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Steady State Thermal Analysis of Engine Cylinder Fin by Changing Geometry and Material

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ABSTRACT:

The principle implemented in this project is to increase the heat dissipation rate by using the invisible working fluid, nothing but air. An air cooled motor bike engine dissipates waste heat from the cylinder through the cooling fins to the cooling air flow created by the relative motion of moving motor bikes. The cooling system is an important engine subsystem.

The air cooling mechanism of the engine is mostly depending on the fin design of the cylinder head and block. In this present study, the parametric model of cylinder with Trapezoidal fin, Elliptical fin and Triangular fin bodies are created in 3D modeling software Pro/Engineer. Steady state thermal analysis is done on the fins to determine Temperature Distribution, Total Heat flux and Directional Heat flux that are caused by thermal loads that do not vary over time. Analysis is conducted by varying material. The present used material for the fin bodies are LM13 which has thermal conductivity of 0.28cal/cm2/0C at 250 c. we are analyzing the cylinder fins using this material and also using AL356 which has 150 to 179W/m-K thermal conductivity.

Key words: Geometry of the fin, material and steady state thermal analysis.

INTRODUCTION

A system which controls the engine temperature is known as cooling system. Engine gets heated up due to heat of combustion of fuel inside the cylinder and due to friction between rubbing parts. It is found that about 30% of the total heat produced is absorbed by the cylinder and other components. Temperature of explosion is about 15000c to 20000 c and that of exhaust gases is about 6600 c. Hence an engine is to be cooled while running.

Further, life of spark plug will reduce due to overheating, volumetric efficiency will reduce; power output will reduce.

An efficient cooling system should dissipate only that quantity of heat which over heats the engine, since excessive cooling reduces thermal efficiency and does not allow fuel to vaporize properly. Excessive cooling May also cause dilution of lubricating oil as UN vaporized fuel gets mixed with it. At the same time over cooling causes condensation of acid, moisture on cylinder walls which leads lo corrosion.

Necessity for Engine Cooling

The cooling system is provided in the internal combustion engine to avoid below difficulties

- Engine valves warp (twist) due to overheating.
- Damage to the materials of cylinder body and piston.
- Lubricating oil decomposes to form gummy and carbon particles.
- Thermal stresses are set up in the engine parts and causes distortion (twist or change shape) and cracking of components.
- Pre–ignition occurs.
- Reduces the strength of the materials used for piston and piston rings.
- Overheating also reduces the efficiency of the engine.

Requirements of a good Cooling System
It should remove only about 30% of the heat generated in the combustion chamber. Too much cooling reduces the thermal efficiency of the engine.

A good cooling system should remove heat at a faster rate when the engine is hot. During starting, the cooling should be very slow.

Methods of cooling

In order to cool the engine a cooling medium is required .This can be either air or a liquid. Accordingly there are two types of system in general use for cooling the IC engines.
They are

- Air cooling or direct cooling,
- Water cooling or indirect cooling

AIR COOLING SYSTEM

In this type of cooling system which is conducted to the parts of the engine, is radiated and conducted away by the stream of air, which is obtained from the atmosphere. In order to have efficient cooling by means of air, providing cooling fins around the cylinder and cylinder head increase the contact area as shown in below

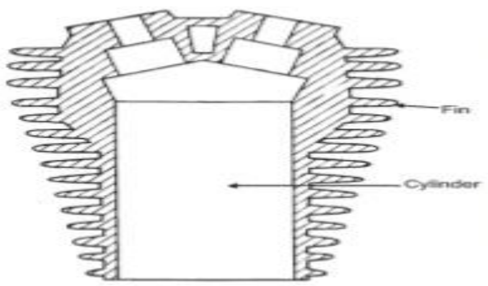

Fig 1: Cylinder with fins

The fins amount of heat carried off by the air-cooling depends upon the following factor:

- The total area of the fin surfaces
- The velocity and amount of the cooling air
- The temperature of the fins and off the cooling

WATER COOLING (INDIRECT COOLING)

In this system, water is circulated around the cylinder and cylinder heat to carry away the heat. The water passes through a passage called "water jacket" There are two methods of water cooling;

- Natural circulation of water
- Forced circulation of water

Cooling by Natural Circulation of Water

The cooling by natural circulation of water is also known thermo-syphon cooling. The principle that water becomes less dense 'heating is the basis of this method of cooling. The radiator is connection the water jacket at the top and bottom ends. As the water gets heat moves up and travels through the radiator. There it gets cooled by the radiator fins and travels downwards.

The word radiator is not the correct word. In a radiator the transfer of heat from coolant to the air is by conduction and forced convention and not radiation.
A drain tap is provided for removing water periodically.

Forced Circulation of Water

Cooling by Forced Circulation of Water

This system has a centrifugal water pump. The water pump gets the power from the rotating engine crankshaft.

The water pump draws cold water from the radiator. This cold water is forced into the water jackets of the cylinder. The rate of circulation of water is increased. Thus the engine parts are cooled efficiently. After circulating, the hot water enters the radiator top. The hot water in the radiator flows from top to bottom. The heat from the water is cooled by the radiator fins and it gets circulated again by the water pump. A fan also is provided near the radiator for rapid transfer of heat from radiator to the outside air.

Since water is circulated by a pump it may become very cold. The water temperature should not go below 75°C, since this will cause corrosion and acid formation which attack the cylinder barrel. A temperature controller thermostat valve is provided to control the cooling of water. If the temperature below 75°C, water is bypassed and when temperature reaches

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75°C or above thermostat valve opens, hot water flows through the radiator and get cooled.

A drain tap is provided at the bottom of the radiator for the removal of water periodically.

Objectives of present work:

- To design cylinder with ten number of fins by varying the geometry such as trapezoidal, elliptical and triangular fins.
- To determine steady-state thermal properties of the proposed fin models.
- Finally compare the results of heat transfer by fins.

S.NO	Parameter	Forms
1.	Type of fins	1.Trepezoidal 2.Elliptical 3.Traingular
2.	Thickness of the fin	40 mm
3.	Material of the	1.LM13

ANALYSIS BY ANSYS

The ANSYS Multi physics, ANSYS Mechanical, ANSYS FLOTRAN, and ANSYS Professional products support steady- state thermal analysis. A Steady -state thermal analysis calculate the effects of steady thermal loads on a system or component. Analyst often performs a steady state analysis before performing a transient analysis, to help establish initial condition.

Steady-state thermal analysis to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by a thermal loads that do not vary over period of time. Such loads include the following:

- Convection
- Radiation
- Heat flow rates
- Heat Fluxes
- Heat generation rates
- Constant temperature boundaries

A Steady- state thermal analysis may be either linear, with constant material properties, or nonlinear with material properties that depend on temperature. The thermal properties of most material do vary with temperature, so the analysis usually is nonlinear. Including radiation effects also makes the analysis nonlinear.

MODELLING DETAILS

The procedure for solving the problem is

Analysis:

Steady state thermal analysis to determine temperature distribution, total heat flux and directional heat fluxes in cylinder with trapezoidal fin, elliptical fin and triangular fin bodies that are caused by thermal loads that do not vary over time.

Build geometry:

Construct a three dimensional representation of the cylinder with Trapezoidal fin, Elliptical fin and Triangular fin shapes as shown in fig 3.1, 3.2, 3.3.It is assumed that all the fins have the same dimensions (fin length l= 5524.5mm and its width w= 7112mm no of perforation n=10, thickness of the fin t= 40mm) same thermal conductivity and same base and ambient temperature. The analysis is done for two different materials such as LM13and A356. The volume and mass of Trapezoidal geometry of the material LM13 (A356) are $406343e^{+010}mm^3$ and $1.2466e^{+005}kg$ For the Elliptical geometry volume and mass are $4.7042e^{+}1010mm3$and $1.2654e^{+005}kg$. Same for the Triangular geometry volume=$3.9791e^{+010}mm^3$, mass=$1.0704e^{+005}kg$. The total number of elements in the Trapezoidal model =27922, Elliptical model =34491 and Triangular model =20678.The total number of nodes in the Trapezoidal model=53714, Elliptical model=68357 and Triangular model=38796

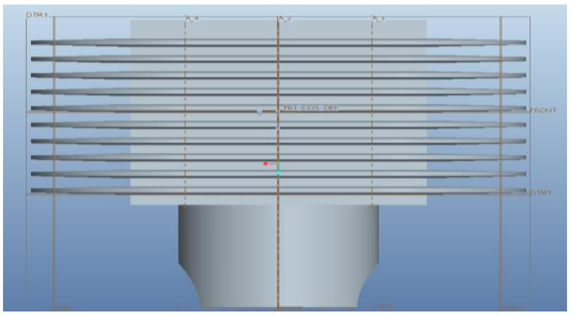

Fig 2: Pro/E model of Trapezoidal fin body

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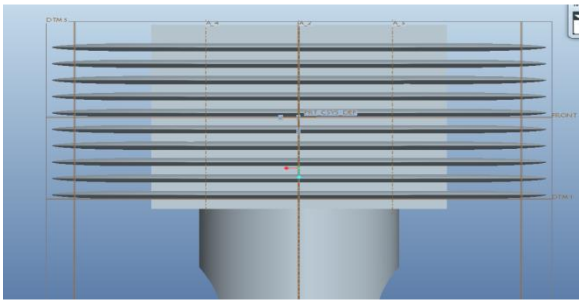

Fig: 3: Pro/E Model of elliptical fin body

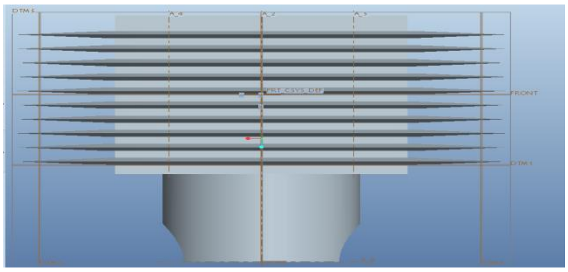

Fig 4: Pro/E Model of Triangular fin body

Material properties

In this study, the materials LM13 and AL356 is taken as constant. So material properties of LM13(AL356) are

Density	2.69e-006 kg mm^-3
Coefficient of Thermal Expansion	1.9e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	0.16 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm
Tensile Yield Strength MPa	170
Tensile Ultimate Strength MPa	250
Relative Permeability	1000
Reference Temperature C	25
Young's Modulus MPa	70000
Poisson's Ratio	0.33
Bulk Modulus MPa	68627
Shear Modulus MPa	26316

Generate mesh:

At this point ANSYS understand the makeup of the part. Now the modeled system should be broken down in to finite pieces.

Boundary conditions:

Once the system is fully designed the last task is to burden the system with the following thermal boundary conditions may be specified at the base of the fin

Base temperature $t_b = 2500^0$C

Ambient temperature =22^0C

Convective type boundary condition may be applied at the tip of the fin and radiation type boundary condition may be applied at inside of the cylinder.

Obtain solution:

This is actually a step, because ANSYS needs to understand with in what steady state of the problem must be solved

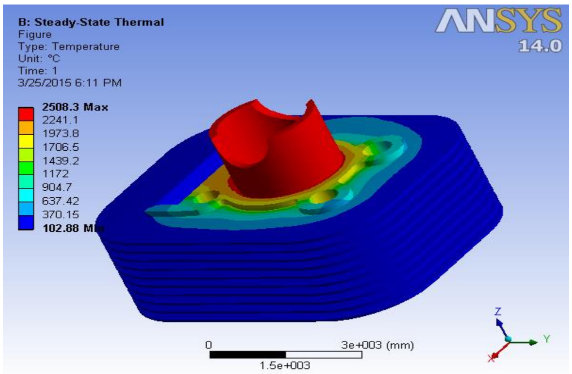

Fig 5: temperature distribution through Trapezoidal fin for LM13

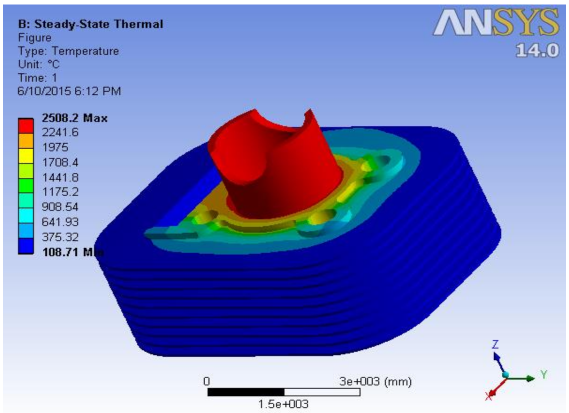

Fig 6: Temperature distributions throughtrapezoidal fin for A356

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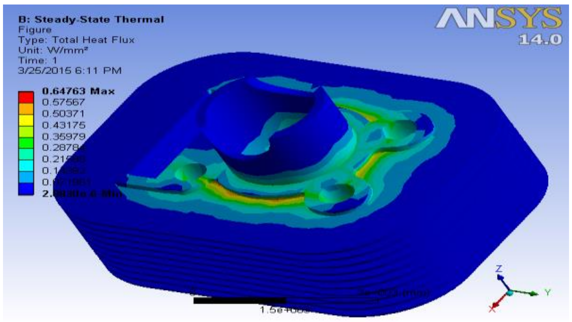

Fig 7: Total heat flux through trapezoidal for LM13 material

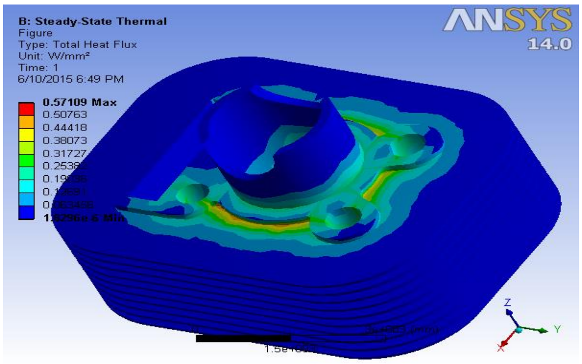

Fig 8: Total heat flux through trapezoidal fin for A356 Material

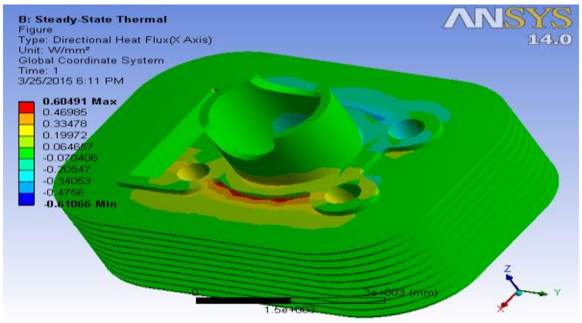

Fig 9: Directional Heat flux through Trapezoidal Fin for LM13 Material

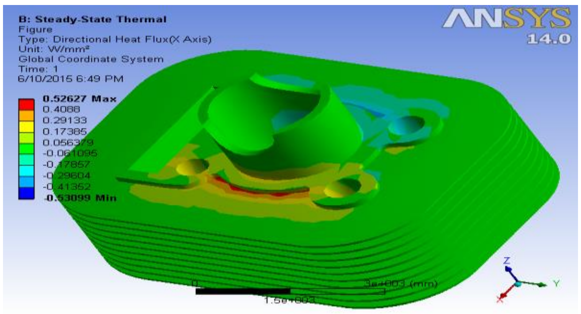

Fig 10:Directional Heat flux through trapezoidal fin for A356

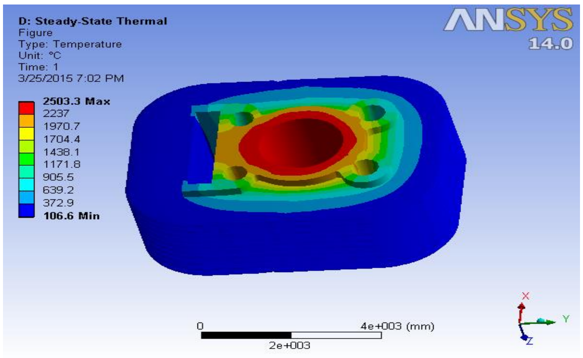

Fig 11: Temperature distributions through elliptical Fin for LM13

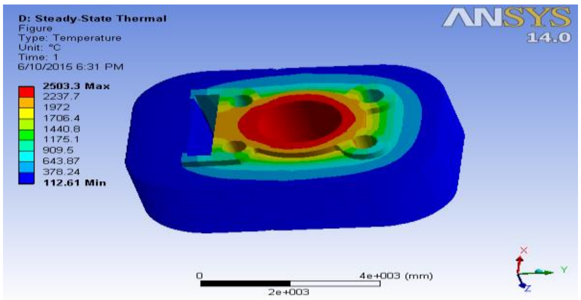

Fig 12: Temperature distributions through elliptical Fin for A356

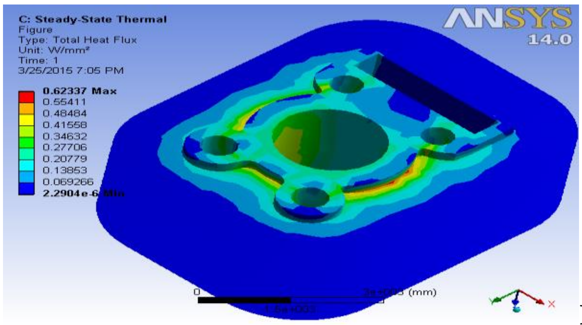

Fig 13: Total heat flux through Elliptical fin for LM13 Material

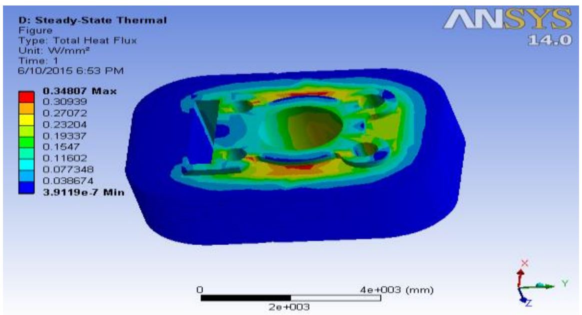

Fig 14: Total heat flux through elliptical fin for A356 Material

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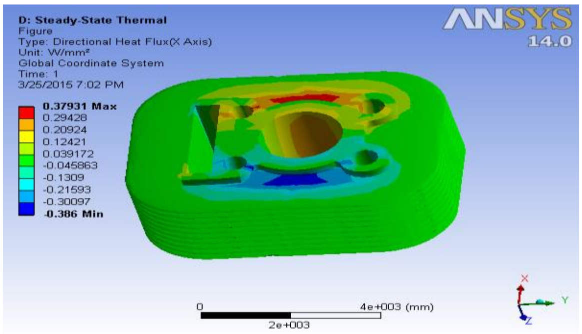

Fig 15: Directional Heat flux through elliptical fin for LM13 Material

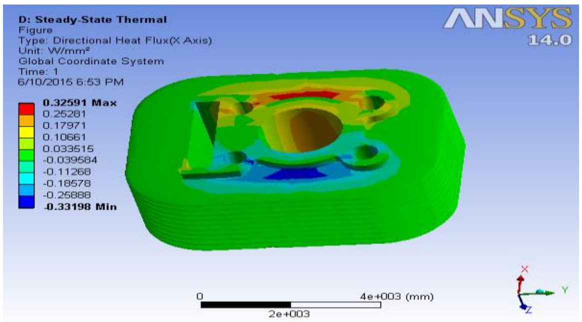

Fig 16: Directional heat flux through Elliptical Fin for A356 Material

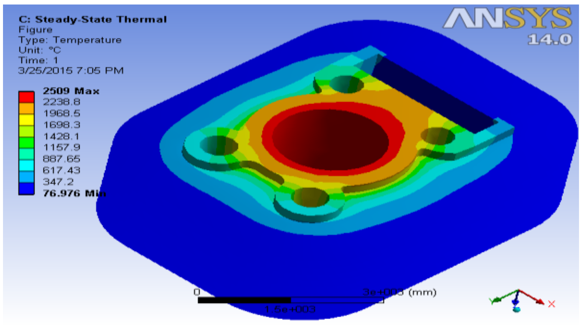

Fig 17: Temperature distribution through Triangular Fin for LM13 Material

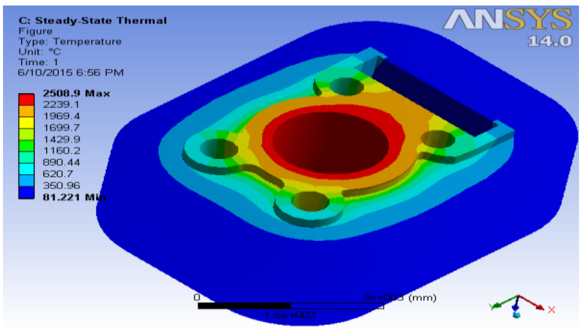

Fig 18: Temperature distribution through triangular Fin for A356 Material

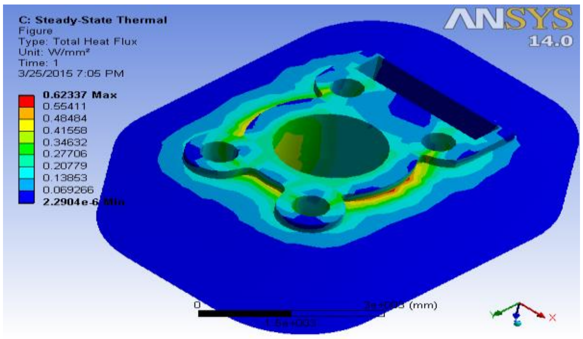

Fig 19: Total heat flux through Triangular fin for LM13 Material

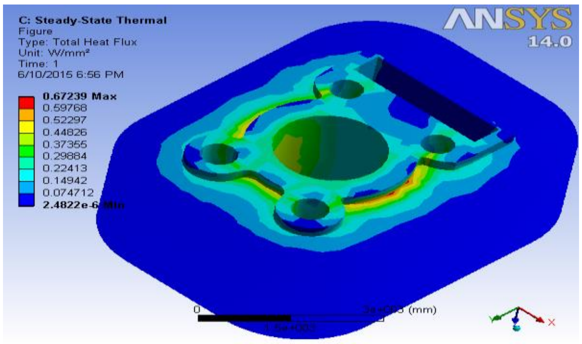

Fig 20: Total Heat flux through triangular fin for A356

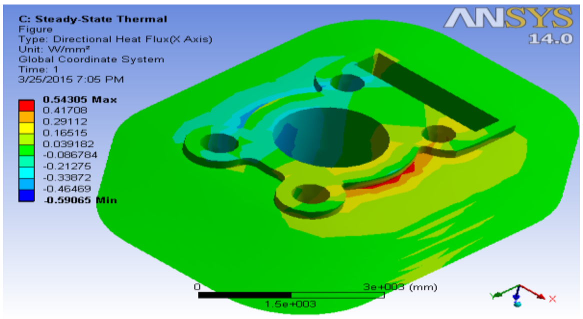

Fig21: Directional Heat flux through triangular fin for LM13 Material

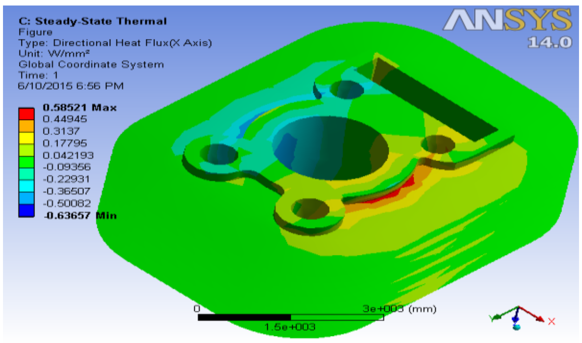

Fig 22: Directional Heat flux through triangular fin for A356 Material

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Table: 1 Trapezoidal fin

	LM13		A356	
	Min	Max	Min	Max
Temperature distribution (°C)	102.88	2508.3	108.71	2508.2
Total Heat Flux (W/mm²)	2.0838 e^{-6}	0.64163	1.28296e^{-6}	0.57109
Directional Heat Flux (W/mm²)	-0.61066	0.60411	-0.53099	0.52677

Table: 2 Elliptical fin

	LM13		A356	
	Min	Max	Min	Max
Temperature distribution (°C)	106.6	2503.3	112.61	2503.3
Total Heat Flux (W/mm²)	4.5622 e^{-7}	0.40485	3.919 e^{-7}	0.34807
Directional Heat Flux (W/mm²)	-0.386	0.37931	-0.3319	0.3259

Table: 3 Triangular Fin

	LM13		A356	
	Min	Max	Min	Max
Temperature distribution (°C)	76.979	2509	81.221	2508.9
Total Heat Flux (W/mm²)	2.2904 e^{-6}	0.62337	2.4822 e^{-6}	0.67239
Directional Heat Flux (W/mm²)	-0.59065	0.54305	-0.6365	0.58521

In this work we have designed a cylinder fin body used in two wheeler motor bikes and modeled in parametric 3D modeling software Pro/Engineer. Two materials used for thermal analysis are LM13 and A356. Shapes of fins used for analysis are Trapezoidal, Elliptical and Triangular fins. Thickness for fins used is 40mm. A Thermal analysis is carried out on the fin body by changing material and geometry. Fig 3.4 to 3.21 and Tables 3.1, 3.2 & 3.3 shows the results. From table 3.3 Triangular fin (A356) Have more value of Total Heat flux (i. e more transfer rate per unit area) compared to LM13 Material and also with Trapezoidal and Elliptical fin. A356 Total Heat flux is for Triangular fin is 0.67239w/mm2, whereas for LM13 it is 0.62337w/mm2 and also compared with Trapezoidal fin and Elliptical fin. From all above the results it is clear that A356 Triangular fin have more Effectiveness.

CONCLUSION

In present work, a cylinder with Trapezoidal fin, Elliptical fin and Triangular fin bodies are modeled and Steady state thermal analysis is done by using Pro/Engineer and ANSYS. These fins are used for air cooling system for two wheelers. In present study, LM13 and A356 are used as material.

By observing the thermal analysis results, Total Heat flux is more for Triangular A356 than other Trapezoidal fin and Elliptical fin by using both the material.

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