Abstract—This paper describes the stress distribution of two different aluminium alloys piston by using CAE Tools. The specifications used for the study of these pistons belong to four stroke single cylinder engine of Bajaj Pulsar 150cc motorcycle. This paper illustrates the procedure for analytical design of two different aluminium alloy pistons. The results predict the maximum stress and critical region on the different aluminium alloy pistons using CAE Tools. It is important to locate the critical area of concentrated stress for appropriate modifications.

A parametric model of Piston is modeled using PTC Creo Parametric 2.0 software and analysis of that model is carried out by using ANSYS 14.5 Software. The best aluminum alloy material is selected based on parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two wheeler piston were done in ANSYS 14.5 software.

I. INTRODUCTION

A piston is a component of reciprocating IC-engines. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. As an important part in an engine, piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston, such as piston side wear, piston head/crown cracks and so on. The investigations indicate that the greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure.

In designing a piston for an engine, the following points should be taken into consideration:

- It should have enormous strength to withstand the high pressure.
- It should have minimum weight to withstand the inertia forces.
- It should form effective oil sealing in the cylinder.
- It should provide sufficient bearing area to prevent undue wear.
- It should have high speed reciprocation without noise.
- It should be of sufficient rigid construction to withstand mechanical distortions.
- It should have sufficient support for the piston pin.

A. ENGINE SPECIFICATIONS

The engine used for this work is a single cylinder four stroke air cooled type Bajaj Pulsar 150cc petrol engine. The engine specifications are given in Table 1.1

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Type</td>
<td>Four stroke, Petrol engine</td>
</tr>
<tr>
<td>Induction</td>
<td>Air cooled type</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>Single cylinder</td>
</tr>
<tr>
<td>Bore</td>
<td>57 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>56.4 mm</td>
</tr>
<tr>
<td>Length of connecting rod</td>
<td>112.8 mm</td>
</tr>
<tr>
<td>Displacement volume</td>
<td>143.91 cm3</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>9.5 +/-0.5 : 1</td>
</tr>
<tr>
<td>Maximum power</td>
<td>9.57 KW at 8500 rpm</td>
</tr>
<tr>
<td>Maximum Torque</td>
<td>11.68 Nm at 6500 rpm</td>
</tr>
<tr>
<td>Number of revolutions/cycle</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1.1 Engine Specifications.

B. PROPERTIES OF MATERIALS

The materials chosen for this work are A2618 and Al-GHY1250 for an internal combustion engine piston. The mechanical properties of A2618 and Al-GHY1250 aluminum alloys are listed in the following table 1.2

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>PARAMETERS</th>
<th>A2618</th>
<th>Al-GHY1250</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Young’s Modulus (GPa)</td>
<td>73.7</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>Ultimate Tensile Strength (MPa)</td>
<td>480</td>
<td>1250</td>
</tr>
<tr>
<td>3</td>
<td>Possion’s Ratio</td>
<td>0.33</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>Density(Kg/m³)</td>
<td>2767.99</td>
<td>2880</td>
</tr>
</tbody>
</table>

Table 1.2 Mechanical Properties.
Creation of 3D models of piston using PTC Creo Parametric 2.0 and then imported in ANSYS 14.5
- Mesh of 3D models using ANSYS 14.5
- Analysis of pistons using static stress analysis method.
- Comparative performance of two aluminium alloy pistons under static stress analysis method.
- Select the best aluminium alloy.

### III. ANALYTICAL DESIGN

Let,
- \( IP \) = indicated power produced inside the cylinder (W)
- \( \eta \) = mechanical efficiency = 0.8
- \( n \) = number of working stroke per minute = \( \frac{N}{2} \) (for four stroke engine)
- \( N \) = engine speed (rpm)
- \( L \) = length of stroke (mm)
- \( A \) = cross-section area of cylinder (mm\(^2\))
- \( r \) = crank radius (mm)
- \( l_c \) = length of connecting rod (mm)
- \( a \) = acceleration of the reciprocating part (m/s\(^2\))
- \( m_p \) = mass of the piston (kg)
- \( V \) = volume of the piston (mm\(^3\))
- \( t_h \) = thickness of piston head (mm)
- \( D \) = cylinder bore (mm)
- \( P_{max} \) = maximum gas pressure or explosion pressure (MPa)
- \( \sigma_t \) = allowable tensile strength (MPa)
- \( \sigma_{ult} \) = ultimate tensile strength (MPa)
- F.O.S = Factor of Safety = 2.25
- \( K \) = thermal conductivity (W/m K)
- \( T_c \) = temperature at the centre of the piston head (K)
- \( T_e \) = temperature at the edge of the piston head (K)
- HCV = Higher Calorific Value of fuel (kJ/Kg) = 47000 kJ/kg
- \( B.P. \) = brake power of the engine per cylinder (kW)
- \( m \) = mass of fuel used per brake power per second (kg/kW s)
- \( C \) = ratio of heat absorbed by the piston to the total heat developed in the cylinder = 5\% or 0.05
- \( b \) = radial width of ring (mm)
- \( Pw \) = allowable radial pressure on cylinder wall (N/mm\(^2\)) = 0.025 MPa
- \( \sigma_p \) = permissible tensile strength for ring material (N/mm\(^2\)) = 110 N/mm\(^2\)
- \( h \) = axial thickness of piston ring (mm)
- \( h_1 \) = width of top lands (mm)
- \( h_2 \) = width of ring lands (mm)
- \( t_1 \) = thickness of piston barrel at the top end (mm)
- \( t_2 \) = thickness of piston barrel at the open end (mm)
- \( l_s \) = length of skirt (mm)
- \( \mu \) = coefficient of friction (0.01)
- \( l_1 \) = length of piston pin in the bush of the small end of the connecting rod (mm)
- \( d_o \) = outer diameter of piston pin (mm)

#### Mechanical efficiency of the engine (\( \eta \)) = 80 %.
\[
\eta = \frac{\text{Brake Power} (B.P.)}{\text{Indicated Power} (I.P.)}
\]
\[
B.P. = \frac{2nNT}{60} = \frac{2\times 11.6 \times 6500}{60} = 7.950 \text{ kW}
\]
\[
I.P = \frac{BP}{\eta} = \frac{7.95}{0.8} = 9.94 \text{ kW}
\]
\[
I.P = P \times A \times L \times \frac{N}{2}
\]
\[
I.P = P \times \frac{\pi}{4} \times D^2 \times L \times \frac{N}{2}
\]
\[
9.94 \times 1000 = P \times \frac{\pi}{4} \times (0.051)^2 \times (0.0564) \times x
\]
\[
\text{So, } P = 12.75 \times 10^5 \text{ N/m}^2 \text{ or } P = 1.275 \text{ MPa}
\]

#### B. ANALYTICAL DESIGN FOR A2618 ALLOY PISTON.

Analytical design for A2618 alloy piston is as follows:
- Thickness of the Piston Head: \( t_h = 6.03 \text{ mm} \)
- Piston Rings: \( b = 1.488 \text{ mm and } h = 1.04 \text{ mm} \)
- Width of Top Land: \( h_1 = 6.03 \text{ mm} \)
- Ring Lands: \( h_2 = 0.78 \text{ mm} \)
- Thickness of piston barrel at the Top end: \( t_1 = 8.098 \text{ mm} \)
- Open end: \( t_2 = 2.02 \text{ mm} \)
- Length of the skirt: \( l_s = 34.2 \text{ mm} \)
- Length of piston pin in the connecting rod bushing: \( l_1 = 25.65 \text{ mm} \)
- Piston pin diameter: \( d_o = 15.96 \text{ mm} \)
- The centre of piston pin should be 0.02D to 0.04D above the centre of skirt.

#### C. ANALYTICAL DESIGN FOR AL-GHY1250 ALLOY PISTON.

Analytical design for Al-GHY1250 alloy piston is as follows:
- Thickness of the Piston Head: \( t_h = 3.739 \text{ mm} \)
- Piston Rings: \( b = 1.488 \text{ mm and } h = 1.0418 \text{ mm} \)
- Width of Top Land: \( h_1 = 3.7391 \text{ mm} \)
- Ring Lands: \( h_2 = 0.7813 \text{ mm} \)
- Thickness of piston barrel at the Top end: \( t_1 = 7.651 \text{ mm} \)
- Open end: \( t_2 = 1.912 \text{ mm} \)
- Length of the skirt: \( l_s = 34.2 \text{ mm} \)
- Length of piston pin in the connecting rod bushing: \( l_1 = 25.65 \text{ mm} \)
- Piston pin diameter: \( d_o = 15.96 \text{ mm} \)
- The centre of piston pin should be 0.02D to 0.04D above the centre of skirt.

### IV. RESULT AND DISCUSSION

#### A. A2618 alloy piston
The value of different parameter for both materials are given in table 1.3.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>PARAMETERS</th>
<th>A2618</th>
<th>Al-GHY1250</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Von-Misses Stress</td>
<td>159.9 MPa</td>
<td>362 MPa</td>
</tr>
<tr>
<td>2</td>
<td>Total Deformation</td>
<td>0.1539 mm</td>
<td>0.21832 mm</td>
</tr>
<tr>
<td>3</td>
<td>Mass</td>
<td>0.1841 kg</td>
<td>0.136 kg</td>
</tr>
<tr>
<td>4</td>
<td>Safety Factor</td>
<td>3</td>
<td>3.45</td>
</tr>
</tbody>
</table>

Table 1.3 Result After Analysis

CONCLUSION

Following conclusion can be drawn from above analysis
- About 26% mass reduction is possible with Al-GHY1250 Alloy.
- Safety factor increased by 15% at same working condition.

From above results we can conclude that Al-GHY1250 alloy piston is better than conventional alloy piston.

REFERENCES
