Design and Thermal Analysis of Engine Fins Using ANSYS Workbench

Sravan Arimadla, K. Kishor Kumar and P Divya

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Design and Thermal Analysis of Engine Fins by Using ANSYS Workbench

Arimadla Sravan [1]
K. Kishore Kumar [2]
P. Divya [3]

[1] Research Scholar
Mechanical Engineering,
Kakatiya Institute of Technology and Science, Warangal,
Telangana, India.
b19me190l@kitsw.ac.in

[2] Assistant professor,
Mechanical Engineering,
Kakatiya Institute of Technology and Science, Warangal,
Telangana, India.
kkk.me@kitsw.ac.in

[3] Assistant professor,
Mechanical Engineering,
Kakatiya Institute of Technology and Science, Warangal,
Telangana, India.
pd.me@kitsw.ac.in

Abstract: The Engine cylinder fin is one of the major automobile components, which is subjected to high temp erature variations and thermal stresses. In order to cool the cylinder of the engine, fins are provided on the surface of the cylinder to increase the rate of heat transfer. By doing thermal analysis on the cylinder fins of the engine, it is helpful to know the heat dissipation in side the cylinder. by increasing the surface area, the heat dissipation rate will increase, so designing such a large complex engine is very difficult. The main aim of the project is to analyze the thermal properties by varying geometry of cylinder fins using Ansys workbench bench 19.2 version. The 3D model of the geometry is created using CATIA V5 and its thermal properties are analyzed using Ansys workbench19.2. The variation of temperatu re distribution over time is of interest in many applicatio ns such as in cooling. The accurate thermal simulation could permit critical design parameters to be identified for improved life. Presently Material used for manufactu ring cylinder fin body is Aluminum Alloy which has thermal conductivity of 160 W/mk. Presently analysis is carried out for cylinder fins using this material.

Keywords: Dissipation, Thermal conductivity, cylinder, fins,3D model, CATIA V5, Ansys.

I. INTRODUCTION

1.1.* ENGINE CYLINDER FINS*: The internal combus tion engine is an engine in which the combustion of a fue l takes place in a combustion chamber. All two wheelers use Air cooled engines, because Air-cooled engines are lighter weight and lesser space requir ement. In Internal engine combustion engines, combustio n of air – fuel mixture takes place inside the engine cylinder and h ot gases are produced. The temperature of gases will be a round 200 – 600°C.The high temperature may result in burning of oil film between moving parts and may result in seizing or welding. Hence, this temperature must be reduced to incr ease the efficiency of the engine.It has been observed th at the heat dissipated by fins used in engine by changing geometry and material the effectiveness may varied ineff icient when it is cold and hence the cooling system is des igned in such a way that it prevents cooling when the en gine is warming up and till it attains to maximum efficie nt 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 would be proper to say the cooling syste m as a temperature regulation system. It should be remember ed that abstraction of heat from the working medium by way of cooling the engine components is a direct thermodynamic loss.

The rate of heat transfer depends upon the wind velocity , geometry of engine surface, external surface area and the a mbient temperature. In this work analysis is done on engine block fins considering temperature inside by means of condu ction and convection, air velocity is not considered in this w ork. Motorbikes engines are normally designed for operating at a particular atmosphere temperature, however cooling bey ond optimum limit is also not considered because it can redu ce overall efficiency. Thus it may be observed that only suffi cient cooling is desirable.

Air-cooled engines generally use individual cases for the cylinde rs to facilitate cooling. Inline motorcycle engines are an exce ption, having two-, three-, four-, or even six-cylinder air-cooled units in a common block. Water-cooled engines with only a few cylinders may also use indivi dual cylinder cases, though this makes the cooling system m ore complex. The Ducati motorcycle company, which for ye ars used air-cooled motors with individual cylinder cases, retained the ba sic design of their V-twin engine while adapting it to water-cooling.

1.2. AIR COOLING:

Air cooled systems generally used IC engines ,Air compress ors, Induction motor etc. In this system fins or (extended surf aces) are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and Convection takes place due to air flow over the surface of fins.

The amount of heat dissipated(convection) to air depends upon:

(a) Amount of air flowing through the fins.

(b) Fin surface area.

(c) Thermal conductivity of metal used for fins

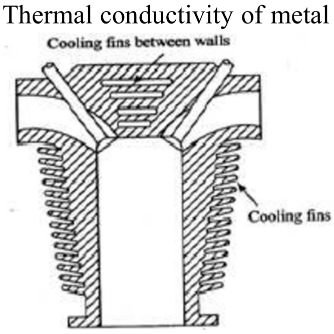


Fig-1.2. Automobile Fin

Advantages of Air Cooling System :

(a) Radiator/pump is absent hence the system is light in weight.

(b) In case of a water cooling system there are leakages, but in this case of air cooling there are no leakages.

(c) Coolant and antifreeze solutions are not required in air cooling systems.

(d) This system can be used in cold climates, where if water is used it may freeze.

Disadvantages of Air Cooling System:

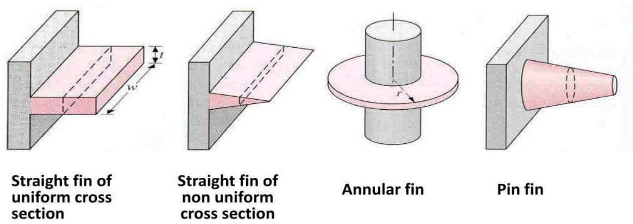
(a) It is less efficient compared to a water cooling system.

(b) Heat transfer rate is less compared to water cooling systems.

(c) Not suitable for a heavy diesel engine.

1.3.1. Fin types:

- Straight fin,
- Variable cross-sectional area fin,
- *Spine* or a pin fin,
- *Annular* or cylindrical fin.



<u>**Cast**</u> <u>**iron**</u>: Cast iron is basically an alloy of carbon and silicon with iron. It is containing 2.4 – 3.7 % C, 1.1 – 2.8% Si, 0.3 – 1.1% Mn, 0.16% P and 0.11% S. Cast iron possesses high fluidity and hence it is cast into any complex shapes and thin sections. It has an excellent wear resistance of grey iron under lubricating sliding conditions has been attributed to the presence of graphite in the microstructure. It possesses high damping capacity in addition to that cast iron provided the working conditions are clean. The material properties of cast iron are given below

Density	7593.48 Kg/m^3
Specific heat	0.4184 KJ/Kg K
Thermal conductivity	42.97 W/ m^2 K

<u>Aluminum:</u>

Aluminum is a silvery white metal and it possess following characteristics:

Light metal, good conductivity, higher resistance to corrosion and very ductile. The melting point of aluminum alloy varies from 520 – 650ºC. It is common to see aluminum fins on engine cylinders and heat exchangers.

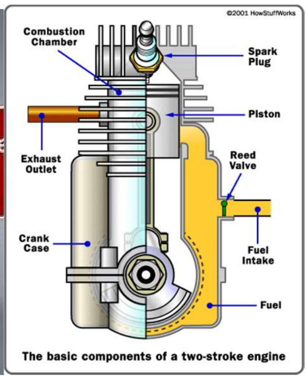
In general, Aluminum is mostly used as fin material because:

- It has good thermal conductivity compared to the cast iron
- Aluminum is lighter in weight.
- High corrosion resistance.
- High surface finish

Density	2627.00 Kg/m^3
Specific heat	0.854 kJ/kgK
Thermal conductivity	161.00 W/mK

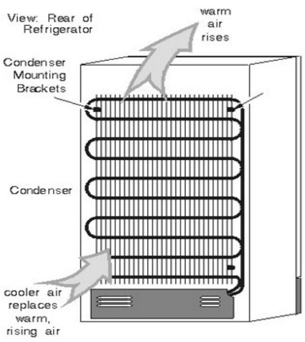
1.4.APPLICATION OF FINS:

- ➢ Fins mostly used in Internal combustion engine



Fins used in 4stroke engine   Fins used in 2stroke engine

Fins used in Air compressors   Fins used in induction motor



Fins used in AC   Fins used in refrigerator

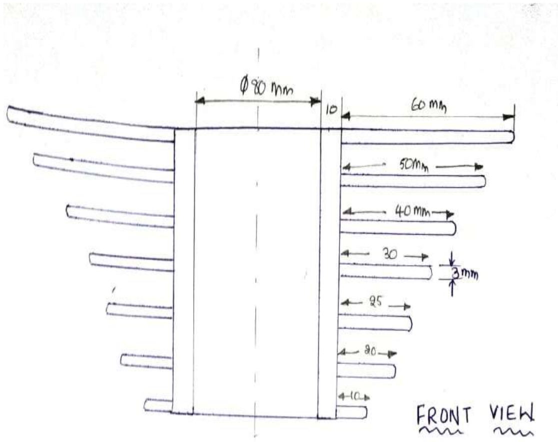
II.DESIGN AND MODELLING:

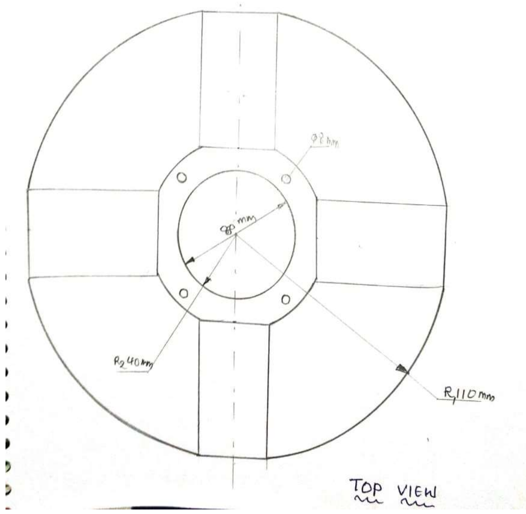
- ➢ The design of engine fins done by using CATIA V5 R21 software.
- ➢ CATIA is a Computer Aided Three dimensional Int eractive Application. It is a solid modelling tool that unites the 3D parametric features to 2D tools and a ddresses every design to manufacturing process. Cat ia provides the capability to visualise design in 3D.
- ➢ Steps involved in design of fins using CATIA:
- ● Draw the individual components of the part in 2D u sing the draw command.
- ● Set the dimensions for each line using dimensions c ommand.
- ● Convert the 2D sketch to 3D using pad command.
- ● Make the holes using pocket command.
- ● Set the material as aluminum using material comma nd.
- ● Assemble the individual components in the part dra wing.

2.1. SPECIFICATIONS OF DESIGN:

- ➢ Engine type: Kawasaki KX 450CC engine
- ➢ Bore: 80mm
- ➢ Stroke: 90mm
- ➢ Fin length: max 60mm
- ➢ Fin length: min 10mm
- ➢ Fin thickness: 3mm
- ➢ Fin type: rectangular fin with curved edges

2.2. DRAWINGS MODELS:





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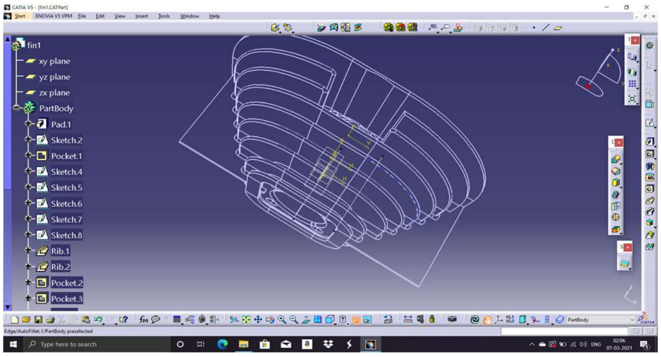
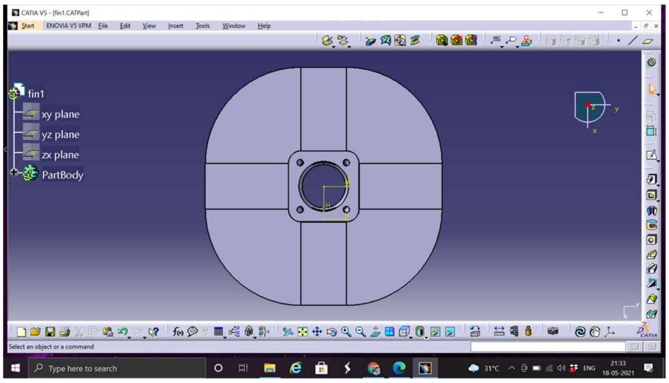
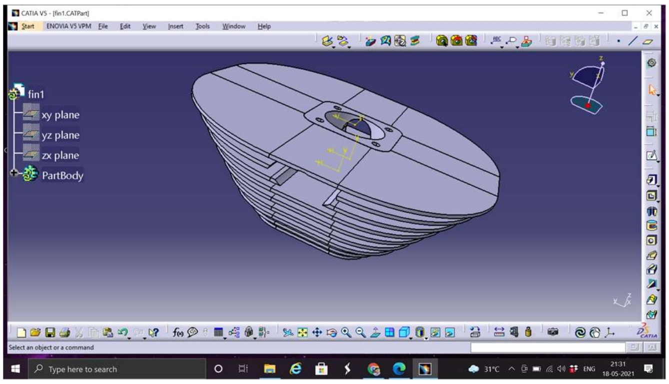
2.3. DESIGN MODELS IN CATIA:

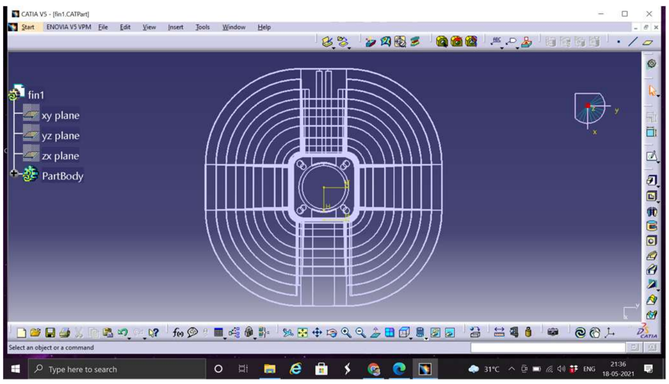


3D-view



Top view





Wired frame view

III ANALYSIS:

3.1. STATIC THERMAL ANALYSIS:

- Thermal static analysis is done by using Ansys 19.2 software.
- **ANSYS:** Ansys 19.2 is an advanced simulation software where we can do different analysis such as static analysis, dynamic analysis, fluid flow analysis, thermal analysis etc.
- **Steps involved in Static thermal analysis:**

1. Engineering data
2. Geometry
3. Model
4. Meshing
5. Analysis
6. Results

Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature. Several methods are commonly used – these are distinguished from one another by the property which is measured. Thermal analysis calculates the temperature and heat transfer within and between components in your design and its environment. This is an important consideration of design, as many products and materials have temperature dependent properties. Product safety is also a consideration—if a product or component gets too hot, you may have to design a guard over it.

The heat flow through the components can be in a steady state (where the heat flow does not change over time) or transient in nature. The thermal analogy of a linear static analysis is a steady-state thermal analysis, while a dynamic structural analysis is analogous to a transient thermal analysis.

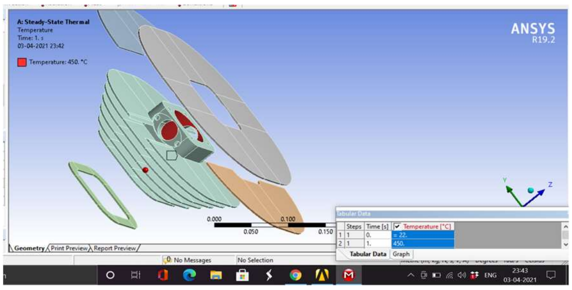
Heat transfer problems can be solved using structural and fluid flow analysis methods:

- In a thermal structural analysis, the effect of the moving air or a moving liquid is approximated by a series of boundary conditions or loads.
- In a thermal fluid analysis, the effect of the air or a liquid is calculated, increasing the run time but also increasing overall solution accuracy.

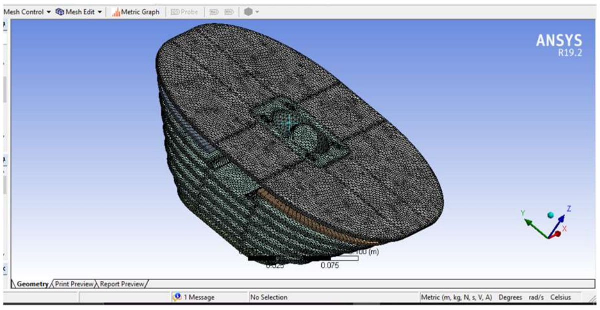
3.2. BOUNDARY CONDITIONS:

Sl. N o.	Loads	Value
1	Inlet temperature	450ºC
2	Heat transfer coefficient	69 W/m^2 K
3	Ambient temperature	27ºC
4	Material used	Aluminum Alloy
5	Thermal conductivity	165 W/m^2 K

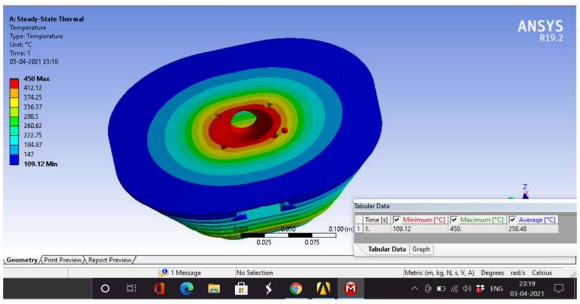
3.3. ANSYS MODELS:



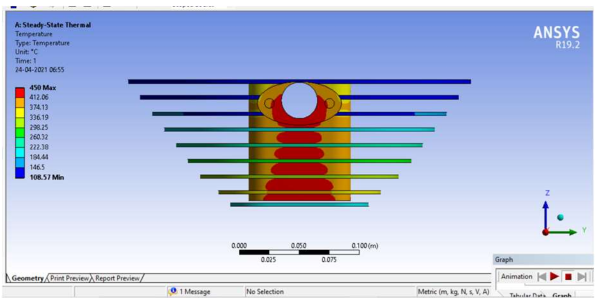
1. Design imported from CATIA



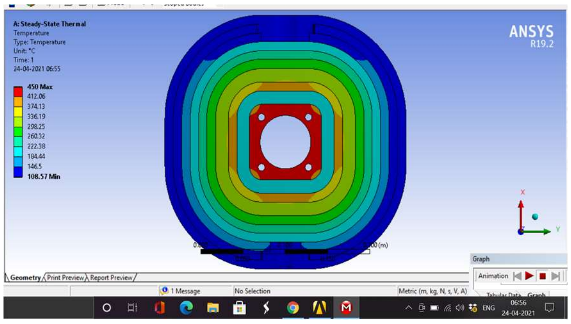
2. Meshing



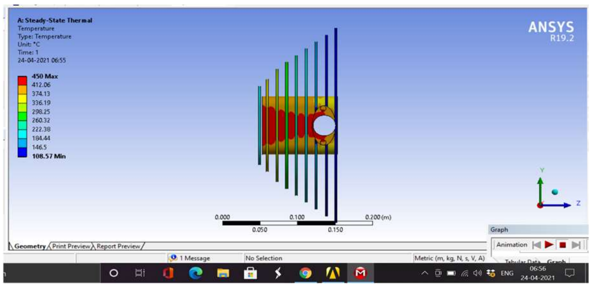
Temperature Distribution (isometric view)



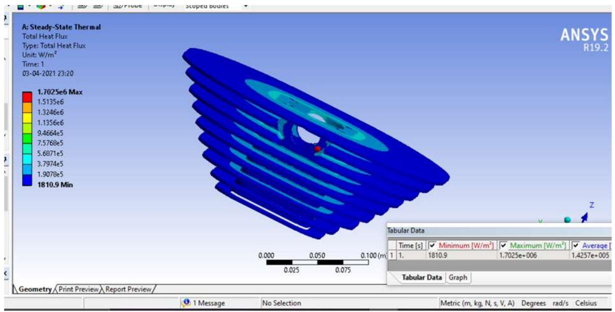
Temperature Distribution (Front view)



Temperature Distribution (Top view)



Temperature Distribution (Side view)



Heat flux Distribution

IV. LITERATURE SURVEY

In this project the designed part simulated and the heat tr ansfer from cylinder to air of a two-stroke internal combustion finned engine. The cylinder body provided with fins have been numerically analyzed and opti mized in order to increase the effectiveness of cooling.The m aximum temperature admissible at the hottest point of the en gine has been adopted as the limiting condition. In parallel w ith the total volume reduction, a slight increase in engine He at transfer efficiency has been achieved. And I analyzed the t hermal properties by varying geometry, material and thickne ss of cylinder fins. The models were created by varying the g eometry, rectangular, circular and modern shaped fins and al so by varying thickness of the fins. Material used for manufa cturing cylinder fin bodies was Aluminum Alloy 204 which has thermal conductivity of 130-170W/m.k and also using Aluminum alloy 6061 and cast iro n alloy. I concluded that by reducing the thickness and by c hanging the shape of the fin to curve shaped, the weight of t he fin body reduces thereby increasing the efficiency. The w eight of the fin body is reduced when a modified design is us ed and using circular fin, material Aluminum alloy 6061 and thickness of 2.5mm is better since heat transfer rate is more and using modified design fins the heat lost is more, efficiency and effectiveness is also more**.** Numerical Simulations used to determine heat transfer characteristics of different fin parameters namely, number of fins, fin thickness and design.

1. Large number of fins with less thickness can be preferred in high speed vehicles than thick fins with less numbers as it helps induce greater turbulence and hence higher heat transfer.

V. METHODOLOGY

The main aim of this project is to increase the heat dissipation rate of the given engine cylinder and to analyze distribution of different properties like Temperature, Total heat flux and Directional heat flux by modifying the design used for the cylinder, Material of the Cylinder and Linear Dimensions.

There are two ways to increase the rate of Heat transfer for dissipation of Heat from the Cylinder walls

1. Increasing the Surface Heat transfer coefficient(h value),
2. Increasing the Outer surface area of the Component (Cylinder) which is in contact with the ambient atmospheric air.
3. Increasing the fin length to get maximum effectiveness.

5.1. Increasing the surface heat transfer coefficient: To increase the Surface Heat transfer coefficient, The flowing fluid which flows with a Natural frequency and To which Heat is transferring need to flow with higher velocity so that value of Surface Heat transfer coefficient may increase. Because heat transfer coefficient is directly proportional to the velocity of fluid flowing. But it requires Artificial means like Installation of Pump or Blower to force which we call it as Forced convection.

One another means that the existing material can be replaced by another material which has a higher value of heat transfer coefficient than that of previous one. But we cannot give any assurance to the Economy of the product because the cost of material may increase or sometimes the replaced material cannot serve as good as the first one concerned with other properties of the Ideal material required. For Example, the requirement is that material for an x-component should be ductile in nature and need to have higher heat transfer coefficient.

Take material-1 which is purely ductile in nature but it's value of heat transfer coefficient is moderate and let us consider that the material-2 is having good heat transfer coefficient value but not ductile in nature may be harder and brittle in nature. For cases like these we go for alloys of different materials to satisfy the needs of both structural and thermal requirements.

Hence maximum effort needs to be put to produce alloys which is not economical and time consuming. That's why the alternate method called fins extended surfaces is followed by Industrialists, Designers etc.

5.2. Few Reasons that Illustrating Importance of usage of fins:

1. "K" should be as high as possible, (copper, aluminum, iron). Aluminum is preferred: low cost and weight, resistance to corrosion, good thermal conductivity.
2. p/A_c should be as high as possible. (Ratio of Perimeter to cross sectional area)
3. Most effective in applications where h is low. (Use of fins justified if the medium is gas and heat transfer is by natural convection).

5.3. Problem Definition:

In the present Project investigation on thermal issues on automobile fins were carried out. Investigation yields the temperature behaviour and Total Heat flux and Directional heat flux of the Cylinder fins due to high temperature in the combustion chamber. ANSYS WORKBENCH is utilized for analysis. The analysis is done for modified Design Also the material is changed so that better heat transfer rate can be obtained.

5.4. Steady state thermal analysis:

A Steady state thermal analysis calculates the effect of steady thermal load on a system or component, analysts were also doing the steady state analysis before performing the transient analysis. We can use this analysis to determine temperature, thermal gradient, heat flow rates and heat flux in an object that does not vary with time.

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 materials do vary with temperature, so analysis is usually nonlinear.

5.5. Assumptions for analysis:

- The temperature of the surrounding air does not change significantly.
- Constant heat transfer coefficient is considered at the air side.
- The heat generation is neglected.
- Most of Material properties are constant(such as Thermal conductivity,Elasticity modulus,Coefficient of thermal expansion,etc)

VI. RESULTS AND DISCUSSION

A model of cylinder with fins mounted on it is used for analysis in the present project. This is imported into ANSYS workbench environment and boundary conditio ns were applied as mentioned above. Analysis is carried out for different geometry of fins (circular and rectangul ar) with various thicknesses and materials. The results ar e shown below,

Fin Type **:** rectangular annular fins with curved edges
Material **:** aluminum alloy
Fin thickness: 3mm

6.1. RESULTS			
	Engine Temperature	Heat flux	Ambient Temperatures
Minimum	108°C	1810 W/m²	27°C
Maximum	750 °C	170250 W/m²	27°C

➢6.1. ***Temperature Distribution:***
From the above results of ANSYS Workbench temperatures are obtained at different locations of the design part. The ma ximum temperature at the inside of the cylinder is 450°C, mi nimum temperature is 108°C and average temperature obtain ed is 320°C.Comparing to the normal design of fins this engi ne fins design improves the cooling rate due to large surface area which is obtained by providing more no. of fins and the length of fin is designed as per the requirement such as at top of cylinder the temperatures are higher than temperatures at bottom dead centre,because combustion initially starts at the top dead center and the gases generated due to combustion ar e expanded to the bottom dead centre. As the surface area is large there is more heat transfer from fin to the atmosphere .

➢6.2. ***Total Heat flux:***
When it is matter of total heat flux conducted by the cyli nder the variation observed is as follows:
In normal design of fins i.e circular or rectangular fins the h eat transfer per unit known as Heat flux is less compared to this design. Finally I observed that there is an increase in hea t flux due to the curved design at the ends of fin.

6.3. Directional Heat flux:
In case of Directional Heat flux all the results are similar to Total Heat flux

The Directional heat flux conducted by the material incr eases with increase in amount of material but decreases with increase in fin thickness and it is high in curved geometry w hen compared with other geometry. Aluminum alloy fin con ducts more directional heat than that of cast iron alloy fin wit h the same geometry and fin thickness.

VII. CONCLUSION

In present work, a cylinder fin body is modelled by using CATIA V5 and Static thermal analysis is done by using ANSYS Workbench. These fins are used for air co oling systems for two wheelers. In present study, the Fin design is modified to improve the effectiveness and Hea t transfer efficiency.

VIII. REFERENCES

1. **G. Ganesh Kumar, K. Sridhar, and B. Anil Kumar, (2015)** " Experimental Studies on Conjugate mixed Convection Heat Tra nsfer Through Perforated Fins", International Journal of Science , Engineering and Technology Research, pp. 1803-1808, E-ISSN: 2278 – 7798.
2. J. G. Bartas and W. H. Sellers," Radiation Fin Effectiveness," J OURNAL OF HEAT TRANSFER , TRANS. ASME , Serie s C , vol. 82 , no . 1. Feb., 1960, p. 73.
3. D. B. MacKay and E. L. Leventhal, "Radiant Heat Transfer Fr om a Flat Plate Uniformly Heated Along One Edge," North Am erican Aviation, Inc., Report M D 58-187, August, 1958.
4. J. E. Wilkins, Jr., "Minimizing the Mass of Thin Radiating Fins ," Journal of Aeronautical Sciences, vol. 27, no. 2, Feb., 1960, p. 145.
5. E. N. Nilson and It. Curry, "The Minimum Weight Straight Fin of Triangular Profile Radiating to Space," Journal of Aeronauti cal Sciences, vol. 27, no. 2, Feb., 1960, p. 146.
6. J. E. Wilkins, Jr., " Minimum Mass Thin Fins Which Transfer Heat Only by Radiation to Surroundings at Absolute Zero," J. S oc. Indust. and Appl Math., Dec., 1960.