Abstract: The fins are generally extended surfaces of projections of materials on the system. The fins are generally used to increase the heat transfer rate from the system to the surroundings by increasing the heat transfer area. The heat transfer rate depends upon the velocity of the vehicle and fin geometry and temperature of cylinder many experimental methods are available in literature to analyze the effect of these factors on the heat transfer rate. The main objective of the research is to accomplish the comparative study of fins of different profile made by different aluminum material alloys. The study is carried out based on the finite element analysis. The aim of the work is to determine the optimum material fin based on the various parameters based on the thermal analysis. The parametric model is created in 3D modeling software CATIA V5-R20. Heat transfer simulation will be conducted using ANSYS Workbench 14.0 software.

Keywords: Fins, Heat Transfer Rate, Circular Fins, Curvature shape, Aluminium alloy 6061, and Aluminium alloy 6026, Aluminium alloy 6066.

INRODUCTION
In heat transfer studies, a fin is defined as an extended surface from an object and is often used as an economical solution to heat transfer problems. Adding a fin to an object can increase the surface area over which convection occurs and helps increase the amount of convection to or from the surrounding fluid. Moreover, as fins are typically made of material with high heat conductivity, the amount of heat transferred by conduction will be increased, which can further enhance the overall heat transfer process. As material deforms when exposed to temperature changes, a thermal stress will be induced, which is usually estimated by the analysis of the thermal strain and the Young’s modulus of the material.

1.1 Utility in Vehicles It is significant to operate at an appropriate temperature for better performance of engines. If the engine always works at extremely high temperature, it will not lead to an optimal combustion process, which causes the aging of the lubricant oil and break down of engine material problems. However, if it is cold, the engine will be less efficient and emit more pollution.
Each and every type of fins having their own importance from the application point of view. Fins come in various shapes; such as rectangular, circular, pin fin rectangular, pin-fin triangular, etc., see Fig. 1-1, depending on the application. Rectangular fins are the most popular fin type because of their low production costs and high thermal effectiveness.

2 SOFTWARE INTRODUCTIONS

2.1 Interpretation of Drawings
Most parts start with a sketch. A sketch is the profile of a feature and any geometry (such as a sweep path or axis of rotation) required to create the feature. All sketch geometry is created and edited in the sketch environment, using Sketch tools on the panel bar. Sketch grid can be controlled, and use sketch tools to draw lines, splines, circles, ellipses, arcs, rectangles, polygons, or points. One can fillet corners, extend or trim curves, and offset and project geometry from other features.

2.2 Procedure for use of FEM in Structural Analysis

i. Divide structure into pieces (elements with nodes)
ii. Describe the behavior of the physical quantities on each element
iii. Connect (assemble) the elements at the nodes to form an approximate system of equations for the whole structure
iv. Solve the system of equations involving unknown quantities at the nodes (e.g., displacements)

2.3 Determine desired quantities (e.g., strains and stresses) at selected elements

Various researchers have been worked on performance analysis of extended surfaces (fins). Some of their works are as follows:

1. Analysis Of Ic Engine Air Cooling Of Varying Geometry And Material, Mahendran.V, Venkatasalakumar.A, May, 2015 The fins are generally extended surfaces of projections of materials on the system. The fins are generally used to increase the heat transfer rate from the system to the surroundings by increasing the heat transfer area. The parametric model is created in 3D modeling software SOLIDWORKS 2012. Heat transfer simulation will be conducted using ANSYS Workbench 14.0 software.

In this paper, a cylinder fin body for Bajaj CT 100cc motorcycle is modelled using parametric software SolidWorks 2012. The thickness of the original model is 3mm, in this thesis it is reduced to 2mm.

The fin shape is Rectangular with curves at corner, in this thesis Circular with curvature fin and radius of curvature is 0.5 mm.

2. Comparative Study Of Thermal Stress Distributions in Fins Operating At High Temperature For Different Profiles And Materials Prajesh Paul1, Ram C Sharma, Rohit Bezewada, Mohammad Wakeel, SM Murigendrappa (2014)

This study presents a comparative study of the distribution of temperature and consequent induced thermal stresses in circular fins of heat transfer equipment. The numerical analysis of this coupled field problem has been performed using the finite element method. They carried out the numerical analysis for computing the temperature and thermal stress distributions in circular fins using commercially available finite element Software ANSYS.

3. An Experimental Analysis of Transient Heat Transfer in Air Cooled IC Engine Fin using FEA, Vipul Shekhada, Dr. Shashi Jain, Jayesh Gundaniya (June 2014)

A fin is a surface which extends from a surface to increase the rate of heat transfer to the environment by increasing convection. The IC Engine fins are made from Aluminum alloy and it is provided for better cooling effect.

In this study the researchers compared and validated the experimental data and FEA data for fin of air cooled IC engine. Also comparing the modified fin FEA data with existing fin data, this research paper give clear idea about fin performance. After the modification of fin with constant volume, effectiveness was increased with minor change in efficiency. So modified fin gives best cooling rate than the existing fin.

3 OBJECTIVE OF PROPOSED WORK

3.1 Aim of the work
As in Internal Combustion engines, combustion of fuel takes place inside the engine cylinder and hot gases of very high temperature are generated. The temperature of gases varies between 800 to 1500 °C. This is a very high temperature and can be hazardous for burning of oil film between the moving parts and could be result into seizing or welding of the same. So, for the proper working of IC engine, this temperature must be reduced up to 150 - 200°C at which the engine can work most efficiently.

The main objective of the research is to accomplish the comparative study of fins of different profile made by different aluminium material alloys. The study is carried out based on the finite element analysis. The aim of the work is to determine the optimum material fin based on the various parameters based on the thermal analysis.
3.2 Research Methodology
The finite element analysis is one of the numerical analysis techniques which are used to obtain the solution of partial differential equations. The iterative mathematical procedures such as Galerkin’s weighted residual method and Raleigh-Ritz methods are used to obtain the finite element formulation of the partial differential equation.

3.2.1 Specification of the problem
The objective of the present work is to design and analyze the fin of the 100 cc Hero Honda Engine with the material it is manufactured and also for the aluminium alloy along with different profile of fin. The solid model of the extended surface was created in CATIA V5-R20. Model was imported in ANSYS 14.0 for analysis by applying the operating conditions. The model was tested for different thermal static conditions.

3.2.2 Preprocessing
The solid model is created using the CATIA V5-R20 and thereafter it is imported in ANSYS workbench. The figure 3.1 shows the Solid model of the fin.

- Part Design using CATIA V5-R20

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Engine Type</td>
<td>Single cylinder</td>
</tr>
<tr>
<td>02</td>
<td>Power</td>
<td>100 cc</td>
</tr>
<tr>
<td>03</td>
<td>Bore</td>
<td>50 mm</td>
</tr>
<tr>
<td>04</td>
<td>Stroke Length</td>
<td>49.2 mm</td>
</tr>
<tr>
<td>05</td>
<td>Length of Fin</td>
<td>130 mm</td>
</tr>
<tr>
<td>06</td>
<td>Thickness of Fin</td>
<td>2.5 mm</td>
</tr>
<tr>
<td>07</td>
<td>No. of Fin</td>
<td>08</td>
</tr>
<tr>
<td>08</td>
<td>Thermal Conductivity</td>
<td>120 W/m·K</td>
</tr>
<tr>
<td>09</td>
<td>Convective heat transfer coefficient</td>
<td>25 W/m²K</td>
</tr>
<tr>
<td>10</td>
<td>Material Used</td>
<td>Aluminium (6061)</td>
</tr>
</tbody>
</table>

Fin Materials

The different fin materials adopted for the thesis analysis are
1. Aluminium Alloy 6061
2. Aluminium Alloy 6026
3. Aluminium Alloy 6066
4. Aluminium Alloy 6063
5. Aluminium Alloy 6070

The different properties and characteristics of different alloys are

1. Aluminium 6061 Alloy
   Aluminium alloy 6061 is one of the most largely used in the 6000 series aluminium alloys. It is a adaptale heat treatable extruded alloy with medium to high strength potential.

2. Aluminium 6026 Alloy
   Aluminium 6026 is a wrought alloy. It has outstanding corrosion resistance and is besy suitable for anodizing so can supply both ornamental and hard anodized finishes. However aluminium 6026 contains little bit tin, which can be the reason for machined parts to become weak and crack when subjected to high stress and high temperature.

3. Aluminium 6066 Alloy
   Aluminium and its Aluminum alloys have good corrosion resistance. They try to lose some of their strength when undergoes to high temperatures. However, their strength can be increased when subjected to subzero temperatures.

4. Aluminium 6063 Alloy
   The fourth material used for the study is Aluminium alloy 6063, which is an aluminium alloy, containing magnesium and silicon as the alloying elements. It has good mechanical properties and is supporting for heat treatment and welding process.
5. Aluminium 6070 Alloy
Aluminium / aluminum alloys are very sensitive to high temperatures. The strength of aluminium alloy 6070 can be increased when they are subjected to subzero temperatures. They have strong corrosion resistance and high ductility.

Table 3.2 Shows the Mechanical Properties of different Aluminium Alloys.

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Aluminium Alloy</th>
<th>6061</th>
<th>6066</th>
<th>6068</th>
<th>6070</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density (g/cm³)</td>
<td>2.7</td>
<td>2.6-2.8</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>2</td>
<td>Modulus of Elasticity (GPa)</td>
<td>70.80</td>
<td>70.80</td>
<td>69</td>
<td>69.5</td>
</tr>
<tr>
<td>3</td>
<td>Poisson Ratio</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>Tensile Strength (MPa)</td>
<td>110-152</td>
<td>150</td>
<td>360</td>
<td>130</td>
</tr>
<tr>
<td>5</td>
<td>Co-efficient of Thermal Expansion (20-100°C) (mm/°C)</td>
<td>23.5x10⁻⁶</td>
<td>23.4x10⁻⁶</td>
<td>23.4x10⁻⁶</td>
<td>23.5x10⁻⁶</td>
</tr>
<tr>
<td>6</td>
<td>Thermal Conductivity (W/m.K)</td>
<td>173</td>
<td>147</td>
<td>138</td>
<td>200</td>
</tr>
<tr>
<td>7</td>
<td>Elongation at Break (%)</td>
<td>14 - 16</td>
<td>1000%</td>
<td>400%</td>
<td>1000%</td>
</tr>
<tr>
<td>8</td>
<td>Melting Point (°C)</td>
<td>500</td>
<td>390</td>
<td>620</td>
<td>600</td>
</tr>
</tbody>
</table>

Table 3.3 Shows the Component Amount (wt.%) of different Aluminium Alloys.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Aluminium Alloy</th>
<th>6061</th>
<th>6066</th>
<th>6026</th>
<th>6063</th>
<th>6070</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Magnesium (Mg)</td>
<td>0.8 - 1.2</td>
<td>1.1</td>
<td>0.60 - 1.20</td>
<td>0.45 - 0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>Silicon (Si)</td>
<td>0.4 - 0.8</td>
<td>1.4</td>
<td>0.60 - 1.40</td>
<td>0.20 - 0.60</td>
<td>1.4</td>
</tr>
<tr>
<td>3</td>
<td>Iron (Fe)</td>
<td>Max. 0.7</td>
<td>0.0 - 0.70</td>
<td>0.0 - 0.70</td>
<td>0.0 - 0.35</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Copper (Cu)</td>
<td>0.13 - 0.40</td>
<td>1</td>
<td>0.20 - 0.50</td>
<td>0.0 - 0.1</td>
<td>0.20</td>
</tr>
<tr>
<td>5</td>
<td>Zinc (Zn)</td>
<td>Max. 0.25</td>
<td>0.0 - 0.30</td>
<td>0.0 - 0.30</td>
<td>0.0 - 0.1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Titanium (Ti)</td>
<td>Max. 0.15</td>
<td>0.0 - 0.20</td>
<td>0.0 - 0.20</td>
<td>0.0 - 0.1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Manganese (Mn)</td>
<td>Max. 0.15</td>
<td>0.0</td>
<td>0.20 - 1.00</td>
<td>0.0 - 0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>8</td>
<td>Chromium (Cr)</td>
<td>0.04 - 0.35</td>
<td>0.0 - 0.30</td>
<td>0.0 - 0.30</td>
<td>0.0 - 0.1</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Others</td>
<td>0.05</td>
<td>0.15</td>
<td>0.01</td>
<td>0.0 - 0.03</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Aluminium (Al)</td>
<td>Balance</td>
<td>Balance</td>
<td>Balance</td>
<td>Balance</td>
<td>Balance</td>
</tr>
</tbody>
</table>

DISCRETIZATION PROCESS (MESHING)
Structured meshing method done in ANSYS 14.0 Workbench was used for meshing the geometry. 64112 nodes and 33925 elements were created. The mesh model is shown in figure 3.2.

Figure 3.3 Mesh Model

4 RESULT & DISCUSSION
The analysis is done on different materials for a single part design. Thus the chapter is broadly divided into five parts in which results obtained from each part are discussed separately.

4.1 Transient Thermal Analysis of Aluminium Alloy 6061
The Transient thermal analysis determines temperatures and other thermal quantities that vary over time. For the transient thermal analysis following parameters have been determined:

1. Temperature Distribution:
From these parameters the anisotropic property of the material defined, the distribution of the temperature must be uniform so that less chances of thermal stresses.

Figure 4.1 the Temperature Distribution for Alloy 6061

2. Directional Heat flux: These parameters give information regarding, the amount of heat dissipated along the major axis (X-axis) from unit cross-sectional area of fins surface.
3. **Total Heat Flux:** These parameters give us information regarding the amount of heat dissipated from unit cross-sectional area of fins surface. Figure 4.3 shows the results for Total heat flux in the case of 6061 alloy. The maximum value achieved for directional heat flux is about $1.4192 \times 10^5$ W/m$^2$.

4. **4.2 Transient Thermal Analysis of Aluminium Alloy 6026**

   All the three parameters for transient analysis are shown in figures 4.4-4.6.
The total heat flux achieved the maximum value of $1.345 \times 10^5$ W/m$^2$.

### 4.3 Transient Thermal Analysis of Aluminium Alloy 6066

All the three parameters for transient analysis are shown in figures 4.7-4.9.

![Figure 4.7 Temperature Distribution for alloy 6066](image)

The maximum temperature is reached up to 284.85°C and the minimum value is about 215.07°C.

![Figure 4.8 Directional heat fluxes for alloy 6066](image)

The maximum value obtained for directional heat flux is about $1.228 \times 10^5$ W/m$^2$. While the minimum value is about $-1.2629 \times 10^5$ W/m$^2$.

### 4.4 Transient Thermal Analysis of Aluminium Alloy 6063

All the three parameters for transient analysis are shown in figures 4.10-4.12.

![Figure 4.9 Total heat fluxes for alloy 6066](image)

The total heat flux achieved the maximum value of $1.367 \times 10^5$ W/m$^2$.

![Figure 4.10 Temperature Distribution for alloy 6063](image)

The maximum temperature is reached up to 284.85°C and the minimum value is about 230.04°C.
Figure 4.11 Directional heat fluxes for alloy 6063

The maximum value obtained for directional heat flux is about 1.314×10^5 W/m^2. While the minimum value is about -1.352×10^5 W/m^2.

Figure 4.12 Total heat fluxes for alloy 6063

The total heat flux achieved the maximum value of 1.461×10^5 W/m^2.

Figure 4.13 Temperature Distribution for alloy 6070

The maximum temperature is reached up to 284.85°C and the minimum value is about 223.87°C.

Figure 4.14 Directional heat fluxes for alloy 6070

The maximum value obtained for directional heat flux is about 1.279×10^5 W/m^2. While the minimum value is about -1.315×10^5 W/m^2.

Figure 4.15 Temperature Distribution for alloy 6070

The maximum temperature is reached up to 284.85°C and the minimum value is about 223.87°C.

4.5 Transient Thermal Analysis of Aluminium Alloy 6070

All the three parameters for transient analysis are shown in figures 4.13-4.15.
The total heat flux achieved the maximum value of $1.4228 \times 10^5\text{W/m}^2$.

Some Important Tables for Comparisons are:

The various results are obtained during the analysis are tabulated.

**Table 4.1 Temperature Profile**

<table>
<thead>
<tr>
<th>Time in Sec</th>
<th>Al Alloy 6026</th>
<th>Al Alloy 6061</th>
<th>Al Alloy 6066</th>
<th>Al Alloy 6063</th>
<th>Al Alloy 6070</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>204.05</td>
<td>176.06</td>
<td>178.27</td>
<td>204.05</td>
<td>209.43</td>
</tr>
<tr>
<td>2</td>
<td>279.62</td>
<td>205.48</td>
<td>204.05</td>
<td>204.05</td>
<td>204.05</td>
</tr>
<tr>
<td>3</td>
<td>274.4</td>
<td>274.88</td>
<td>273.11</td>
<td>276.14</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>273.11</td>
<td>276.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>263.94</td>
<td>264.91</td>
<td>269.19</td>
<td>267.43</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>258.72</td>
<td>259.93</td>
<td>265.28</td>
<td>263.07</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>253.49</td>
<td>254.95</td>
<td>261.36</td>
<td>258.72</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>248.20</td>
<td>249.90</td>
<td>257.42</td>
<td>254.30</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>243.04</td>
<td>244.98</td>
<td>253.53</td>
<td>250.01</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>217.01</td>
<td>239.99</td>
<td>249.62</td>
<td>245.65</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>232.58</td>
<td>235.01</td>
<td>245.7</td>
<td>241.2</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>227.36</td>
<td>230.03</td>
<td>241.79</td>
<td>236.94</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>222.13</td>
<td>225.04</td>
<td>237.87</td>
<td>232.58</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>216.69</td>
<td>223.52</td>
<td>230.06</td>
<td>228.23</td>
<td></td>
</tr>
</tbody>
</table>

Compared to 6061: 5.2123 / 2.3643 / 2.0488 / 1.9472 / 1.9472

The various results are obtained during the analysis are tabulated in Table 4.5.

**Table 4.5 Comparison of results for different alloys**

<table>
<thead>
<tr>
<th>Material</th>
<th>Directional Heat Flux (W/m²)</th>
<th>Temperature (°C)</th>
<th>Total Heat Flux (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Aluminium Alloy 6051</td>
<td>1.275 × 10⁵</td>
<td>-1.317 × 10⁵</td>
<td>204.05</td>
</tr>
<tr>
<td>Aluminium Alloy 6026</td>
<td>1.209 × 10⁵</td>
<td>-1.242 × 10⁵</td>
<td>204.05</td>
</tr>
<tr>
<td>Aluminium Alloy 6063</td>
<td>1.314 × 10⁵</td>
<td>-1.352 × 10⁵</td>
<td>204.05</td>
</tr>
<tr>
<td>Aluminium Alloy 6066</td>
<td>1.228 × 10⁵</td>
<td>-1.262 × 10⁵</td>
<td>204.05</td>
</tr>
<tr>
<td>Aluminium Alloy 6070</td>
<td>1.279 × 10⁵</td>
<td>-1.311 × 10⁵</td>
<td>204.05</td>
</tr>
</tbody>
</table>

From the table 4.1 after comparing the results following observations can be concluded:

**CONCLUSION**

In this dissertation work we have designed a cylinder fin body used in a 100cc Hero Honda Motorcycle and modeled in parametric 3D modeling software CATIA V5. The Aluminium alloy 204 is the material for fin body which is presently adopted. In this dissertation work the existing material is replaced with five different Aluminium alloys i.e. 6061, 6026, 6066, 6063 and 6070. The profile of the fin is circular and it is adopted for all the materials adopted.

The thermal analysis of the fin is done by varying the three important heat transfer parameters i.e. Directional and total heat flux and the temperature difference.

According to the results obtained in terms of heat flux analysis alloy 6063 is most optimum but results are not significant for the term temperature difference. The higher temperature difference is obtained in the case of aluminium alloy 6026. It increases heat transfer upto 5.21% from alloy 6061.

**References**

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