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# Enhancement of Heat Transfer Analysis and Optimization of Engine Fins of Varying Geometry and Materials

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## ABSTRACT

In automobiles, the engine cylinder is subjected to high temperature variations and thermal stresses. So as to cool the engine cylinder, fins are mounted on the engine cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins you can know the rate of heat transfer inside the cylinder. The main objective of the project is to analyze the thermal behavior of cylinder fins by varying geometries, materials. In this project 2.5 thickness of fins are considered for various fin geometries and they are designed using ANSYS WORKBENCH. Thermal analysis on the fins is done by using ANSYS WORKBENCH.

In present paper we have taken materials aluminum alloy and gray cast iron. The geometries circular, rectangular fins with Aluminum alloy,gray cast iron of thickness 2.5mm compared on the basis of total rate of heat flux & effectiveness. It is found that aluminum alloy of circular geometry with 2.5 mm thickness is having more rate of heat flux &effectiveness.

**Keywords:** engine cylinder, ansys, aluminium alloy.

## INTRODUCTION

In 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. Heat engines generate mechanical power by extracting energy from heat flows, much as a water wheel extracts mechanical power from a flow of mass falling through a distance. Engines are inefficient, so more heat energy enters the engine than comes out as mechanical power; the difference is waste heat which must be removed. Internal combustion engines remove waste heat through cool intake air, hot exhaust gases, and explicit engine cooling. A typical distribution for the fuel energy is given below:
Useful work at the crank shaft = 25 per cent
Loss to the cylinder's walls = 30 per cent
Loss in exhaust gases = 35 per cent
Loss in friction = 10 per cent

Heat transfer rates can be increased by increasing the

- Temperature gradient between the object and the environment
- Convection coefficient
- Surface Area of the object.

## LITERATURE OVERVIEW

Heat engines generate mechanical power by extracting energy from heat flows, much as a water wheel extracts mechanical power from a flow of mass falling through a distance. Engines are inefficient, so more heat energy enters the engine than comes out as mechanical power; the difference is waste heat which must be removed. Internal combustion engines remove waste heat through cool intake air, hot exhaust gases, and explicit engine cooling. Engines with higher efficiency have more energy leave as mechanical motion and less as waste heat. Some waste heat is essential: it guides heat through the engine, much as a water wheel works only if there is some exit velocity (energy) in the waste water to carry it away and make room for more water.

Thus, all heat engines need cooling to operate. Cooling is also needed because high temperatures damage engine materials and lubricants. Internal combustion engines burn fuel hotter than the melting temperature of engine materials, and hot enough to set fire to lubricants. Engine cooling removes energy fast enough to keep temperatures low so the engine can survive.

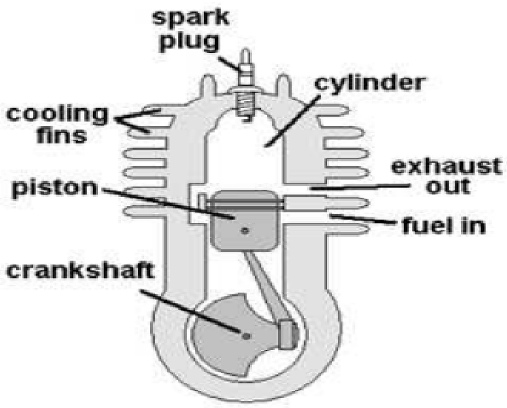
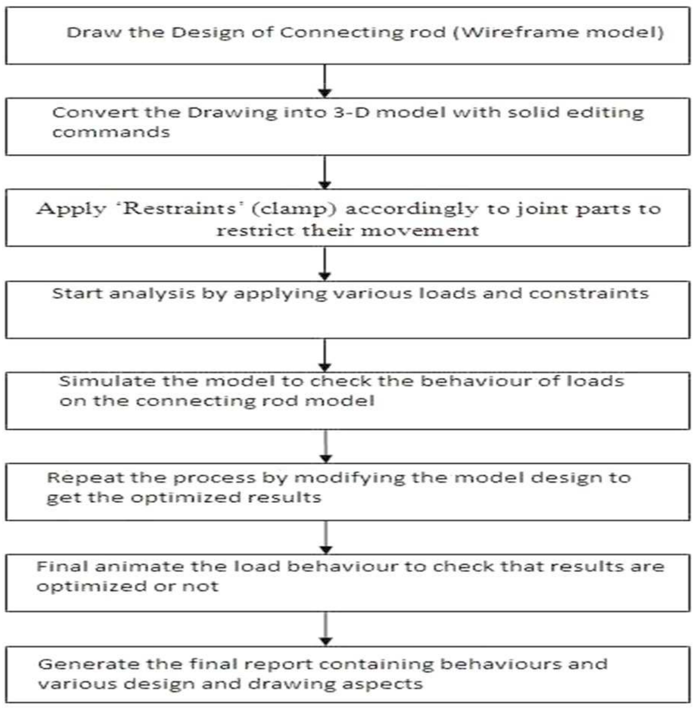



**FIG. 2. 1. ENGINE**

Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant run through a heat exchanger (radiator) cooled by air. Marine engines and some stationary engines have ready access to a large volume of water at a suitable temperature. The water may be used directly to cool the engine, but often has sediment, which can clog coolant passages, or chemicals, such as salt, that can chemically damage the engine. Thus, engine coolant may be run through a heat exchanger that is cooled by the body of water.

## METHODOLOGY




This paper includes the selection of optimal design of connecting rod which is considered to give better results as compared with the previous results maintaining various parameters which make sure that the optimal design and better results are result of findings and analysis of connecting rod by making various modified designs. Then the Finite Element Analysis method is applied on this design to get the optimized results with the help of various Computer Aided Engineering tools and software.

### CYLINDER TEMPERATURE HEAT DISTRIBUTION

Whenever a moving gas comes into contact with a wall, there exists a relatively stagnant gas layer which acts as a thermal insulator. The resistance of this laver heat flow is quite high. Heat transfer from the cylinder gases takes place through the gas layer and through the cylinder walls to the cooling medium. A large temperature drop is produced in the stagnant layer adjacent to the walls. The peak cylinder gas temperature may be 2800 K while the temperature of the cylinder inner wall surface may be only 450 K due to cooling. Heat is transferred from the gases to the cylinder walls when the gas temperature is higher than the wall temperature. The rate and direction of flow of heat varies depending upon the temperature differential. If o cooling is provided, there could be no heat flow, so that the whole cylinder wall would soon reach an average temperature of the cylinder gases. By providing adequate cooling, the cylinder wall temperature can be maintained at optimum level.

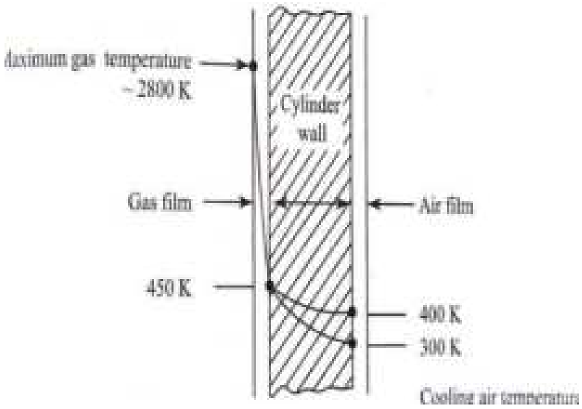



**FIG 4. 1. CYLINDER TEMPERATUE DISTRIBUTION**

**FIN MATERIALS**

GRAYCAST IRON

MATERIAL PROPERTIES:

Thermal Conductivity – 0.05 w/mmk

Specific Heat –500 J/kg ºC

Density –7.1 g/cc

ALUMINUM ALLOY 6082

MATERIAL PROPERTIES:

Thermal Conductivity –180 w/mmk

Specific Heat – 0.963 J/g ºC

Density – 2.7 g/cc

Chemical composition of AL Alloy

| Element | Weight % |
|---|---|
| C | 0.25 |
| Mn | 0.9 |
| P | 0.03 |
| S | 0.04 |
| Si | 0.15-0.30 |
| Mo | 0.45-0.60 |
| Ni | 0.05 |

**Table 1. ALUMINUM ALLOY PROPERTIES**

## DIMENSIONS AND ANALYSIS OF FINS

Dimensions for fins and cylinder have been taken from the standard dimensions. We have made some changes to the standard dimensions according to our project. We have changed the thickness, length of the fins and pitch of fins. Following Table is the considered dimensions for design.
All Dimensions are in mm.

THERMAL ANALYSIS

The design properties are considered for the circular and rectangular fins with variable materials like 2.5mm and 3.0mm. For the same the fin is designed using design software and analyzed using ANSYS R14.5.

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 is also often used as a term for the study of Heat transfer through structures. Many of the basic engineering data for modelling such systems comes from measurements of heat capacity and Thermal conductivity

**5.1.1. ALUMINIUM ALLOYCIRCULAR FIN:**

Steady state thermal analysis output for the Circular fin geometry with 2.5mm thickness.

**Temperature**

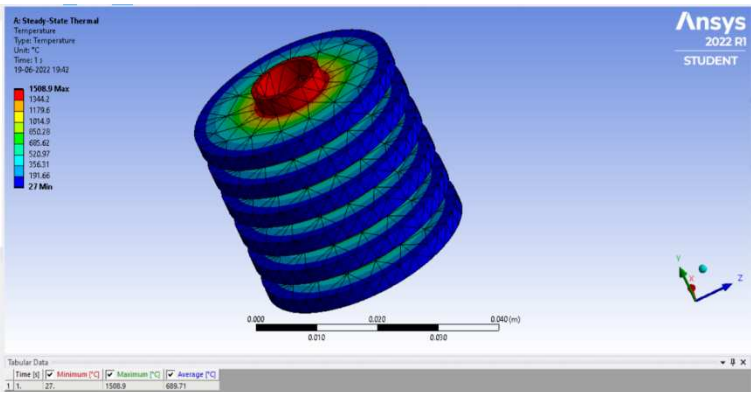



**FIG. 6. 1. ALUMINIUM ALLOY CIRCULAR FIN TEMPERATURE**

**Total Heat flux**

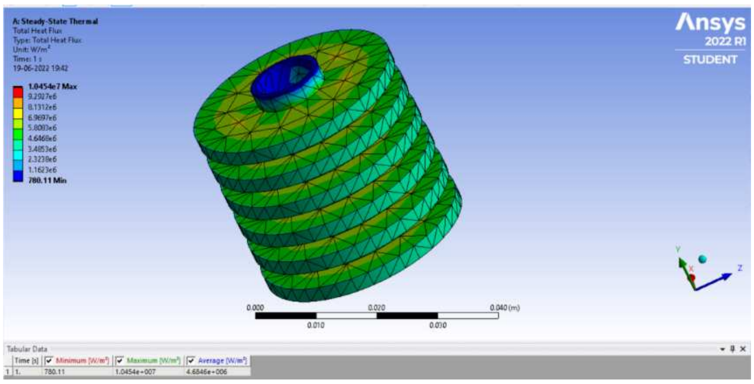



**FIG. 6. 2. ALUMINIUM ALLOY CIRCULAR FIN HEAT FLUX**

### 5.1.2. ALUMINIUM ALLOY RECTANGULAR FIN:

Steady state thermal analysis output for the rectangular fin geometry with 3.0mm thickness.

**Temperature**

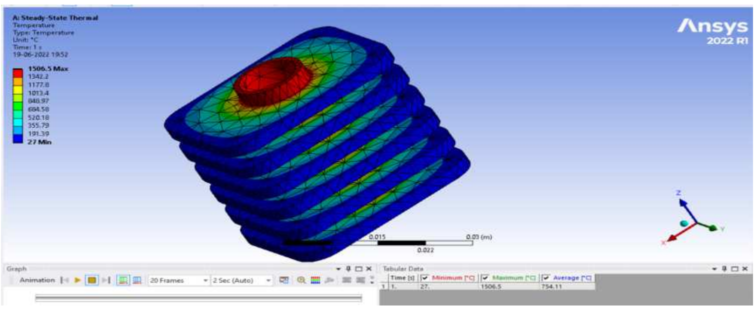



**FIG. 6. 3. ALUMINIUM ALLOY RECTANGULAR FIN TEMPERATURE**

**Total heat flux**

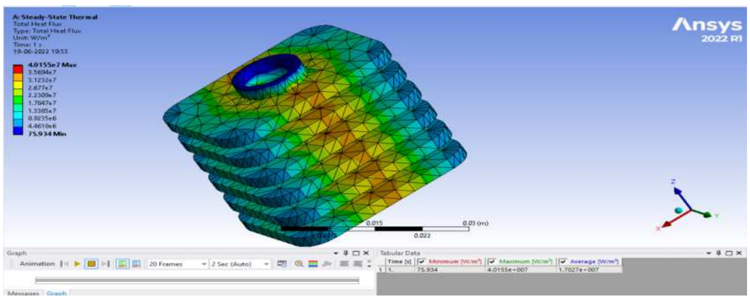



**FIG. 6. 4. ALUMINIUM ALLOY RECTANGULAR FIN HEAT FLUX**

### 5.1.3. CAST IRON CIRCULAR FIN:

**Temperature**

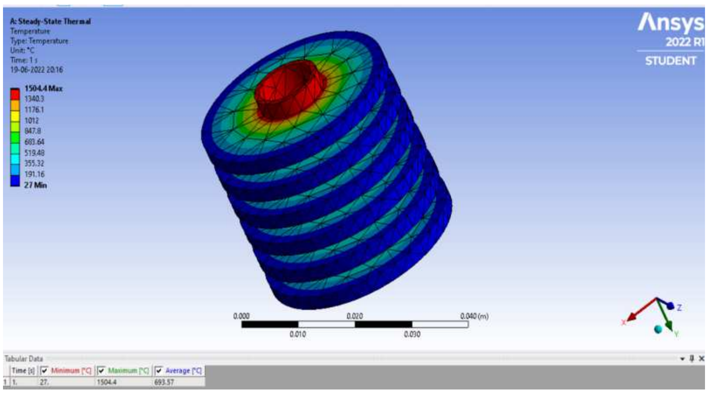



FIG. 6. 5. CAST IRON CIRCULAR FIN TEMPERATURE

**Total heat flux**

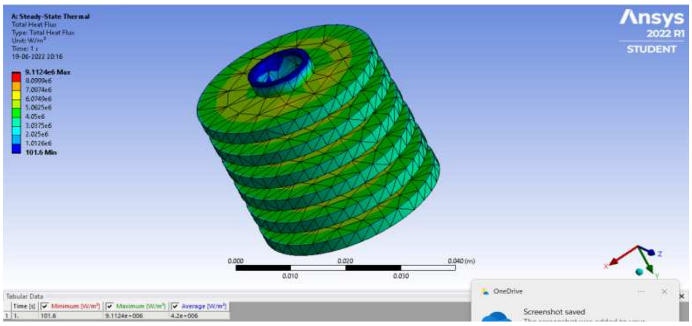



FIG. 6. 6. CAST IRON CIRCULAR FIN HEAT FLUX

**Temperature**

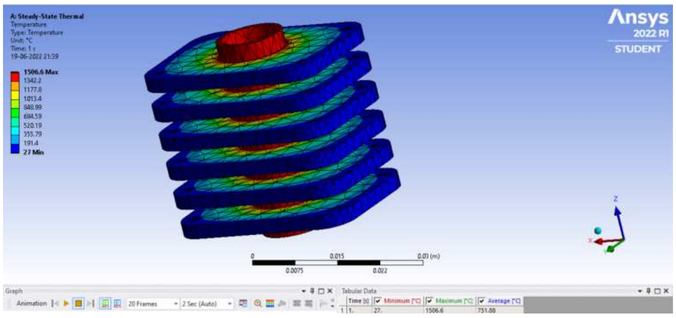



FIG. 6. 7. CAST IRON RECTANGULAR FIN TEMPERATURE

**Total heat flux**

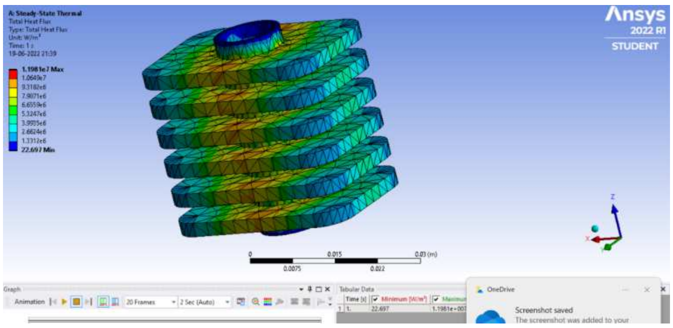



FIG. 6. 8. CAST IRON RECTANGULAR FIN HEAT FLUX

## RESULTS

Table gives data of results from ANSYS simulation. The maximum and minimum temperature in each case is mentioned. The minimum temperature is clearly a function of thermal conductivity (k) and thermal diffusivity (α). The materials which have higher value of minimum temperature is a clear indicator of better material in terms of its thermal properties. So, from the data aluminum alloy is best material which we have chosen. The average heat flux value also give idea about, which material is to be chosen; by this criterion also aluminum alloy is better among all. The weight which is the function of density of material is also an important parameter which influence the selection of the material. The aluminum alloy is having lowest density considered in this study. So, from above analysis aluminum alloy seems to be a better material among the two materials to be used as material for manufacturing of fins. The simulation software results are compared with the weighted point method to find the better material.

| **Steady state temperature (□)** | **Circular geometry** | | **Rectangular geometry** | |
|---|---|---|---|---|
| | **Aluminum alloy** | **Gray cast iron** | **Aluminum alloy** | **Gray cast iron** |
| Minimum Temperature | 27□ | 27□ | 27□ | 27□ |
| Maximum Temperature | 1508.9□ | 1504.4□ | 1506.5□ | 1506.6□ |
| Average Temperature | 689.71□ | 693.57□ | 754.11□ | 751.88□ |

**Table 2. THERMAL ANALYSIS**

| **Heat flux** | **Circular geometry** | | **Rectangular geometry** | |
|---|---|---|---|---|
| | **Aluminum alloy** | **Gray cast iron** | **Aluminum alloy** | **Gray cast iron** |
| Minimum heat flux | 780.11 | 101.6 | 75.938 | 22.697 |
| Average heat flux | 4.6846e+006 | 4.2e+006 | 1.707e+007 | 12352 |
| Maximum heat flux | 9.0454e+007 | 2.1124e+007 | 4.0155e+007 | 1.181e+007 |

**Table 3. TOTAL HEAT FLUX ANALYSIS**

**EFFECTIVENESS OF FIN**

The performance of the fin is judged on the basis of the enhancement in heat transfer relative to the no-fin case. The performance of fin is expressed in terms of the fin effectiveness is defined as the ratio of the heat transfer rate from the fin of base area to the heat transfer rate from the surface of area i.e. It is equal to the base area of fin.

$$\mathcal{E}=\frac{q_{Fin}}{q_{No\ Fin}}$$

Where, $\mathcal{E}$ = Effectiveness of fin

qfin = Heat flux with fin

qNo fin = Heat flux without fin

## CONCLUSION

In this project we have compared the materials aluminum alloy and gray cast iron varying geometry and material. The fin geometries are modeled and then thermal analysis is done on ANSYS workbench. By observing thermal analysis results, we can clearly conclude that fin material aluminum alloy of circular geometry with 2.5mm thickness is most effective in terms of rate of heat flux & effectiveness. By using circular fins with aluminum alloy, the weight of the fin body is also reduces compared with the existing material of fin.

| $\mathcal{E}$ | Aluminum alloy | | Gray cast iron | |
|---|---|---|---|---|
| | circular | rectangular | circular | rectangular |
| Effectiveness | 2.2903 | 1.9902 | 1.31 | 1.12 |

FUTURE SCOPE

The shape of the cylinder fin body is modified and proven analytically that it can be used. But more experiments have to be done on that modified model to check the feasibility of the arrangement in the two wheelers. Since the shape of the fins of modified model is curved, the cost for manufacturing is also to be considered. Since to manufacture this model, if the cost is very high, it is not preferable since it may increase the cost of two wheeler.

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