Design and Optimization of Composite Connecting Rod using Finite Element Analysis

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Abstract: Connecting rod is a component that every engine and for that matter every compressor need. This work represents by taking different material for connecting rod load carrying capacity where analysed. In this work for connecting rod is analysed by using three different material such as AISI4340 steel alloy, AISI7068 and Titanium alloy. Results of axial load carrying capacity and weight reduction of connecting rod of material AISI4340 and Titanium alloy is compared.

Keywords: Connecting rod, Piston pin end, Crank pin end, FEA

1. Introduction

The automobile engine connecting rod is a high volume production, critical component. It connects reciprocating piston to rotating crankshaft, transmitting the thrust of the piston to the crankshaft. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine.

Connecting rod is integral component of internal combustion engine, it acts as a linkage between piston and crankshaft. Connecting rod has three main zones. The piston pin end, the central shank and the big end. The piston pin end is the small end, the crank end is the big end and the central shank is of I-cross section. Connecting rod is a pin jointed strut in which more weight is concentrated towards the big end. In that point of view the location of the CG point of connecting rod lies more towards the big end. This connecting rod are most made of steel for production engines, but can be made of Aluminum (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron.

Automobile industry always require cost efficient and high quality product. This gives us an opportunity to study design methodology so as to improve and provide industrial requirement. The time spend in trial and error analysis in the design process need to be eliminated in order to sustain in this fast moving market. Therefore, computational method have been used in early stage of the design. Finite element method is applied during modal analysis of connecting rod. Modal analysis is the process of determining the inherent dynamic characteristics of a system in form of natural frequencies, damping factors and mode shapes, and using them to formulate a mathematical model for its dynamic behaviour. Hence, mesh determination is too critical in order to ensure that the best mesh size is to be use in carry out the analysis for other parameter involves. As stability and convergence of various mesh processing applications depend on mesh quality, there is frequently a need to improve the quality of the mesh.

2. FEA with ANSYS 14.5

A stress analysis is performed using finite element analysis (FEA). The complete procedure of analysis has been done using ANSYS Workbench. The design connecting rod is modeled in Catia Software.

Automotive should be light in weight, consume less fuel and at the same time they should provide comfort and safety to passengers, which unfortunately leads to increase in weight of the vehicle. This tendency in vehicle construction led the invention and implementation of quite new materials which are light and meet design requirements. Lighter connecting rods help to decrease lead caused by forces of inertia in engine as it does not require big balancing weight on crankshaft. Application of metal matrix composite enables safety increase and advances that leads to effective use of fuel and to obtain high engine power.

3. Model of Connecting Rod
4. Results and Discussions

4.1 Finite element analysis of AISI 4340 Steel alloy material.

Material Properties of AISI 4340 Steel alloy

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>7.85 g/cm³</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>745 mpa</td>
</tr>
<tr>
<td>Yield strength</td>
<td>470 mpa</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.27</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>210 GPa</td>
</tr>
</tbody>
</table>

Calculation of Maximum Axial Load Limit

Calculation of maximum axial load limit of AISI 4340 Alloy steel material use factor of safety as 2.5 and material strength 470 mpa.

Factor of safety=Material strength/Design load

\[ \text{Factor of safety} = \frac{470}{\text{Design load}} \]

Design load=\( \frac{470}{2.5} \)

Design load=188 mpa.

1. Load applied at crank end in tension and piston pin end is constrained. 
Von mises stress

2. Load applied at crank end in compression and piston pin end is constrained. 
Von mises stress

3. Load applied at Piston pin in tension and crank pin end is constrained. 
Von mises stress

4. Load applied at Piston pin in compression and crank pin end is constrained. 
Von mises stress

4.2 Finite element analysis of Al 7068 aluminum alloy material.

Material Properties of AISI 4340 Steel alloy

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>2.85 g/cm³</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>641 mpa</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>590 mpa</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>211 GPa</td>
</tr>
<tr>
<td>Poissons Ratio</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Calculation of maximum axial load limit.

Calculation of maximum axial load limit for material AI7068 use actor of safety 2.5 and material strength 590 mpa

Factor of safety=Material strength/Design load

2.5=590/Design load

Design load=590/2.5

Design load=236mpa

1. Load applied at crank end in tension and piston pin end is constrained

Von mises stress

![Figure 6](image)

**Figure 6:** Von mises stress distribution with tensile load at crank end and piston pin end is restrained

2. Load applied at crank end in compression and piston pin end is constrained

Von mises stress

![Figure 7](image)

**Figure 7:** Von mises stress distribution with compressive load at crank end and piston pin end is restrained

3. Load applied at Piston pin end in tension and crank end is constrained

Von mises stress

![Figure 8](image)

**Figure 8:** Von mises stress distribution with tensile load at piston pin and crank pin end is restrained

4. Load applied at Piston pin end in compression and crank end is constrained

Von mises Stress

![Figure 9](image)

**Figure 9:** Von mises stress distribution with compressive load at piston pin end and crank pin end is restrained

4.3 Finite element analysis of Titanium alloy.

In the analysis of connecting rod with material AI7068, where maximum stress is occurred in this part property of Titanium is used.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>4.43 g/cm³</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>590 mpa</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>930 mpa</td>
</tr>
<tr>
<td>Poissons Ratio</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Calculation of maximum axial load limit.

Calculation of maximum axial load limit Titanium alloy use factor of safety 2.5 and material strength 930 mpa

Design load=370mpa

1. Load applied at crank end in tension and piston pin end is constrained.

Von mises Stress

![Figure 10](image)

**Figure 10:** Von mises stress distribution with tensile load at crank end and piston pin end is restrained

2. Load applied at crank end in compression and piston pin end is constrained.

Von mises Stress
3. Load applied at Piston pin end in tension and crank end is constrained.

Von mises stress

4. Load applied at Piston pin end in compression and crank end is constrained.

Von mises stress

5. Calculation

1. Weight of AISI4340 Steel = Volume x Density
   = 0.85380 x 10^-4 x 7850
   = 0.670233 Kg

2. Weight of Aluminum 7068 Alloy = Volume x Density
   = 0.85380 x 10^-4 x 2850
   = 0.24333 Kg

3. Weight of Titanium alloy
   Weight of aluminum part of connecting rod
   = Volume x Density
   = 0.27872 x 10^-4 x 2850
   = 0.0794352 Kg
   Weight of Titanium alloy part of connecting rod
   = Volume x Density
   = 0.57514 x 10^-4 x 4430
   = 0.25471 Kg
   Total weight = 0.794352 + 0.2591 = 0.3342222
   Reduction in weight in Titanium alloy vs Alloy Steel = 0.336011 Kg

4. For axial loading at Crank End and piston pin end.
   4.1 Max equivalent stresses for AISI4340 Steel = 183.49 mpa
   4.2 Max equivalent stress for Aluminum 7068 Alloy = 231.89 mpa
   4.3 Max equivalent stress for Titanium alloy = 358.58 mpa

6. Conclusion

By checking and comparing the results of materials in finalizing the results are shown in below:

1) ANSYS Equivalent stress for the Titanium alloy is greater than the AISI4340 alloy steel.
2) The weight of the Titanium alloy material is less than the existing AISI 4340 alloy steel material.
3) When compared to both of the materials, Titanium alloy have more load carrying capacity than AISI4340 alloy steel also with reduced weight.

References

[5] Moon Kyu Lee a, Hyungyil Lee a,* Tae Soo Lee a, Hoon Jang b