INFLUENCE OF CERAMIC COATING ON PISTON SURFACE IN I.C ENGINE

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ABSTRACT
Aim of this work is to improve the structural analysis coated with ceramic layer on surface of the piston. Generally cast steel material is used for piston in I C engines; it can be withstanding the structural and thermal analysis, and producing the power from the combustion. In this work the ceramic material like zirconium and silicon coating is applied on the surface of piston with 0.4 mm thickness in order to get better results and testing the piston using ansys software analyze the structural analysis. The results obtained in this work were deformation, stress, strain and safety factor, the obtained results were comparable with the steel material. 

Keywords: Piston, Ceramic Coating, Ansys, Structural analysis.

I. INTRODUCTION
Now days, internal combustion engines are used in most of the automobiles and mechanical machineries. The piston is a part without which no internal combustion engine can work i.e., piston plays a vital role in almost all types of vehicles [1]. The main function of the piston of an IC engine is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod [2]. The piston must also disperse a large amount of heat from the combustion chamber to the cylinder walls. Cast iron, Aluminium Alloy and Cast Steel etc. are the common materials used for piston of an Internal Combustion Engine and to compare behaviour of the piston made of different type of materials under thermal load [3]. The new composite material was primarily considered due to low hysteresis of the coefficient of thermal expansion for heating and cooling [4]. The piston skirt is the main area of the piston at which the deformation may appear while at work, which usually causes crack on the upper end of piston head. Due to this deformation, the greatest stress concentration is caused on the upper end of piston [5]. The existing piston is redesigned using Pro-E software and analyzed by ansys software. The coating of ceramic (magnesium oxide (MgO) and zirconium oxide (ZiO)) over existing aluminum alloy piston is done and behaviour is analyzed to improve the performance of the given engine [6]. The finite element results show that steel piston is showing maximum surface temperature than AlSi alloy piston for selected boundary conditions and coatings. It is due to lower thermal conductivity of steel material than AlSi material. It is also observed from the results the surface temperature in uncoated piston is less than coated piston [7]. The maximum surface temperature of the coated piston with material which has low thermal conductivity has improved approximately by 14%. Because of reduced heat losses, efficiency will improve. According to the experimental results, brake thermal efficiency and indicated thermal efficiency have improved by 5.89% and
11.14% respectively [8]. The numerical simulations clearly show that temperature and thermal stress distribution are a function of coating thickness [9]. The maximum von mises stress in the piston crown is reduced with increase in bond coating thickness [10].

II. DESIGN PARAMETERS

In this work, we have design one piston model by using CAD tool (CATIA) and then imported into CAE tool (ANSYS). We selected steel and additives to the steel material. To change the design of the piston by adding additive like SiO$_2$ and ZrO$_2$ 0.4 mm thickness ceramic layer on the top surface of piston and applied 6 MPa pressure and analyzed the results using ANSYS.

![Fig.1. Dimensions of reference piston](image1)

![Fig.2. 3D model of piston](image2)

### Table.1. Properties of Steel Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s modulus (Pa)</th>
<th>Poisson ratio</th>
<th>Density (Kg/m$^3$)</th>
<th>Yield strength (MPa)</th>
<th>Conductivity (W/m.k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>2.0 x 10$^{11}$</td>
<td>0.3</td>
<td>7850</td>
<td>250</td>
<td>60.5</td>
</tr>
<tr>
<td>Zirconia(ZrO$_2$)</td>
<td>94.5 x 10$^9$</td>
<td>0.33</td>
<td>6530</td>
<td>280</td>
<td>2</td>
</tr>
<tr>
<td>Silica(SiO$_2$)</td>
<td>74.8 x 10$^9$</td>
<td>0.19</td>
<td>2650</td>
<td>155</td>
<td>1.5</td>
</tr>
</tbody>
</table>

III. STRUCTURAL ANALYSIS

ANSYS is the standard finite element analysis (FEA) software tool. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solve them all, this type of analysis is typically used for analyze the structural analysis as follows.
Fig. 3. Finite element Analysis

Fig. 4. Fixed supports on piston

Fig. 5. Structural analysis of Steel Material
Fig. 6. Structural Analysis of Steel coated with SiO₂
IV. RESULTS AND CONCLUSION

Using ANSYS software the structural analysis has been carried out as shown in table below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Deformation (mm)</th>
<th>Stress (MPa)</th>
<th>Strain</th>
<th>Safety factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>0.11397</td>
<td>199.06</td>
<td>0.0011518</td>
<td>1.4065</td>
</tr>
<tr>
<td>Steel-SiO₂</td>
<td>0.11853</td>
<td>196.97</td>
<td>0.0010904</td>
<td>1.4842</td>
</tr>
<tr>
<td>Steel-ZrO₂</td>
<td>0.11617</td>
<td>195.02</td>
<td>0.0055075</td>
<td>1.5056</td>
</tr>
</tbody>
</table>

Table 2. Structural Analysis of steel and its alloy

From the above table the analyses like deformation, stress and strain are nearly closer to the steel and safety factor is higher than the steel.
From the above graph it is observed that the stress factor of SiO₂ and ZrO₂ are lower than the Steel. Deformation, Strain and safety factor of SiO₂ and ZrO₂ values are nearly closer to the steel value.

V. CONCLUSIONS

- In this work a 3D model Piston has been designed, developed and analyzed by adding additives.
- In static conditions when we applied 6Mpa pressure, on existing piston (steel) produced 199.06MPa by changing design and by adding SiO₂ and ZrO₂ coating and reduced to 195.02Mpa.
- 4Mpa stress has been reduced by coating with SiO₂ and ZrO₂ 0.4 mm thick layer on surface of piston.
- Finally we conclude that the Steel with SiO₂ and ZrO₂ ceramic coated piston will satisfy the static conditions and it increases the piston efficiency.

REFERENCES


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