C as shown in figure1. In this analysis it is observed the temperature at its tip level is 57. 045°C.This is because of its high thermal conductivity and thermal resistance of material

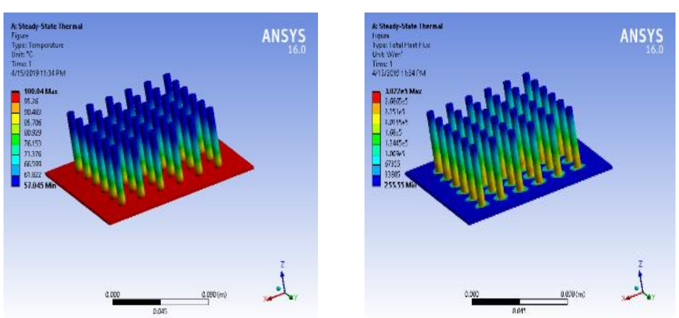


Figure1.Result of heat transfer of Circular pin fin 50:50

Circular fins 40:60

The following images are obtained for circular fins. The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°C as shown in figure2.In this analysis it is observed the temperature at its tip level is 35. 87°C

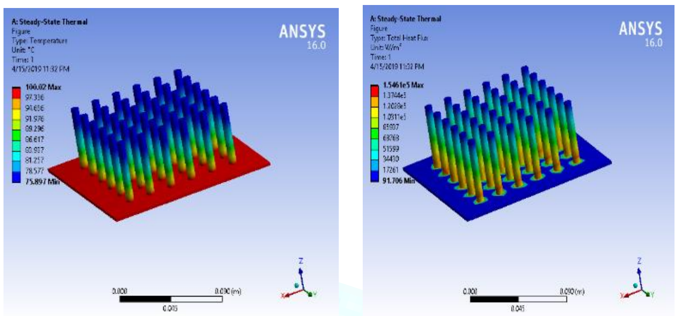


Figure2.Result of heat transfer of Circular pin fin 40:60

Circular fins 60:40

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°C as shown in figure3. In this analysis it is observed the temperature at its tip level is 55.903°C.

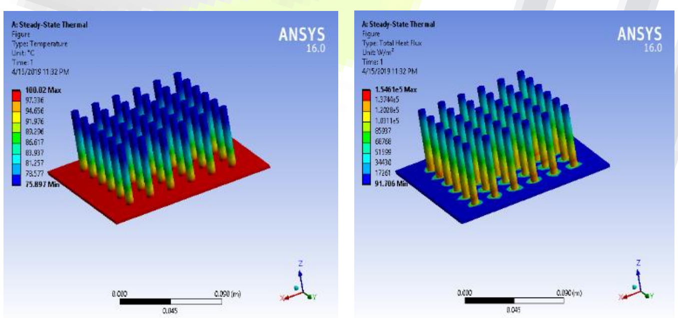


Figure3.Result of heat transfer of Circular pin fin 40:60

Square fins 50:50

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°C as shown in figure4. In this analysis it is observed the temperature at its tip level is 54.085°C.

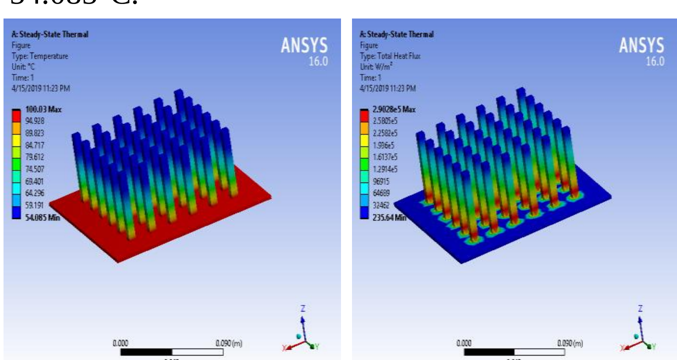


Figure4. Result of heat transfer of square pin fin 50:50

Square fins 60:40

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°C as shown in figure5. In this analysis it is observed the temperature at its tip level is 71.538°C

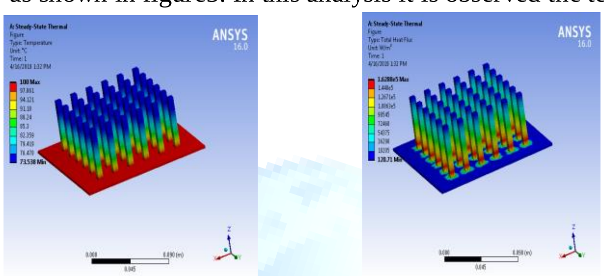


Figure5. Result of heat transfer of square pin fin 60:40

Square fins 40:60

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°C as shown in figur6. In this analysis it is observed the temperature at its tip level is 57.395°C

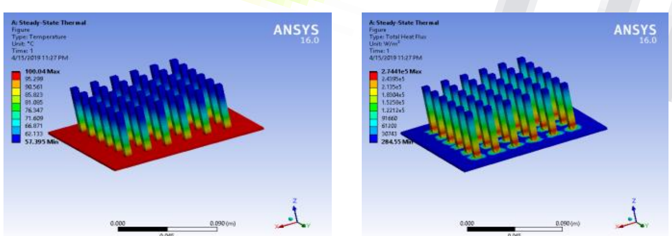


Figure6. Result of heat transfer of square pin fin 40:60

Hexagonal fins 50:50

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°C as shown in figure7.In this analysis it is observed the temperature at its tip level is 74.675°C

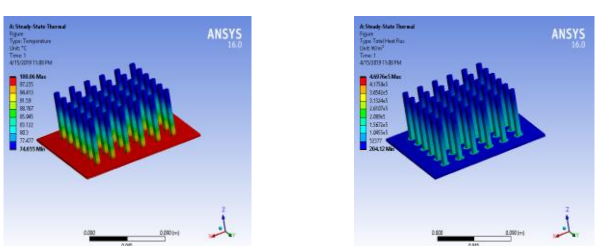
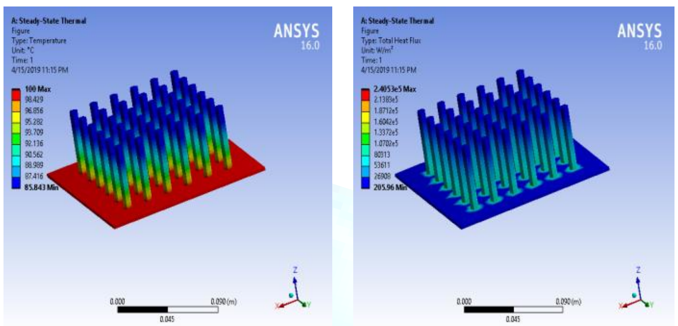


Figure7.Result of heat transfer of hexagonal pin fin 50:50

Hexagonal fins 40:60

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°c as shown in figure8.In this analysis it is observed the temperature at its tip level is 85.843°c



Figur8.Result of heat transfer of hexagonal pin fin 40:60

Hexagonal fins 60:40

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°c as shown in figure9.In this analysis it is observed the temperature at its tip level is 75.096°c

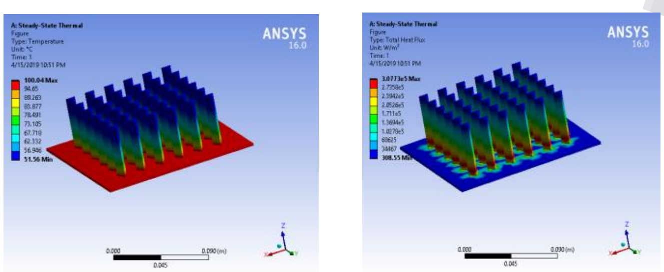


Figure9. Result of heat transfer of hexagonal pin fin 60:40

Triangular fins 50:50

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°c as shown in figure10. In this analysis it is observed the temperature at its tip level is 51.56°C

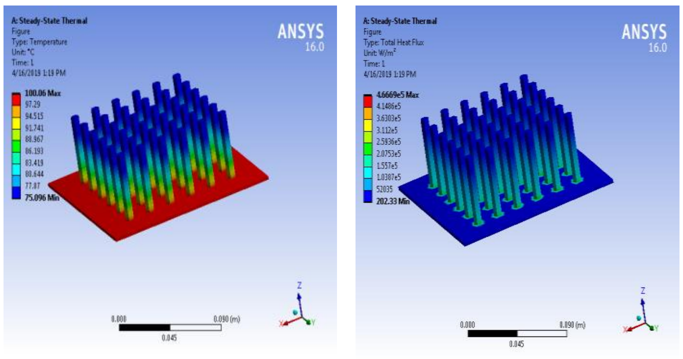


Figure10.Result of heat transfer of triangular pin fin 50:50

Triangular fins 40:60

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°c as shown in figure11. In this analysis it is observed the temperature at its tip level is 71.499°c

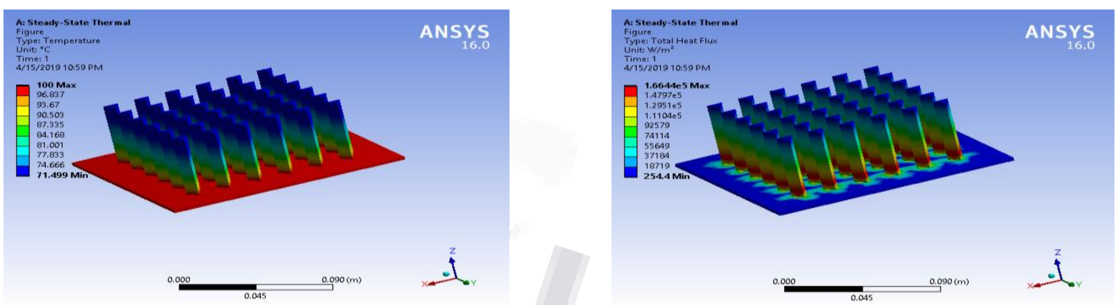


Figure11.Result of heat transfer o f triangular pin fin40:60

Triangular fins 60:40

The temperature distribution at the tip of the pin fin is found out by providing the temperature at the base of the pin fin as 100°c as shown in figure12. In this analysis it is observed the temperature at its tip level is 42.219°c.

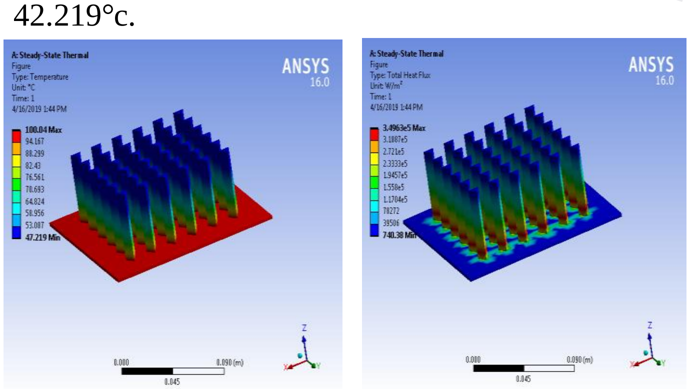


Figure12.Result of heat transfer of triangular pin fin 60:40

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Graphical Comparison

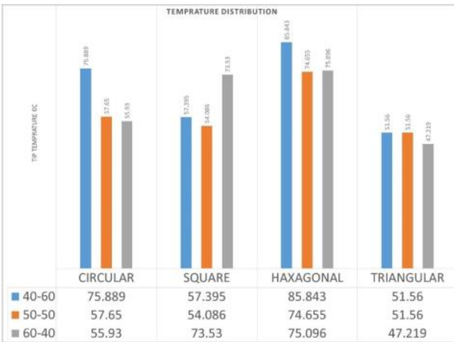

Figure13. Graphical Representation of Results

The figure 13 shows the graphical comparison of temperature distribution between different shapes and configurations. Differentcolorrepresentations are given for each configuration; each bar represents the magnitude of tip temperature.

The least set of values are obtains for triangular shaped fins and the least attained temperature is for 60-40configeration.

IV. Conclusion

The overall performance of the four different profile heat sinks was studied in this paper The paper presents computer simulation and thermal analysis of different shape fins heat sink for a system under steady state

In this an attempt is made to compare the fin tip temperatures obtained by analysis of values obtained from simulation software ANSYS. A constant cross section of fins is considered for all materials. In simulation analysis, a sandwich type fin triangular in shape with 60% copper pin fins shows the least temperature at the end (tip) of the of pin fin.

The maximum value of total heat flux was obtained for 50:50 hexagonal pin fin which was observed as $4.69x10^5 W/m^2$.

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