Design and Optimization of Composite Connecting Rod using Finite Element Analysis

Manoj Subhash Patil[1], N. K. Chhapkhane[2]

[1, 2]Department of Mechanical Engineering, Rajarambapu Institute of Technology, Sakharale 415414, India

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.

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.

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.

Loading conditions are assumed to be static cases were analyzed. The load applied at the crank end and restrained at the piston pin end in tensile and compression in nature and restrained at the crank end and load applied in tension and compression in nature. The maximum axial force in the connecting rod is taken by using factor of safety and material yield point.

Factor of safety=Material Strength/Design load

Therefore by using factor of safety and Material strength calculate the maximum axial load. Taking factor of safety as 2.5 and material yield strength by multiple iteration in Ansys the maximum axial load limit is calculated.

3. Model of Connecting Rod

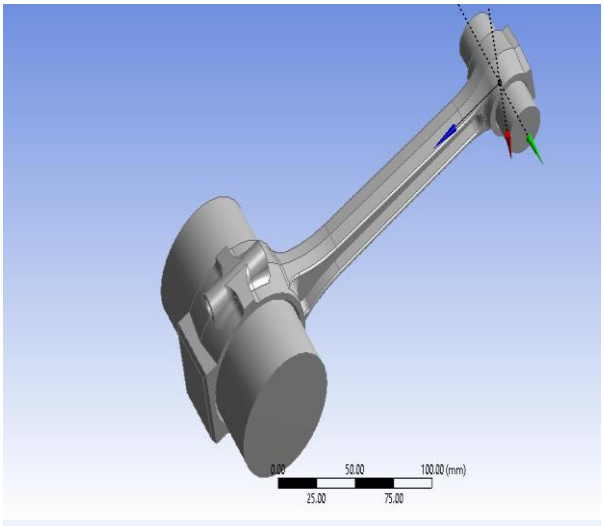

Figure 1: Model of connecting rod

4. Results and Discussions

4.1 Finite element analysis of AISI 4340 Steel alloy material.

Material Properties of AISI 4340 Steel alloy

Density	7.85mg/cm^2
Tensile strength	745 mpa
Yield strength	470 mpa
Poisson's ratio	0.27
Modulus of elasticity	210 gpa

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

2.5=470/Design load

Design load=470/2.5

Design load=188mpa.

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

Von mises stress

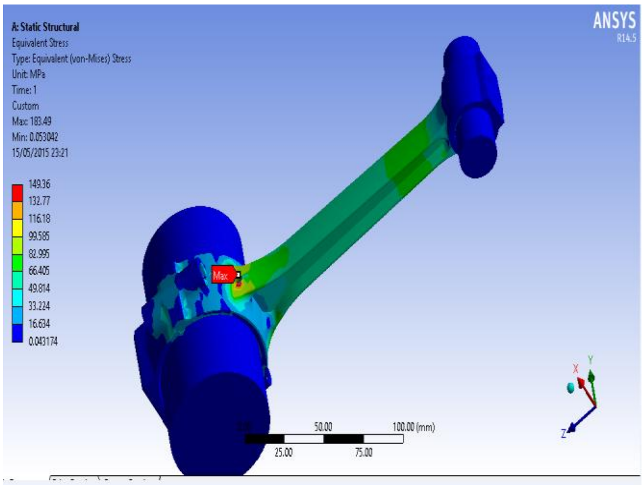

Figure 2: Von mises stress distribution with tensile load at crank end and piston pin end is restrained

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

Von mises stress

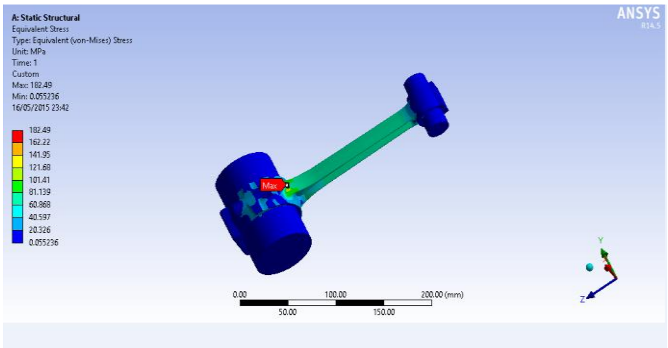

Figure 3: Von mises stress distribution with compressive load at crank end and piston pin end is restrained

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

Von mises stress

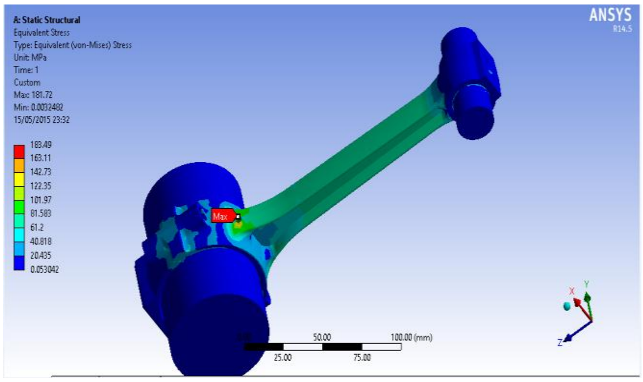

Figure 4: Von mises stress distribution with tensile load at piston pin end and crank pin end is restrained

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

Von mises stress

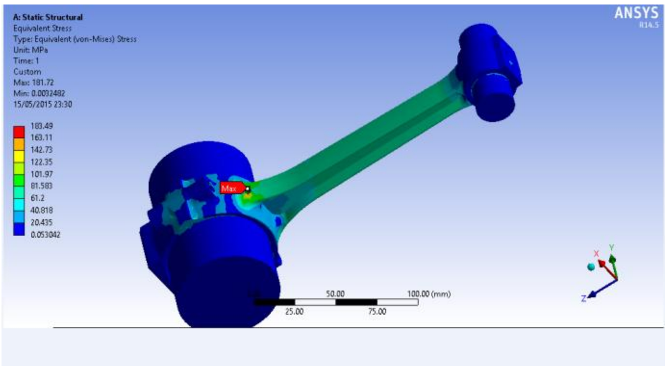

Figure 5: Von mises stress distribution with compressive load at piston pin end and crank pin end is restrained

4.2 Finite element analysis of Al 7068 aluminum alloy material

Material Properties of AISI 4340 Steel alloy

Density	2.85g/cm^2
Tensile Strength	641 mpa
Yield Strength	590 mpa
Modulus of elasticity	211 gpa
Poissons Ratio	0.27

Calculation of maximum axial load limit.

Calculation of maximum axial load limit for material AI 7068 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

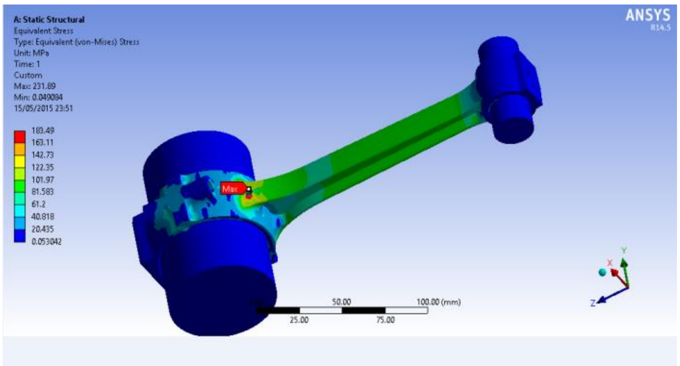

Figure 6: Von mises stress distribution with tensile load at crank end and piston pin end is restrained

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

Von mises stress

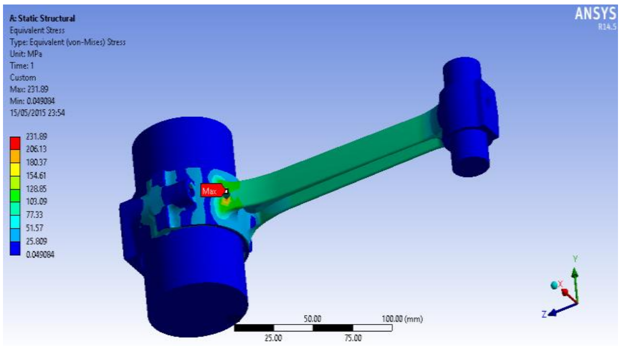

Figure 7: Von mises stress distribution with compressive load at crank end and piston pin end is restrained

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

Von mises stress

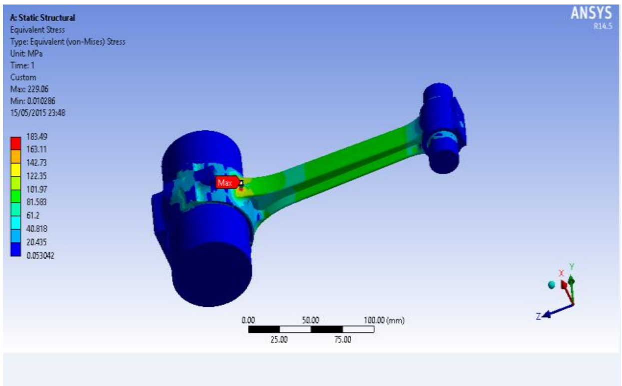

Figure 8: Von mises stress distribution with tensile load at piston pin and crank pin end is restrained

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

Von mises Stress

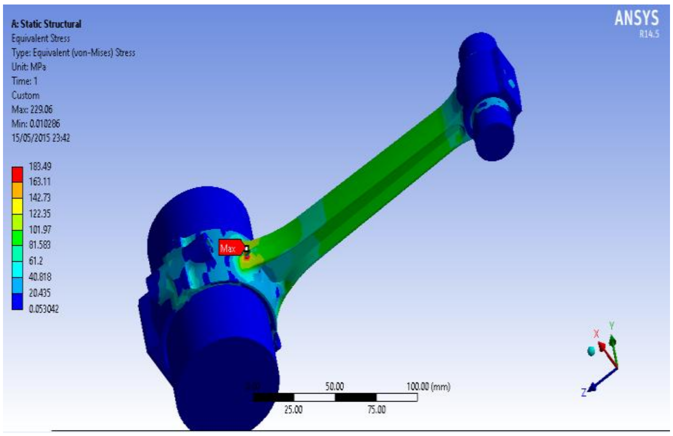

Figure 9: Von mises stress distribution with compressive load at piston pin end and crank pin end is restrained

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.

Density	4.43g/cm^2
Tensile Strength	590 mpa
Yield Strength	930 mpa
Poissons Ratio	0.27

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

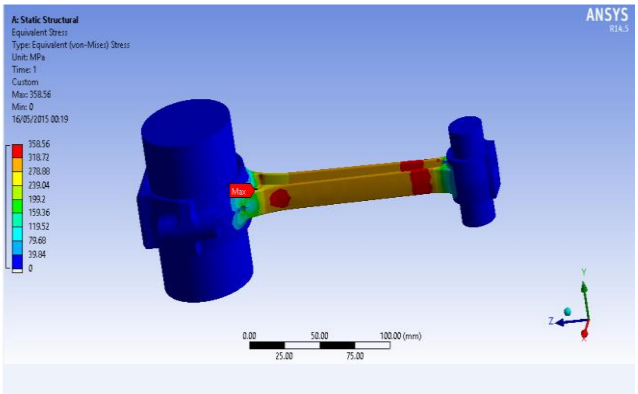

Figure 10: Von mises stress distribution with tensile load at crank end and piston pin end is restrained

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

Von mises stress

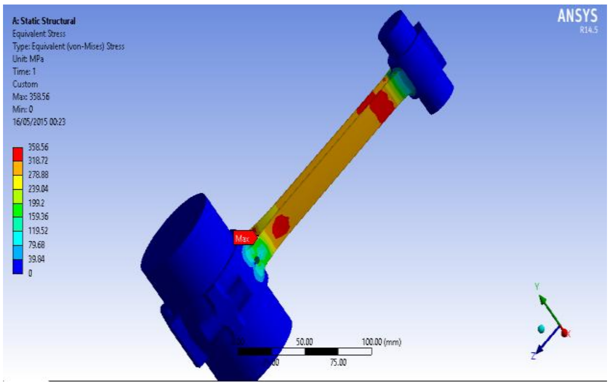

Figure 11: Von mises stress distribution with compressive load at crank end and piston pin end is restrained

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

Von mises stress

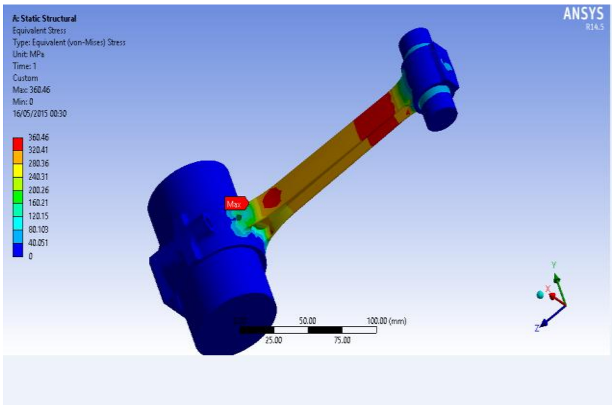

Figure 12: Von mises stress distribution with tensile load at piston pin and crank pin end is restrained

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

Von mises stress

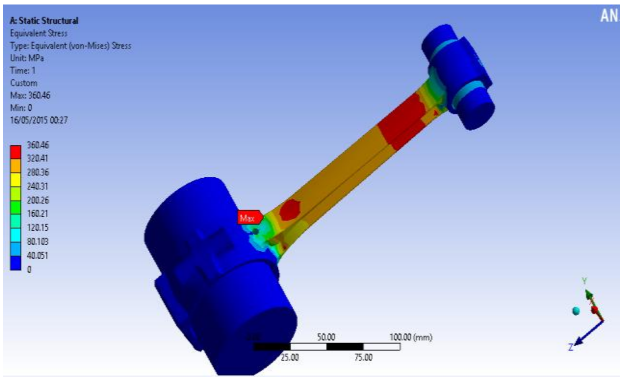

Figure 13: Von mises stress distribution with compressive load at piston pin end and crank pin end is restrained

5. Calculation

1. Weight of AISI4340 Steel =Volume × Density
=0.85380 x 10^{-4} x7850
=0.670233Kg

2. Weight of Aluminum 7068 Alloy=Volume × Density
=0.85380x10^{-4}x2850
=0.24333Kg

3. Weight of Titanium alloy
Weight of aluminum part of connecting rod
= Volume × Density
=0.27872 x 10^{-4} x 2850
=0.0794352Kg
Weight of Titanium alloy part of connecting rod
= Volume × Density
=0.57514 x 10^{-4} x 4430
=0.25471kg
Total weight=0.794352+0.2591=0.33422222
Reduction in weight in Titanium alloy vs Alloy Steel=0.336011kg

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

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.

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