DESIGN AND THERMAL ANALYSIS OF TRAPEZOIDAL CYLINDRICAL FINS FOR COOLING APPLICATION

[1]R.SIVA KRISHNAM RAJU,[2]SK.JOHNY

[1,2]Assistant Professor

[1]Department of Mechanical Engineering,

[1]KKR & KSR INSTITUTE OF TECHNOLOGY AND SCIENCES, Vinjanampadu, Guntur, A.P, INDIA.

ABSTRACT: An air-cooled motorcycle engine releases heat to the atmosphere through the mode of forced convection to facilitate this, fins are provided on the outer surface of the cylinder. The heat transfer rate depends upon the velocity of the vehicle, fin geometry and the ambient temperature. Insufficient removal of heat from engine will lead to high thermal stresses and lower engine efficiency. The cooling fins allow the wind to move the heat away from the engine. . In order to cool the cylinder, fins are provided on the cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. In this project trapezoidal cylinder fins designed by UNIGRAPHICS CAD software with thickness 2.5 mm. Thermal heat transfer analysis of cylinder fins is explained in details for different types of materials like Aluminum, Copper. Ansys FEA software is considered for developing thermal analysis of engine cylinder fins.

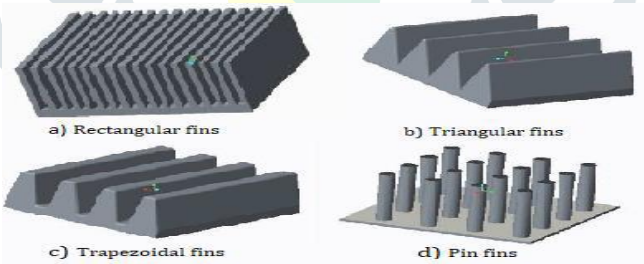
Index Terms– uni graphics, ansys, trapezoidal.

1. INTRODUCTION

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result it seizing or welding of same. So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. To avoid overheating, and the consequent ill effects, the heat transferred to an engine component (after a certain level) must be removed as quickly as possible and be conveyed to the atmosphere. It will be proper to say the cooling system as a temperature regulation system. It should be remembered that abstraction of heat from the working medium by way of cooling the engine components is a direct thermodynamic loss.

The different types of fin geometries

This are the different types used for an IC engine are Rectangular fins, Triangular fins, Trapezoidal fins and Pin fins as shown in figure.



2. LITERATURE SURVEY:

J. Ajay paul and sagar chavan vijay [1] parametric study of extended fins in the optimization of internal combustion engine they found that for high speed vehicles engines thicker fins provide better efficiency. When fin thickness increases, the gap between the fins reduces that resulted in swirls being created which helped in increasing the heat transfer. Large number of fins with less thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps inducing greater turbulence.

Fernando illan[2] simulated the heat transfer from cylinder to air of a two-stroke internal combustion finned engine. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analyzed and optimized in order to minimize engine dimensions. The maximum temperature admissible at the hottest point of the engine has been adopted as the limiting condition. Starting from a zero-dimensional combustion model developed in previous works, the cooling system geometry of a two-stroke air cooled internal combustion engine has been optimized in this paper by reducing the total volume occupied by the engine. A total reduction of 20.15% has been achieved by reducing the total engine diameter d from 90.62 mm to 75.22 mm and by increasing the total height h from 125.72 mm to 146.47 mm aspect ratio varies from 1.39 to 1.95. In parallel with the total volume reduction, a slight increase in engine efficiency has been achieved.

G. Babu and m. Lavakumar[3] analyzed the thermal properties by varying geometry, material and thickness of cylinder fins. The models were created by varying the geometry, rectangular, circular and curved shaped fins and also by varying thickness of the fins. Material used for manufacturing cylinder fin body was aluminum alloy 204 which has thermal conductivity of 110-150w/mk and also using aluminum alloy 6061 and magnesium alloy which have higher thermal conductivities. They concluded that by reducing the thickness and also by changing the shape of the fin to curve shaped, the weight of the fin body reduces thereby increasing the efficiency. The weight of the fin body is reduced when magnesium alloy is used and using circular fin, material aluminium alloy 6061 and thickness of 2.5mm is better since heat transfer rate is more and using circular fins the heat lost is more, efficiency and effectiveness is also more.

J. Ajay paul et.al.[4] carried out numerical simulations to determine heat transfer characteristics of different fin parameters namely, number of fins, fin thickness at varying air velocities. A cylinder with a single fin mounted. On it was tested experimentally. The numerical simulation of the same setup was done using cfd. Cylinders with fins of 4 mm and 6 mm thickness were simulated for 1, 3, 4 & 6 fin configurations. They concluded that 1. When fin thickness was increased, the reduced gap between the fins resulted in swirls being created which helped in increasing the heat transfer. 2. Large number of fins with less thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps inducing greater turbulence and hence higher heat transfer.

N. Phani raja rao[5] et.al. Analyzed the thermal properties by varying geometry, material and thickness of cylinder fins. Different material used for cylinder fin were aluminum alloy a 204, aluminum alloy 6061 and magnesium alloy which have higher thermal conductivities and shown that by reducing the thickness and also by changing the shape of the fin to circular shaped, the weight of the fin body reduces thereby increasing the heat transfer rate and efficiency of the fin. The results shows, by using circular fin with material aluminum alloy 6061 is better since heat transfer rate, efficiency and effectiveness of the fin is more.

3. PROBLEM DEFINITION AND METHODOLOGY:

PROBLEM DEFINITION

- The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses.
- In order to cool the cylinder, fins are provided on the cylinder to increase the rate of heat transfer.
- By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder.

METHODOLOGY

- In this project trapezoidal cylinder fins designed by UNIGRAPHICS CAD software with thickness 2.5 mm.
- Thermal heat transfer analysis of cylinder fins is explained in details for different types of materials like Aluminum, Copper.
- In this project Ansys FEA software is considered for developing thermal analysis of engine cylinder fins.

4. 3D MODELING OF TRAPEZOIDAL FINS BY UNIGRAPHICS:

Every component in the auto mobile sector is developed based on 2D drawings. It also called as the manufacturing drawing .Which plays a crucial role in conversion of 2D sketch to 3D model using CAD application.

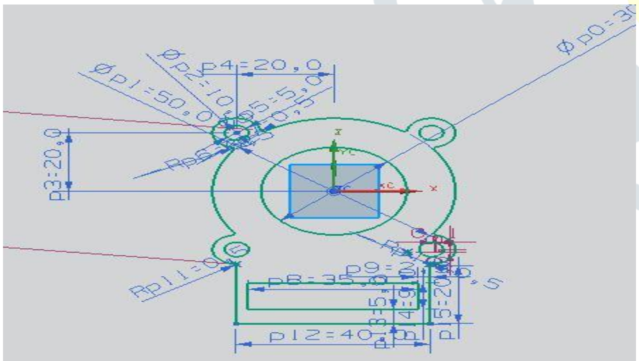


Fig shows the 2D sketch of the engine cylinder fin

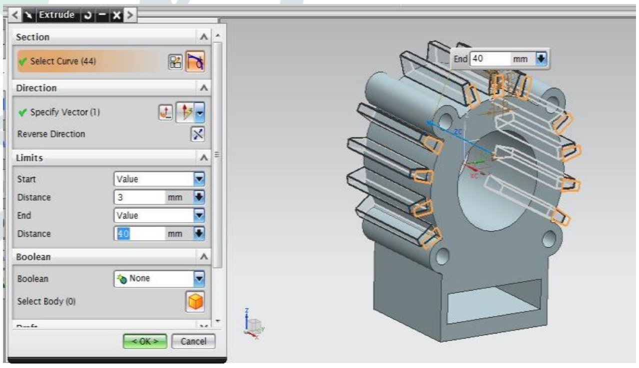


Fig shows the conversion of fins into 3D

5. THERMAL STRESS ANALYSIS:

The meaning of thermal itself is a change in temperatures that effect on material. These thermal effects are including thermal stress. Heat will tend to move from the highest temperature system to the lower-temperature system until thermal equilibrium established when a temperature difference does exit.Meanwhile, stress is the internal distribution of forces within a body that balance and react to the load applied to it. Simplifying assumptions are often used to represent stress as a vector for engineering calculations.The performance ability of mechanical component without failure is depending on the important role of temperature distribution within it. High temperature especially, has a friction by material strength and other properties in many instances.

Thermal stress can be produce by high thermal gradients even at temperatures below property degradation. Due to a non-uniform temperature gradient, there are three ways to induce thermal stress which is by simply restraining a body during a heating or cooling process, expansion of dissimilar materials and by transient stresses.The total stress which can then be used to determine the success or otherwise of the component design can be provided by the combination of thermal stress and mechanical stresses by the use of superposition in linear analyses.However, a satisfactory heat transfer analysis must be undertaken before any stress analysis or assessment. Thermal analysis is simpler than the common liner static/displacement solution in most cases. It's also one of the most straightforward applications of fea but still there are complexities arise in two distinct areas;

1. Quantifying boundary conditions, especially for convection conditions.
2. Solution time in non-liner analysis for radiation convection problems.

5.1.1 heat transfer

The discipline of heat transfer in the simplest terms is concerned with only temperature and flow of heat. The amount of thermal energy available is represented by temperature meanwhile the movement of thermal energy from pace to place is represented by heat flow.

Thermal energy on a microscopic scale is related to the kinetic energy of molecules. A greater thermal agitation of material constituent molecules is cause by the greater temperature of it. Conduction, convection and radiation are three aspects of heat rate. Temperature difference is the driving force for all the three modes in which the direction of heat transfer is from the high temperature to the low temperature.

$$q = q_{conduction} + q_{convection} + q_{radiation}$$

Conduction

It is mode transfer of energy through solid.the rate of heat transfer is over a cross sectional area a with temperature difference is inversely proportional to the thickness x.

$$Qcond = \frac{ka(\Delta t)}{x}; \ (w)$$

Where, k= thermal conductivity (w/m k)
a= cross sectional area (m^2)
Δt= temperature different (k)
x=thickness (m)

Convection

Two types of convection are, free and forced convection. Free convection motion is set up by the temperature of the fluid via natural circulation.Meanwhile, forced convection is forced the fluid to and enhanced the rates of heat transfer between the flowing fluid and solid surface.

The rate of heat transfer over cross sectional area a and temperature difference is proportional to the surface of heat transfer coefficient

$$\dot{Q}_{conc} = hA(\Delta T); \qquad (W)$$

Where, h = convection coefficient (w/m2k)
a=cross sectional area (m2)
Δt= temperature different (k)

Radiation

The heat transfer of heat input is the lumped mass of consequential at temperature rise with specific heat.

$$\dot{Q}_{rad} = mC_p\Delta T; \qquad (W)$$

Where m=weight (m)
c_p =specific heat (kj/kgk)
Δt= temperature difference (k)

5.2 THERMAL ANALYSIS OF TRAPEZOIDAL FINS USING ALUMINIUM ALLOY:

Material properties

Thermal conductivity – 180 w/mk
Specific heat – 0.896 j/g °c
Density – 2.7g/cc

loads :

Temperature -558 k
Film coefficient – 25 w/m2 k
Bulk temperature – 313 k

Creating a finite element mesh Solid element description

Solid188 is a higher order version of the 3-d eight node thermal element. The element has 10 nodes with a single degree of freedom, temperature, at each node. The 10-node elements have compatible temperature shapes and are well suited to model curved boundaries. The 10-node thermal element is applicable to a 3-d, steady-state or transient thermal analysis

The geometry, node locations, and the coordinate system for this element are shown in figure "solid87 geometry". The element is defined by 10 node points and the material properties. A prism-shaped element may be formed by defining duplicate k, l, and s; a and b; and o, p, and w node numbers.

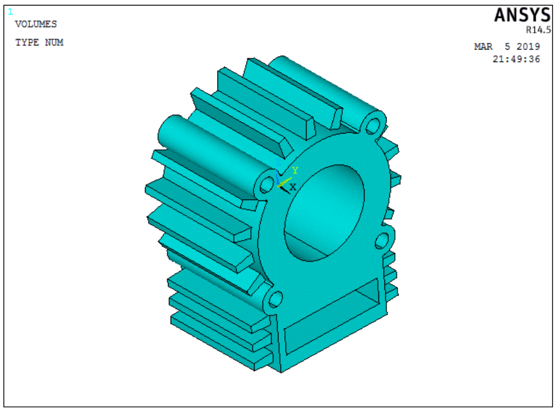
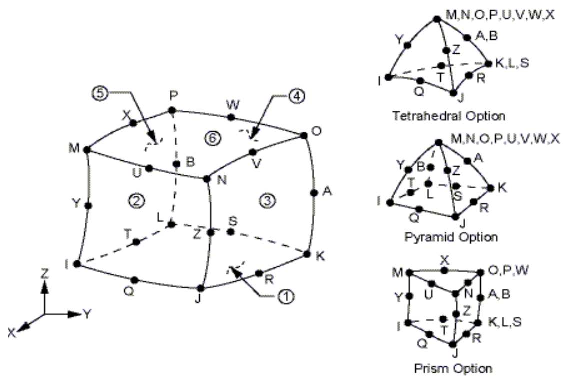


Fig. Imported cylinder fin in ansys

Figure 90.1 SOLID90 Geometry



Thermal boundary conditions

Center region of cylinder fin effected by the temperature of exhaust gases. So maximum temperature (558k) is applied on cylinder fin. Also cylinder fin is cool by atmospheric air condition method. So that film coefficient applied on cylinder fin surrounding.

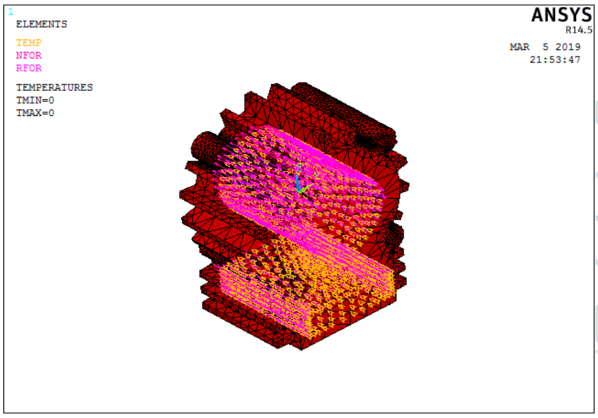


Fig temperature boundary condition of 558 k applied on cylinder fin

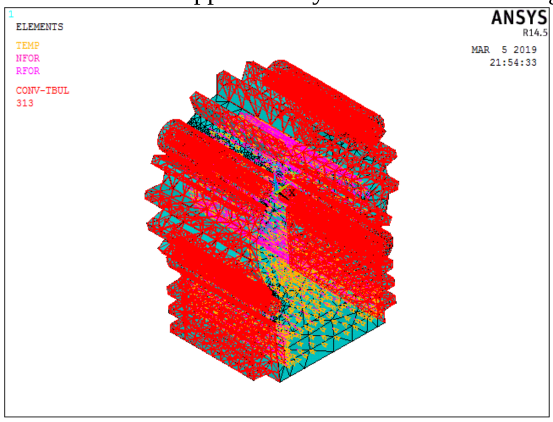


Fig. Convection boundary condition applied on cylinder fin

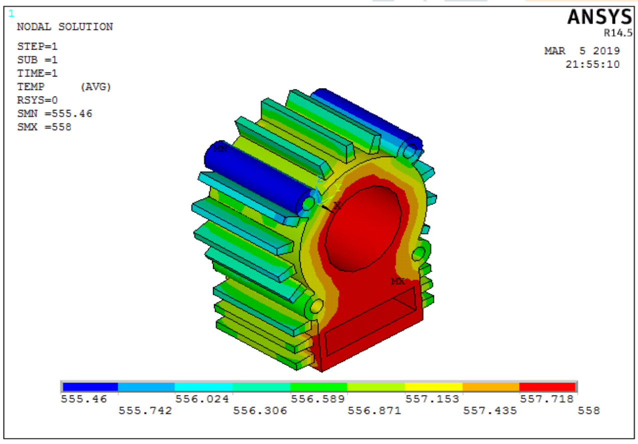


Fig temperature distribution on cylinder

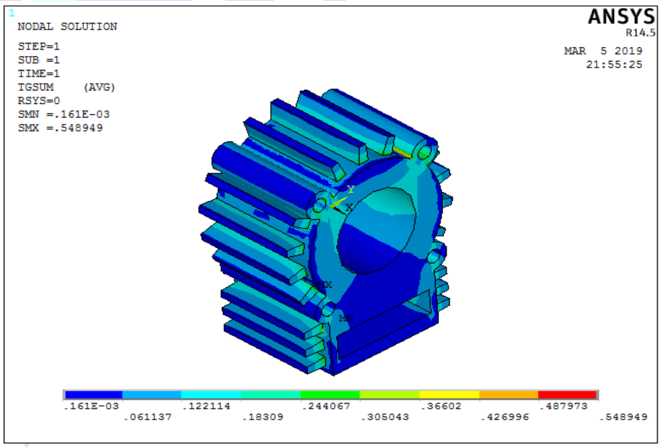


Fig. thermal gradient on cylinder fin

5.3 THERMAL ANALYSIS OF TRAPEZOIDAL FINS USING COPPER MATERIAL PROPERTIES

Material properties

Thermal conductivity – 385 w/mk
Specific heat – 0.385 j/g °c
Density – 8.96g/cc

loads :

Temperature -558 k
Film coefficient – 25 w/m2 k
Bulk temperature – 313 k

Creating a finite element mesh Solid 87 element description

Solid188 is a higher order version of the 3-d eight node thermal element. The element has 10 nodes with a single degree of freedom, temperature, at each node. The 10-node elements have compatible temperature shapes and are well suited to model curved boundaries. The 10-node thermal element is applicable to a 3-d, steady-state or transient thermal analysis The geometry, node locations, and the coordinate system for this element are shown in figure "solid87 geometry". The element is defined by 10 node points and the material properties. A prism-shaped element may be formed by defining duplicate k, l, and s; a and b; and o, p, and w node numbers.

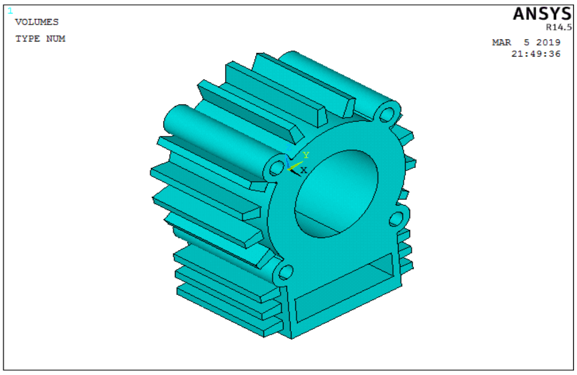
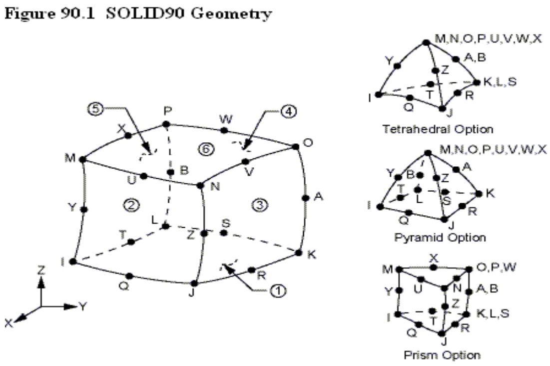


Fig. Imported cylinder fin in ansys



Thermal boundary conditions

Center region of cylinder fin effected by the temperature of exhaust gases. So maximum temperature (558k) is applied on cylinder fin. Also cylinder fin is cool by atmospheric air condition method. So that film coefficient applied on cylinder fin surrounding.

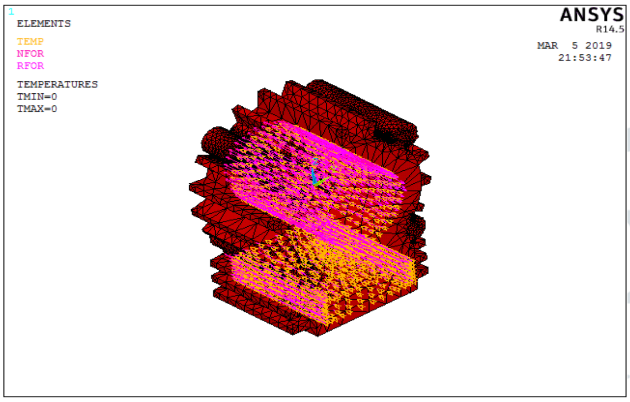


Fig. Temperature boundary condition of 558 k applied on cylinder fin

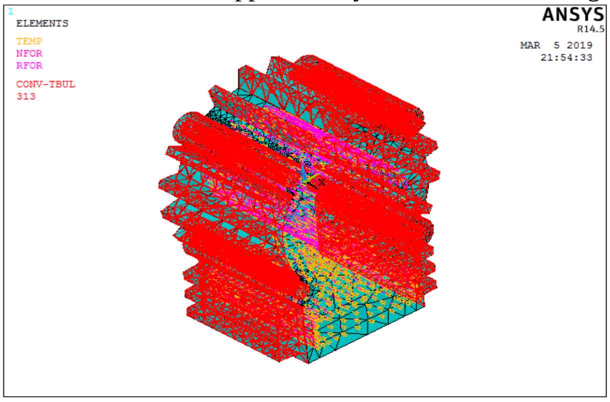


Fig. Convection boundary condition applied on cylinder fin

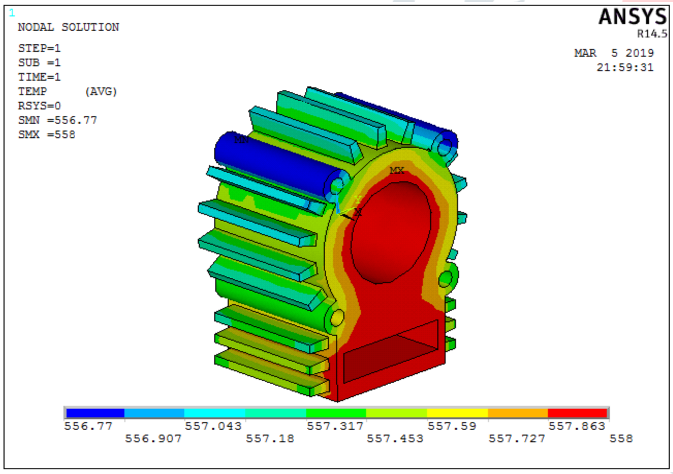


Fig. Temperature distribution on cylinder fin

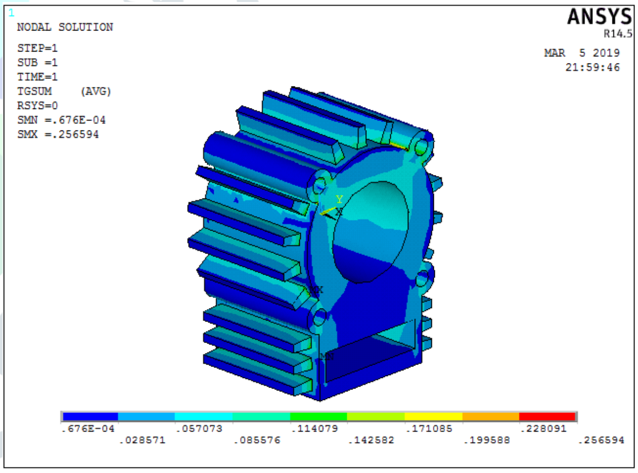


Fig thermal gradient on cylinder fin

6. RESULTS AND CONCLUSION:

In the present project, the cylinder has been studied for thermal behavior for different materials (aluminum al and copper).

The Trapezoidal Cylinder fin was studied for 2 different materials:

- Aluminum
- Copper

CASE-1: Thermal Analysis of Trapezoidal Cylinder fin with Aluminum material:

Max. Temperature (K)	Min. Temperature (K)	Thermal gradient(K/mm)	Thermal flux (W/m^2)
558	555.6	0.25	0.098811

CASE-2: Thermal Analysis of Trapezoidal Cylinder fin with Copper material:

Max. Temperature (K)	Min. Temperature (K)	Thermal gradient(K/mm)	Thermal flux (W/m^2)
558	556.47	0.54	0.098789

From thermal analysis results concluded that minimum temperature found is 555.6 K when trapezoidal cylinder fin made up by the Aluminium material and had higher heat transfer rate compared to copper material. So Aluminium is a best material for Trapezoidal Cylinder fin.

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