International Journal of Mechanical
Engineering (IJME)
ISSN(P): 2319-2240; ISSN(E): 2319-2259
Vol. 3, Issue 4, July 2014, 9-16
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DESIGN OPTIMISATION AND ANALYSIS OF CONNECTING ROD OF VEHICLE ENGINE USING CAE TOOLS

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ABSTRACT

The main aim of the project is to analyse various stresses and fatigue parameters acting on connecting rod, optimise shape and weight. Connecting rod is an intermediate & important engine component which connects piston & crankshaft. It is subjected to multiple compressive & tensile forces. Major consideration in this case is gas force. The high magnitude gas force is responsible for many kinds of failure. These failures need to be prevented & for this purpose analysis was needed to be done. In this project, connecting rod of Hero Honda splendor is chosen as a model for study whose dimensions data belongs to P. G. Charkha & S. B. Jaju's research paper. This project considers two cases, first, static load stress analysis of the connecting rod, and second, optimisation for weight. In this project analysis is done on four stroke single cylinder petrol engine connecting rod. The model was developed in SOLIDWORKS software, saved in IGES format and then imported to ANSYS workbench. Using ANSYS workbench 11 model was analysed for various stresses by applying suitable boundary conditions & using different modules of ANSYS workbench 11. The Von Misses stresses, shear stresses, elastic strain, total deformation and various fatigue parameters like life, damage, safety factor, biaxiality indication, equivalent alternating stresses, etc. are analysed. Here two materials were studied for their performance, viz., Structural Steel & Aluminum Alloy. Shape and weight optimization was done for both the materials. Aluminum being light in weight and having more yield strength became the suitable material. The results obtained from the stress analysis were used to modify the design of existing connecting rod, so that better performance i.e. reduced inertia, fatigue life and manufacturability can be obtained under varying load conditions.

KEYWORDS: ANSYS Workbench, Connecting Rod, FEA, Optimisation, Static Load, Stress Analysis

1. INTRODUCTION

In this project FEM software has been used to study the strength and distortion characteristics of connecting rod and perform various stress analysis on it. The automobile engine connecting rod is a high volume production critical component. It connects reciprocating piston to rotating crankshaft and transmits the thrust of piston to the crankshaft. And thus, it converts the linear, reciprocating motion of a piston into the rotary motion of a crankshaft. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine. Because of limitation of strength of material there are chances of permanent deformation & hence failure in case of high loads. Combustion in I.C. Engine produces very high load which transmits to crankshaft via connecting rod. So connecting rod is susceptible to many stresses including equivalent, shear, etc. also fatigue failure is possible because of frequent alternate loading & change of direction. Forces acting on the connecting rod

- Forces on the piston due to gas pressure and inertia of the reciprocating parts.
- Force due to inertia of the connecting or inertia bending forces.
- Force due to friction of the piston rings and of the piston, and
- Forces due to friction of the piston pin bearing and crank pin bearing.

2. MODELLING AND ANALYSIS

In this project, the first two forces have been considered. The connecting rod is designed of I-section to provide the highest possible rigidity at the lowest weight. So, firstly a proper Finite Element Model is developed using SolidWorks software. Then using Finite Element Analysis software ANSYS, analysis is done to determine the von misses stresses in the existing connecting rod for the given loading conditions. And then, from the results obtained the load for the optimisation study was selected.

Boundary conditions for connecting rod are chosen such that critical case can be observed and studied. Static load of **4319 N** was considered for both compressive and tensile loading and buckling load of **21598 N** was considered for linear buckling. Cylindrical support was given to crank end and bearing load of 4319 N given to piston pin end for static structural (Figure 2.3) analysis and 21598 N for linear buckling.

2.1 Meshing of Connecting Rod

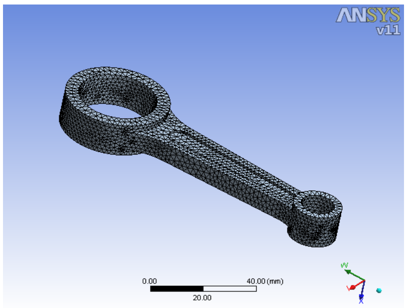


Figure 2.1: Meshed Model of Connecting Rod

2.2 Properties

Table 2.1: Properties of Structural Steel

Material	Structural Steel
Density [Kg/m3]	7850
Young's Modulus [MPa]	2e5
Poisson's Ratio	0.3
Tensile yield strength [MPa]	250
Compressive yield strength [MPa]	250

Table 2.2: Properties of Aluminium Alloy

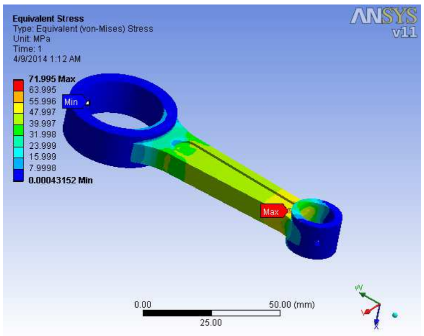
Material	Aluminum Alloy
Density [Kg/m3]	2260
Young's Modulus [MPa]	71000
Poisson's Ratio	0.3
Tensile yield strength [MPa]	280
Compressive yield strength [MPa]	280

3. RESULTS AND DISCUSSIONS

3.1 Figure Shows Results of Structural Steel and Aluminum Alloy after Analysis

- **Equivalent Stress**

Equivalent stresses are minimum at both the ends and moderate at shank.



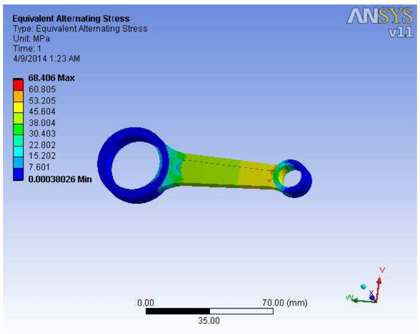
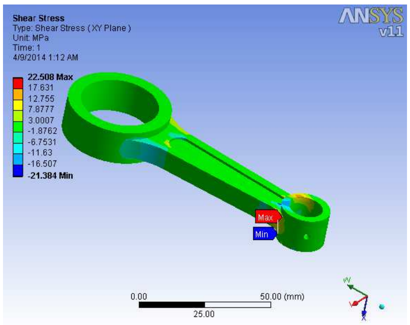


Figure 3.1: (a) Structural Steel **Figure 3.1: (b) Aluminum Alloy**

- **Shear Stress**

In case of conrod shear stresses are minimum. Very less region has shear stress concentrated upon it rest has low shear stress present



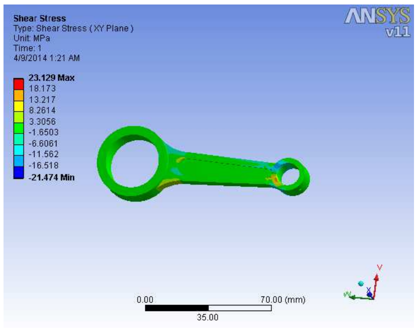
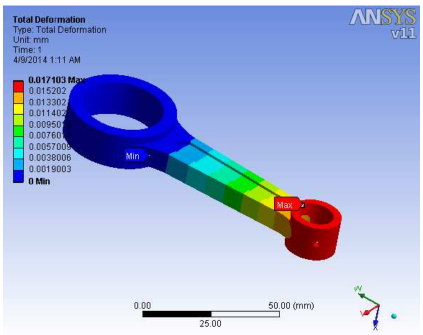


Figure 3.2: (a) Structural Steel **Figure 3.2: (b) Aluminum Alloy**

- **Total Deformation**

It is combined measure of deformation in all directions. It can be seen from Figure 3.3 (a) and Figure 3.3 (b) that deformation goes on increasing from fixed support end to free end.



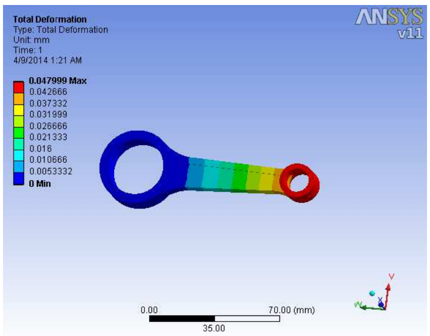


Figure 3.3: (a) Structural Steel **Figure 3.3: (b) Aluminum Alloy**

- **Elastic Strain**

When an exterior stress is applied to a solid body, the body tends to pull itself apart. This induces strain in body. In our case strain is induced due to equivalent elastic stresses so the distribution is same as that of equivalent stress

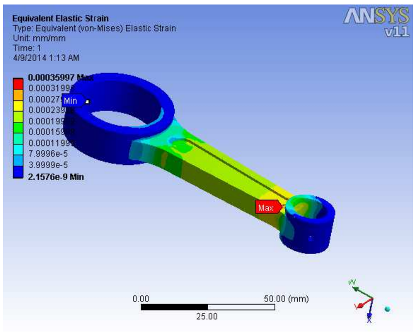


Figure 3.4: (a) Structural Steel

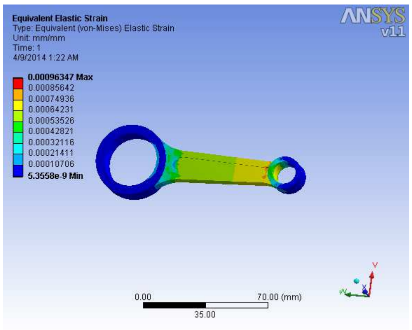


Figure 3.4: (b) Aluminum Alloy

3.2 Fatigue Analysis

- **Life**

It is number of cycles conrod can withstand before any sign of failure occurs.so we have uniform life throughout body of conrod.

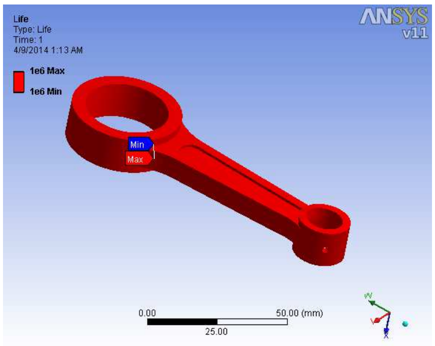


Figure 3.5: (a) Structural Steel

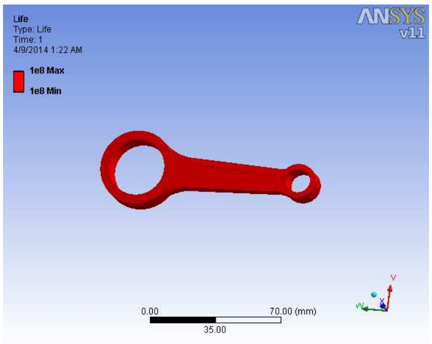


Figure 3.5: (b) Aluminum Alloy

- **Damage**

It is ratio of design life to actual life. Damage greater than 1 indicate part will fail before design life is achieved

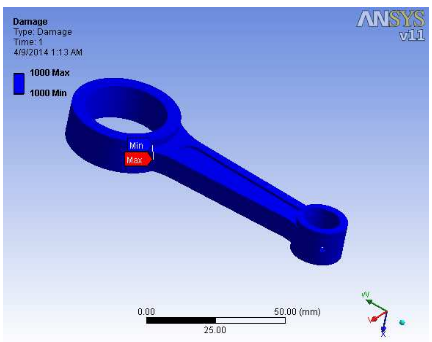


Figure 3.6: (a) Structural Steel

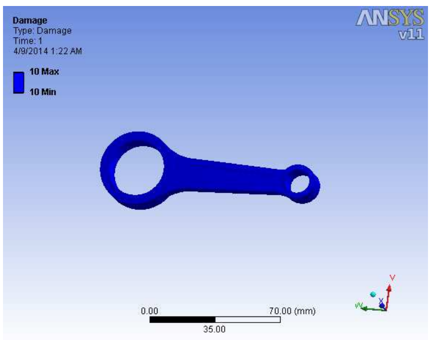


Figure 3.6: (b) Aluminum Alloy

- **Biaxility Indication**

It is qualitative measure of stress. Biaxility indication of -1 represent pure shear, 0 represent uniaxial stresses and 1 represent biaxial stresses

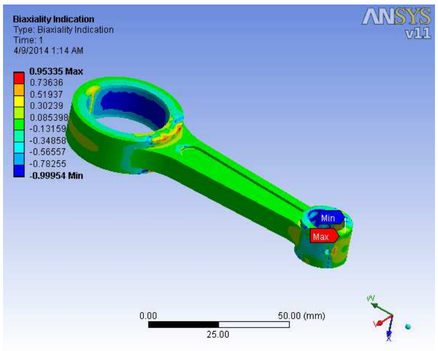


Figure 3.7: (a) Structural Steel

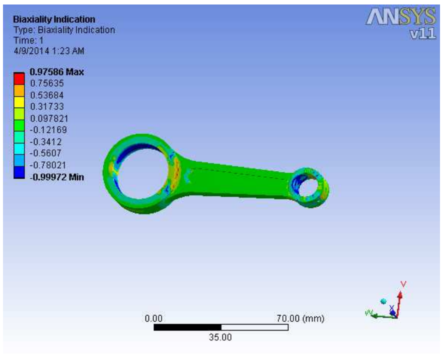


Figure 3.7: (b) Aluminum Alloy

- **Safety Factor**

It is measure of factor of safety for design. Safety factor of 15 is recorded at both the ends which is maximum. In between moderate FOS is present

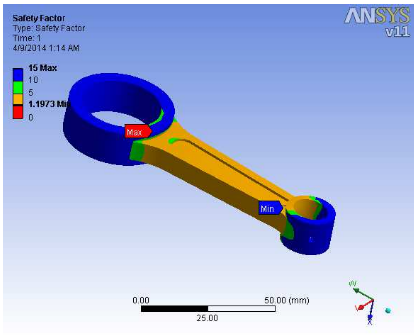


Figure 3.8: (a) Structural Steel

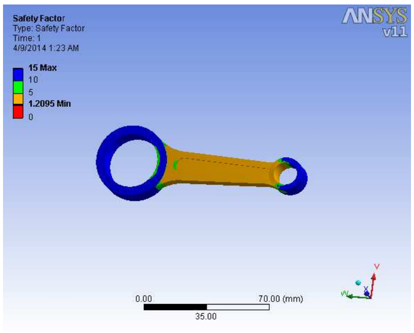


Figure 3.8: (b) Aluminum Alloy

3.3 Linear Buckling

In case of linear buckling piston pin end is deflected in v direction as shown in Figure 3.9. In all computed stresses values obtained are high. They are due to high magnitude of buckling load. This analysis was performed for structural steel only

- **Equivalent Stress**

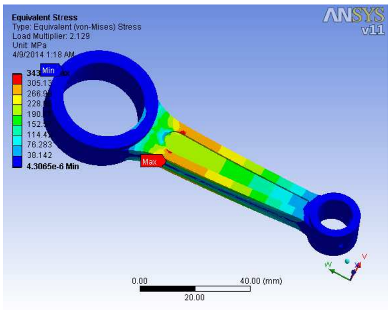


Figure 3.9

- **Shear Stress**

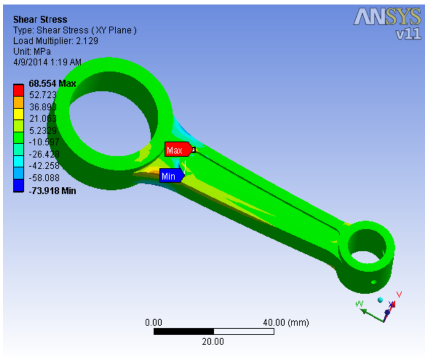


Figure 3.10

- **Total Deformation**

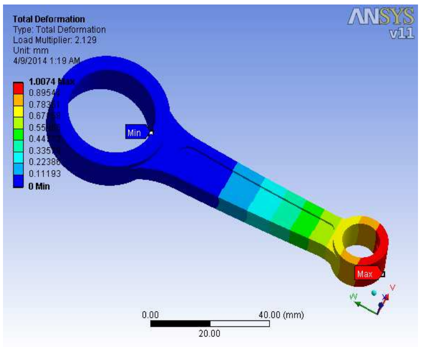


Figure 3.11

3.4 Shape Optimisation Analysis

This analysis has given the part of conrod where material can be safely removed.to optimize shape as well as reduce weight

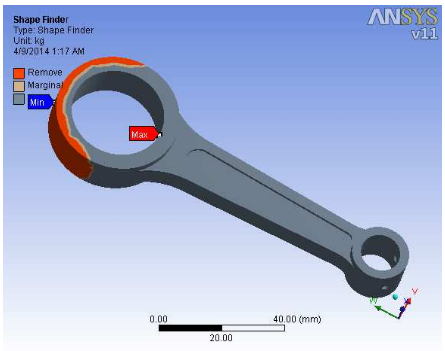


Figure 3.12: (a) Structural Steel

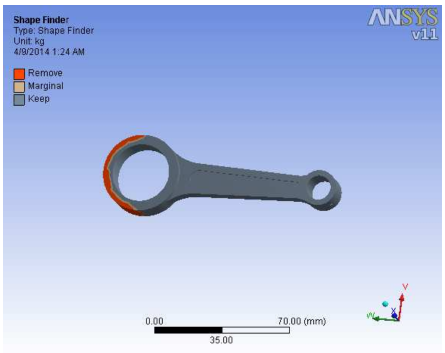


Figure 3.12: (b) Aluminum Alloy

All the results obtained were tabulated and compared and conclusions were drawn based on them

3.4 Results for Static Loading

Table 3.1: Maximum and Minimum Values of Stress Parameters

Parameter	Structural Steel		Aluminum Alloy	
	Min	Max	Min	Max
Equivalent stress(MPa)	4.31e-4	71.995	3.8026e-4	68.406
Shear stress(MPa)	-21.384	22.508	-21.474	23.129
Equivalent elastic strain	2.1576e-9	3.5997e-4	5.3558e-9	9.6347e-4
Total Deformation	**0**	**1.7103e-2**	**0**	**4.7999e-2**

3.5 Fatigue Tool Results

Table 3.2: Maximum and Minimum Values of Fatigue Parameters

Parameter	Structural Steel		Aluminum Alloy	
	Min	Max	Min	Max
Life	1e6	1e6	1e8	1e8
Damage	1000	1000	10	10
Safety Factor	1.1973	15	1.2091	15
Biaxility indication	-0.99954	0.95335	-0.99972	0.97586
Equivalent alternating stress(MPa)	4.3152e-4	71.995	3.8026e-4	68.406

3.6 Results for Linear Buckling at 21598 N

Table 3.3: Maximum and Minimum Values of Parameters Considering Buckling

Parameter	Min.	Max.
Equivalent stress(MPa)	4.3065e-6	343.27
Shear stress(MPa)	-73.918	68.554
Equivalent elastic strain	2.1532e-11	1.7164e-3
Total Deformation(mm)	**0**	**1.0074**

3.7 Results of Shape Optimization

Table 3.4: Weight Optimization Results

	Original Mass	Optimized Mass	Marginal Mass
Structural steel	0.13175 kg	0.11165 kg	1.9572e-004 kg
Aluminum alloy	4.649e-2 kg	3.9396e-2	6.2552e-005 kg

4. CONCLUSIONS

- The analysis performed in this project gave scope for optimization. Analysis of different parameters it has suggested modification in existing connecting rod.
- Reduction of weight was one of our primary aims. We found that weight can be reduced using shape finder tool. But the high density structural steel material has its limitation. So we changed the material to aluminum alloy & this gives significant weight reduction also the results for various stresses are better in case of aluminum. So changing the material is solution for weight reduction. Also life is more in case of aluminum alloy.
- Analysis of linear buckling was performed & this gave maximum deformation of 1.0072mm. This is because of high magnitude of buckling load.
- The stress multiaxiality is high, therefore multiaxial fatigue analysis is needed to determine fatigue strength.

- The maximum stresses occurred in static structural analysis are less than the yield strength of material. Hence the design is safe.

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