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Static, Fatigue and Modal Analysis of Connecting Rod under Different Loading Conditions

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Abstract

Connecting rod is a major link between piston and crankshaft. Its primary function is to convert reciprocating motion into rotary motion of crankshaft. Connecting rod is subjected to more stress than any other engine components. In this study static and modal analysis is performed .The S-N approach by modified Goodman criterion to the fatigue life prediction of the connecting rods is also presented. The model is developed using Solid Modelling software-Solidworks2013 .Further finite element analysis is done using Ansys14 Workbench to determine the von-mises stresses and strains, fatigue life and modal frequencies under different loading conditions.

Keywords: Connecting rod, Solidworks, Ansys, FE Analysis.

Introduction

Connecting rod is a major link between piston and crankshaft which converts reciprocating motion of piston into rotary motion of crankshaft. Connecting rods are subjected to inertial force due to reciprocating mass and gas forces. Gas pressure results in axial and bending stresses. Bending stresses originate due to eccentricities, crankshaft, case wall deformation, and rotational mass force. Therefore a connecting rod must be capable of transmitting axial tension, axial compression and bending stresses caused by the thrust and pull on the piston and by centrifugal force. A connecting rod is subjected to many millions of repetitive cyclic loadings. It consists of a long shank, a small end, a big end. The cross-section of the shank may be circular, rectangular, tubular, I-section or H-section. Generally circular cross-section is used for low speed engines while I-section is preferred for high speed engines.

Material Properties and Dimensions

The material used for connecting rod is structural steel and the material properties are shown below:

Material Selected	Structural Steel
Young's Modulus(E)	2E+05 MPa
Poisson's Ratio	0.3
Density	7850 kg.m^{-3}
Tensile Ultimate Strength	460 MPa
Compressive Yield Strength	250 MPa

Table 1 Properties of Structural Steel

Parameters	Values
Length of Connecting rod	174mm
Outer diameter of big end	72.38mm
Inner diameter of big end	58.74mm
Outer diameter of small end	50mm
Inner diameter of small end	30mm

Table 2 Dimensions of Connecting rod

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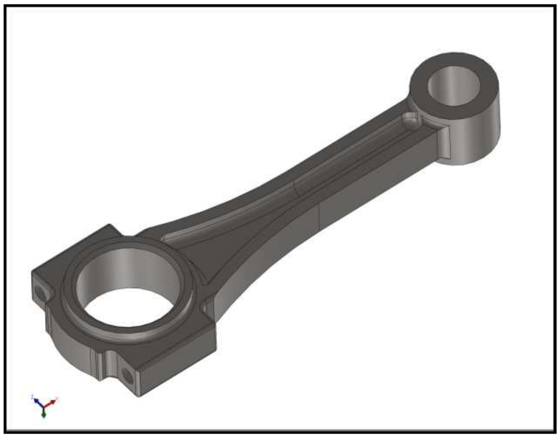

Figure 1 Connecting Rod

Meshing

After modelling the connecting rod in solidworks2013, the IGES format file of it was imported into Ansys14 Workbench and the analysis was started by meshing it. The details of the number of nodes and elements are given below:
Type of Element: Triangular
Number of Elements: 22171
Number of nodes: 37068

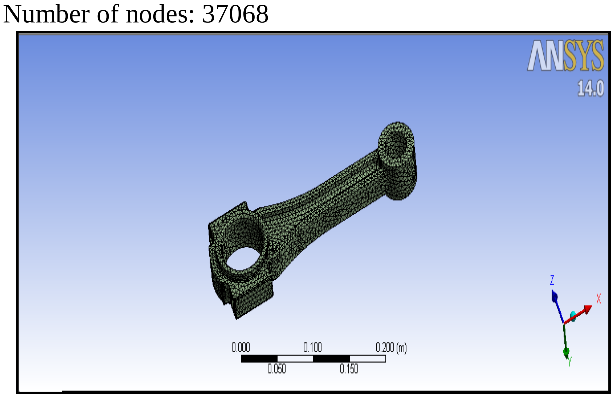

Figure 2 Mesh Model of Connecting rod

Load Analysis

Two assumptions have been considered while solving in Ansys14 Workbench which are as follows:

1. Angle of 20^0 after certain time of expansion stroke.
2. Force acting over piston rod head and compression force of crankshaft under piston rod are equal.

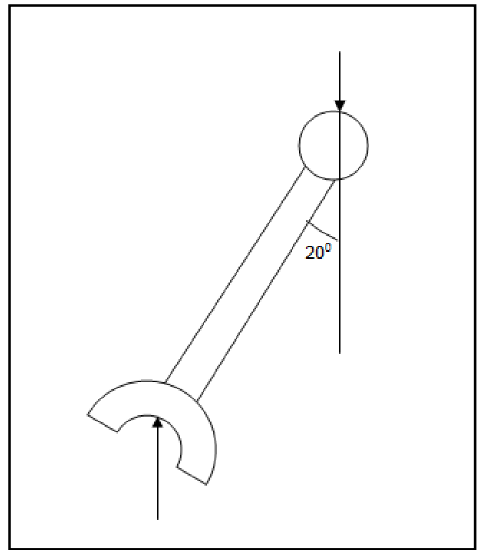

Figure 3 Free Body Diagram of Connecting rod

For the finite element analysis big end of the connecting rod was fixed and compressive forces of equal magnitude of 532.4kN were applied at the small end and at the big end at an angle of 20^0 from the vertical. Besides this, a bending moment of magnitude 15.476 kN-m was applied at the shank and torsion produced by the crankshaft motion acting on the big end was of magnitude 16.9 kN-m.

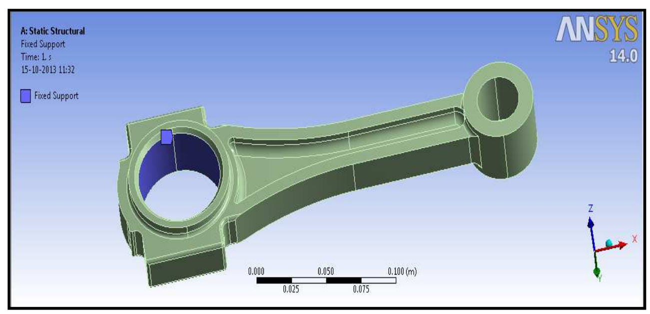

Figure 4 Fixed Big End

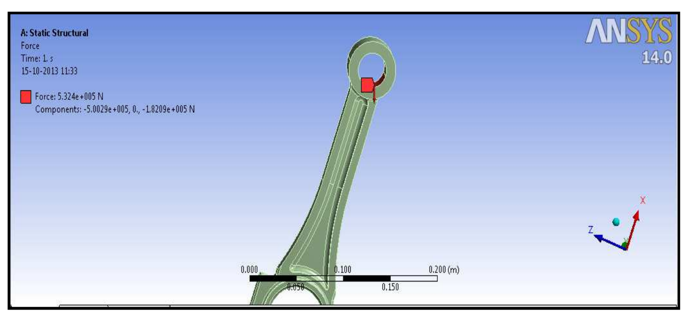

Figure 5 Force at Small End

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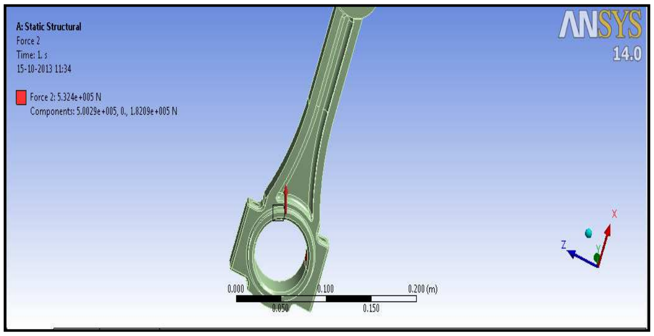

Figure 6 Force at Big End

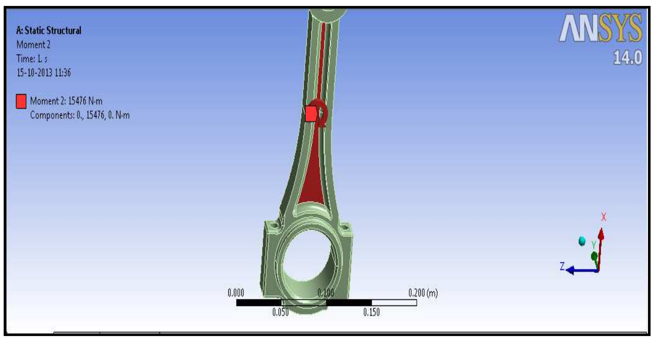

Figure 7 Bending moment at the shank

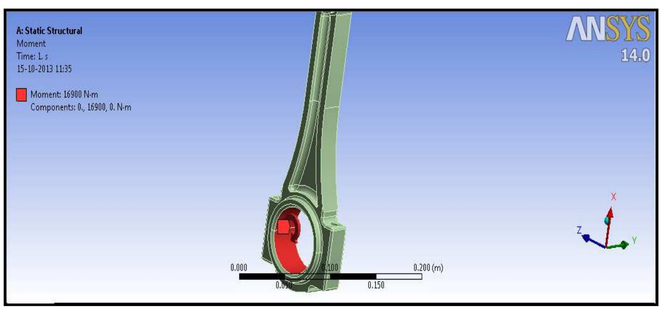

Figure 8 Torsion at the big end

Results

After solving the above mentioned loads in Ansys14 Workbench following results were obtained in static structural module:

a. Deformation: Total deformation with maximum magnitude of 0.044031m was observed at the small end (0.0062544m in x-direction, 0.00020047m in y-direction and 1.3852e-5m in z-direction) and minimum at the big end with magnitude 0m.

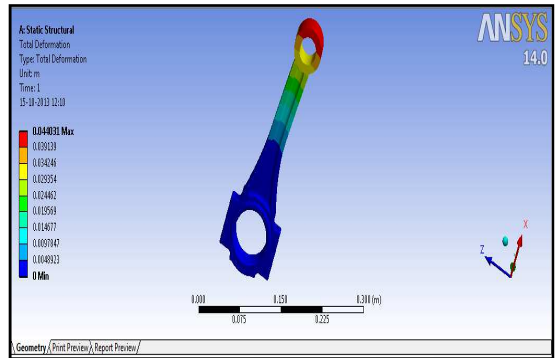

Figure 9 Total deformation

b. Von-mises strain: Maximum Equivalent (von-mises) elastic strain occurred at the upper part of the big end with magnitude 0.059086 and minimum at the lower part of the big end with magnitude 1.8562e-6.

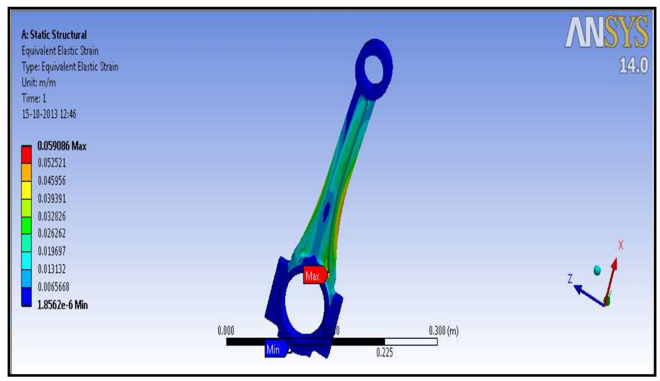

Figure 10 Equivalent(von-mises) strain

c. Von-mises stress: Maximum equivalent (von-mises) stress occurred at the shank with magnitude 1.1399e+4 MPa and minimum at the big end with magnitude 0.26295 MPa.

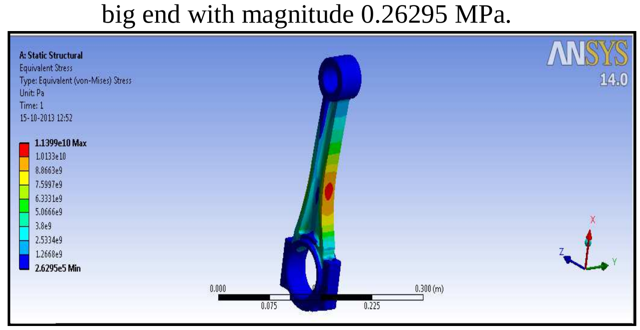

Figure 11 Von-mises stress

d. Strain Energy: Maximum strain energy with magnitude 5.7766 J was observed at the centre of the shank and minimum at the lower part of the big end with magnitude 6.0598e-9 J.

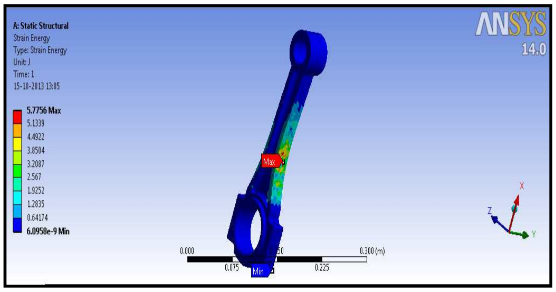

Figure 12 Strain Energy

Modal analysis of the connecting rod was performed upto six iterations and the following results were obtained:

Figure no.	Frequency(Hz)	Max. Total Deformation(m)
13	408.94	1.7577
14	582.81	2.2965
15	1634.1	1.9088
16	2992.8	1.5863
17	3994.8	2.7188
18	4592.9	1.4432

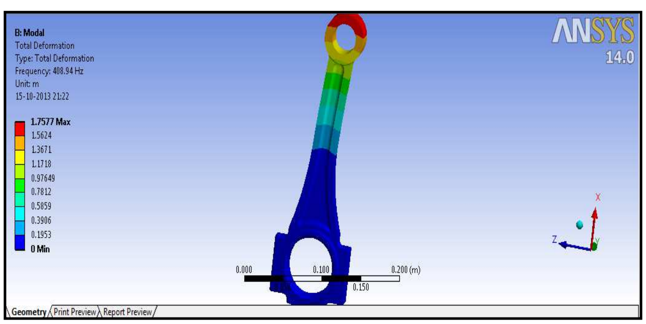

Figure 13

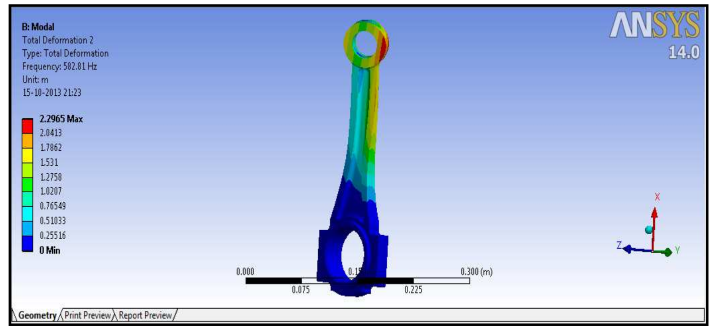

Figure 14

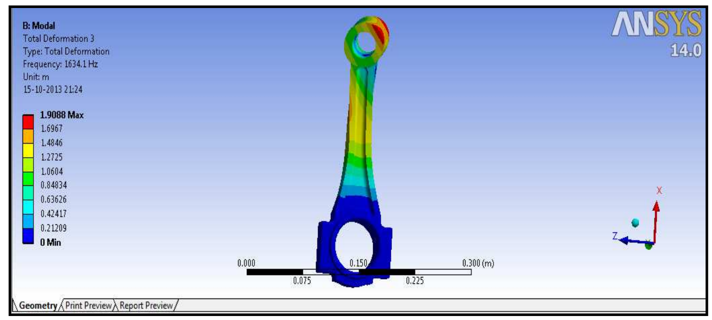

Figure 15

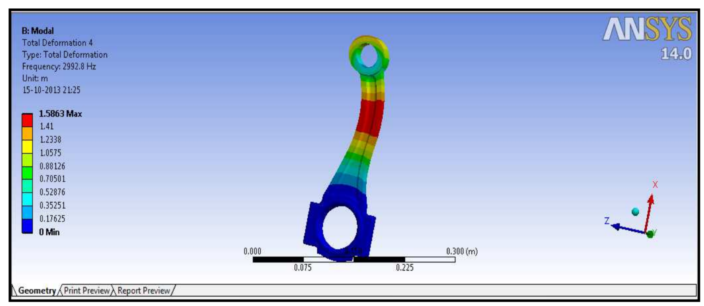

Figure 16

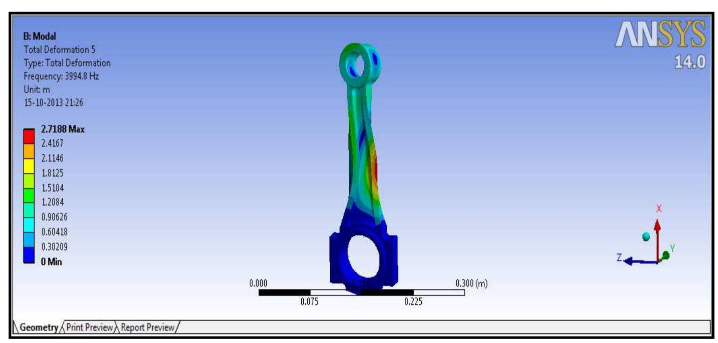

Figure 17

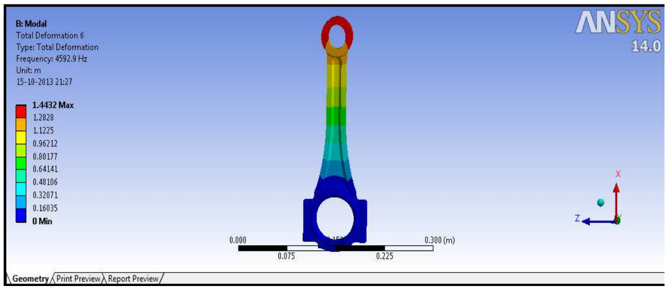

Figure 18

Fatigue Analysis was also done on the connecting rod and the following results were obtained:

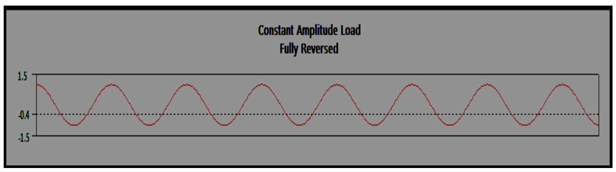

Figure 19 Graph showing fatigue load

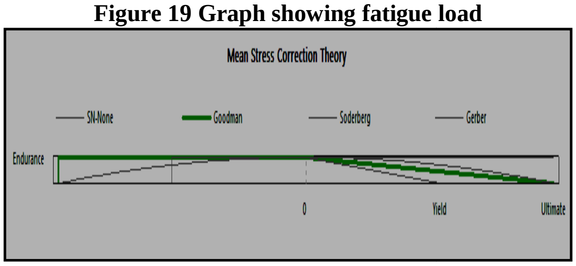

Figure 20 Mean Stress Correction Theory

a. Life: Maximum life of the connecting rod was 1e+06 cycles and the most vulnerable parts to the load conditions are marked red in the figure shown below.

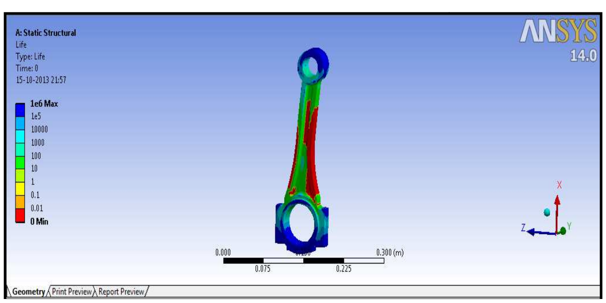

Figure 21 showing expected life of the connecting rod

b. Damage: Maximum damage occurred after 1e+32 cycles and that too started at the sides of the shank (marked red in the figure).

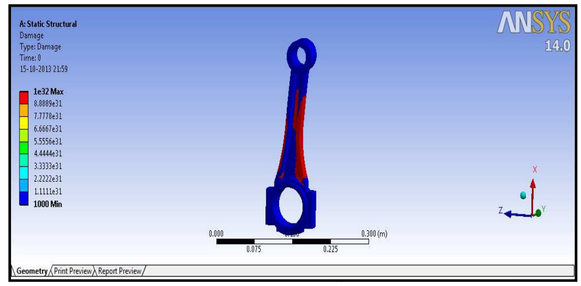

Figure 22 showing damage of the connecting rod

c. Factor of safety: Maximum safety factor recorded is 15 and minimum is 0.0075618.

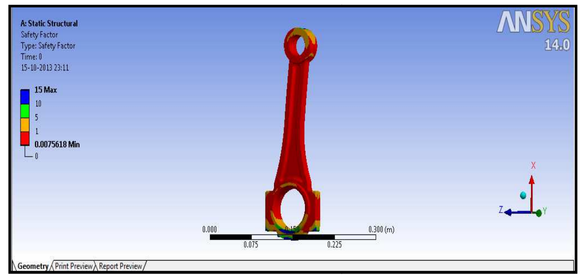

Figure 23 Factor of Safety

Conclusions

a. Maximum deformation occurred at the small end.
b. Maximum Von-mises strain occurred at the upper part of the big end and minimum at the lower part of the big end.
c. Maximum Von-mises stress occurred at the shank and minimum at the big end.
d. Maximum strain energy was observed at the centre of the shank and minimum at the lower part of the big end.
e. Maximum life of the connecting rod was calculated as 1e+06 cycles.
f. Maximum damage occurred after 1e+32 cycles.

Future Scope

This study is based on the static structural module. Further analysis of connecting rod can be done under dynamic environment.

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