Static and Fatigue Damage Analysis of a Connecting Rod

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ABSTRACT

The connecting rod is the intermediate member between the piston and the crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis work describes structural, vibration and fatigue analysis of a connecting rod. A parametric model of connecting rod is modelled using SOLIDWORKS and that model is exported to ANSYS for analysis. Finite element analysis of connecting rod is done by considering forged steel. Forged steel has more factor of safety, less weight, high stiffness and less normal and equivalent stresses. Fatigue analysis is conducted to calculate the lifespan and damage duration of the connecting rod and found that forged steel has the maximum life span.

Keywords: ANSYS, Connecting rod, FEM, Fatigue, SOLIDWORKS

1. INTRODUCTION

Connecting rod is a rigid member that connects a piston to a crank or crankshaft in a reciprocating engine. Together with the crank, it forms a simple mechanism that converts reciprocating motion into rotating motion. The mechanism of the connecting rod is to transmit the push and pull from the piston to the crank so that it converts the reciprocating motion of the piston pin into the rotary motion of the crank pin. The connecting rod is used to connect the piston and crankshaft in an internal combustion engine. The connecting rod is the highest stressed component in a reciprocating piston engine. The connecting rods have two ends, one end is the small end that is the piston end and the other end is the big end that is the crank end. For the internal combustion engine, the connecting rods are made by the drop forging process. The connecting rod has generally three parts pin end, crank end, and long shank. The design of shank can be different types like rectangular, tubular, circular, I-section and H-section. The circular section is generally used for low speed engines. I-section is used for high speed engines. Connecting rod having high stress due to the reciprocating load of the piston and that load is increased, when the speed of the engine will be increased. The failure of the connecting rod is known as throwing a rod, which is the catastrophic engine failure. Due to the high stress fatigue failure also occurs in the connecting rod.

According to Vegi and Vegi [1] they replaced the carbon steel materials of connecting rod with forged steel. They used ANSYS for fatigue analysis and determined the lifetime of the connecting rod. Ravichandran [2] was developed structural modeling, finite element analyzes and the optimization of connecting rod for robust design. Linear static analysis was carried out to obtain the stress strain state results. Doshi [3] found that stresses developed in connecting rod under static loading conditions of compression and tension at crank end pin, end of connecting rod. They also designed the connecting rod by machine design approach and used PRO-E wildfire 4.0, software for modeling of connecting rod and ANSYS software for analysis.

Gupta [4] replaced with the existing connecting rod material by beryllium alloy and magnesium alloy. FEA analysis was carried out by considering three materials Al360, beryllium alloy and magnesium alloy. Shinde [5] analyze static stress developed in connecting rod by using simulation process. The main advantage of using simulation is to save time and cost involved in analysis. The loads on the connecting rod were obtained as a function of crank angle. Mohankumar [6] designing a connecting rod with standard dimensions of a stock one in CREO 3.0 software and analyze the design using designing software ANSYS. They also analyzed factors such as stress, strain, factor of safety, deformation, fatigue analysis and working cycle while taking into consideration the difference in weight and design. Singh [7] replaced the existing connecting rod material by beryllium alloy and magnesium alloy and determine best material for connecting rod after analyzing in ANSYS.

Wankhadel [8] attempts to design and analyze the connecting rod used in a diesel engine in context of the lateral bending forces acting along its length during cycle of it. The lateral bending stress are commonly called as whipping stress and this whipping stress forms the base of evaluation of performance of various materials that can be used for manufacturing of connecting rod. Chumbre [9] have been attempting to analyze and understand the connecting rod structure using finite element analysis method. And the analysis was carried out by considering different material analysis is carried variations of equivalent von-misses stress, strain, total deformation and factor of safety. Gupta [10] illustrate a general study on three designs of connecting rod along with modern structure. After comparison of multiple designs of the connecting rod, the weight optimization by the extraction of material seems difficult. The authentic dimensions of the connecting rod used for the industrial application has been designed on CREO 2.0. Webster et al. [11] performed three-dimensional finite element analysis of a high-speed diesel engine connecting rod. The load distribution on the piston pin end and crank end were determined experimentally. Chauhan [12] investigates and attempt to find the best material of connecting rod & optimization of connecting rod for reduce weight, stress, strain, displacement while increasing or maintaining strength of connecting rod.

A critical review of the literature showed that there are many studied about the connecting rod finite element analysis through ANSYS, fatigue analysis, weight reduction. There is always a space for improvement with considering different factors like stress, strain, factor of safety, deformation of the connecting rod. Optimization is the key ingredient in a research as it increases life, decreases stress generated with less deformation and fatigue.

2. MODELLING OF THE CONNECTING ROD

The geometrical model of connecting rod is done by using SOLIDWORKS software. Then the model has been exported to the ANSYS workbench software for further analysis of the key factors such as stress, deformation, vibration analysis and fatigue damage of the connecting rod. The dimensions and the material properties of the connecting rod are given in Table 1 and 2. Figure 1 and 2 shows the different components of the connecting rod. The assembled view of the connecting rod is shown in Figure 3. A very fine mesh is used to design the model so that the results would be more accurate and precise, as shown in Figure 4. Figure 5 shows the boundary condition applied to the connecting rod with the amount of pressure applied.

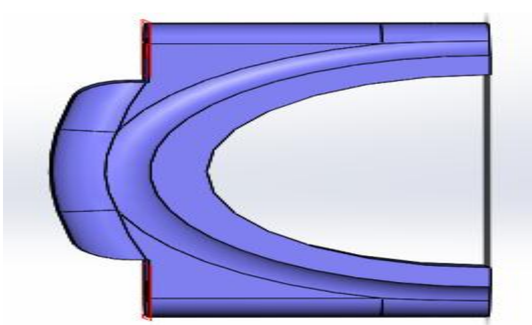

Figure 1. Big end of connecting rod

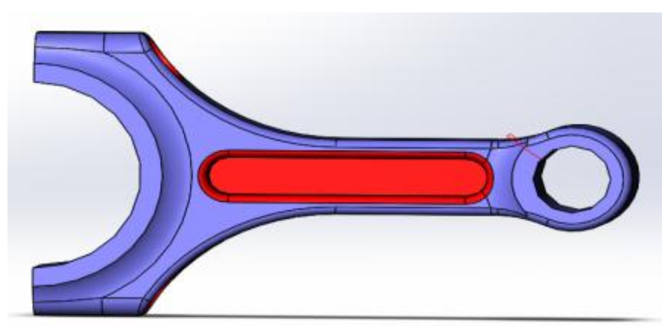

Figure 2. Section of the connecting rod

Table 1. Dimensions of the connecting rod

Sl. No.	Components	Values (in mm)
1	Thickness of the connecting rod (t)	3.2
2	Width of the section (B = 4t)	12.8
3	Height of the section (H = 5t)	16
4	Height at the big end = (1.1 to 1.125) H	17.6
5	Height at the small end = 0.9H to 0.75H	14.4
6	Inner diameter of the small end	17.94
7	Outer diameter of the small end	31.94
8	Inner diameter of the big end	23.88
9	Outer diameter of the big end	47.72
10	Inner diameter of the nut	5.50
11	Outer diameter of the nut	10
12	Inner diameter of the bolt	5.50
13	Outer bolt diameter	5

Table 2. Mechanical properties for forged steel [6]

Sl. No.	Mechanical Properties	Value
1.	Density(g/cc)	7.70
2.	Average hardness (HRB)	101.00
3.	Modulus of elasticity (Gpa)	221.00
4.	Yield strength, YS (Mpa)	625.00
5.	Ultimate strength, Su (Mpa)	625.00
6.	Percent reduction in area, %, RA	58.00
7.	Poison ratio	0.29

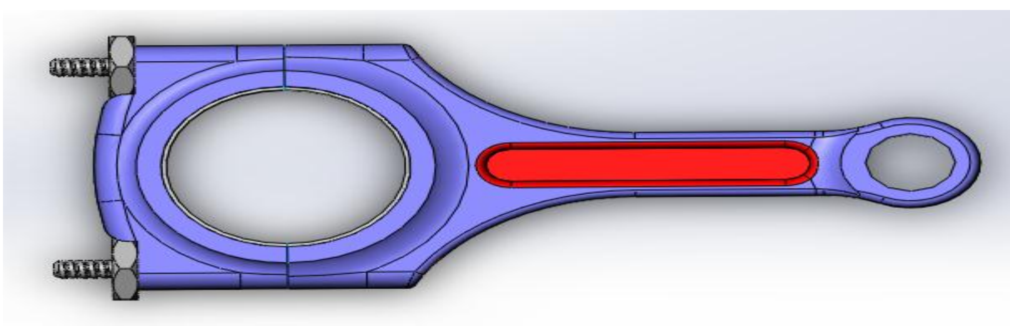

Figure 3. Assembled connecting rod (front view)

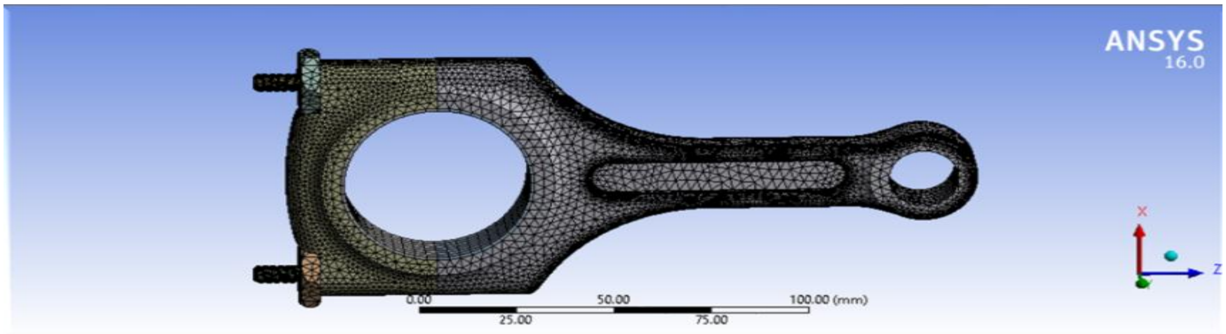

Figure 4. Meshed view of connecting rod

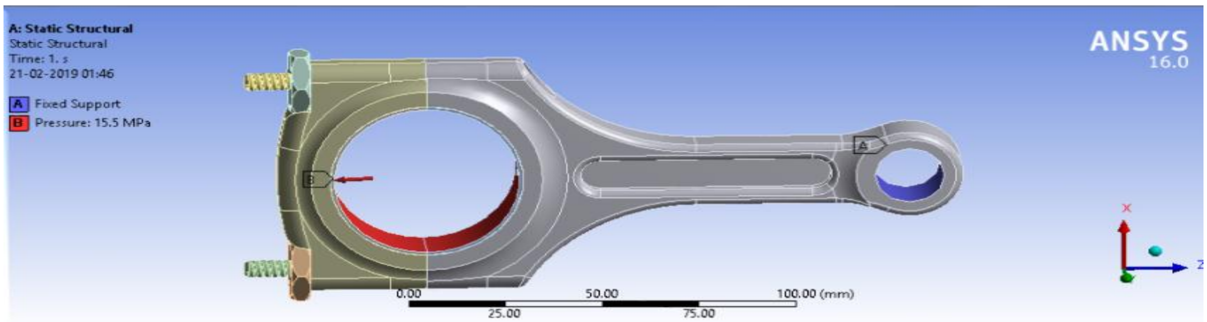

Figure 5. Boundary condition of the connecting rod

3. RESULTS AND DISCUSSION

3.1. Validation Study

Static structural analysis is performed of a connecting rod by useof forged steel material. The nominal stress, equivalent stress and the total deflection value obtained from the analysis, were compared with] results for validation purpose. From the Table 3 it is found that the results obtain show good agreement with Vegi and Vegi [1]. Table 3 shows the comparsion study with the deviation percentage.

Table 3. Comparison between research paper by Vegi and Vegi with present work [1]

Sl. No.	Name of stress	Research paper by Vegi and Vegi [1]	Results after simulation	Percentage of deviation
1	Normal Stress(Max)	25.283 MPa	25.035 MPa	1
2	Equivalent Stress (Max)	38.298 MPa	38.473 MPa	1
3	Total Deflection (Max)	0.0025 MPa	0.0024 MPa	4

3.2 Stress Analysis of Connecting Rod by Using Nut and Bolt Joint at the Big End

The different mechanical parameters (equivalent stress, normal stress) of the connecting rod are calculated. By using ANSYS von-misses stress and other stresses are calculated as below. It observed that the deformation starts due to the stress and it started at the big end of the connecting rod. Figure 6 and 7 show the equivalent stress and normal stress distribution of the connecting rod respectively.

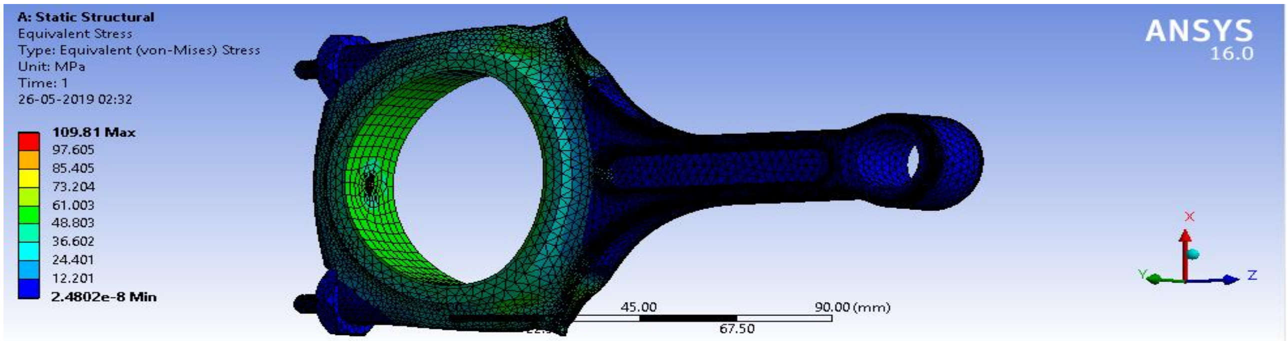

Figure 6. Equivalent stress (von misses stress) of the connecting rod

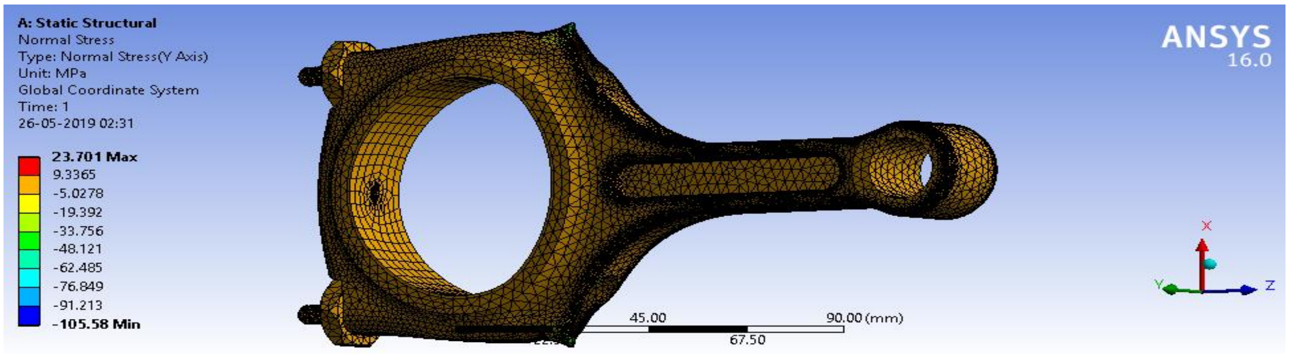

Figure 7. Normal stress of the connecting rod

3.3 Free Vibration Analysis of the Connecting Rod Made of Forged Steel Material

The natural frequencies of the connecting rod are calculated by ANSYS modal analysis. For the modal analysis, here different materials are used and compared with each other. After the comparison of natural frequencies of the three materials (aluminum alloy, cast iron and forged steel) in simulation, the corresponding graph is obtained. From the Figure.8, it is observed that, the aluminum alloy have less vibration as compare to the cast iron but very similar to the forged steel material. The aluminum alloy has less strength and more expensive than forged steel material so in stress analysis and the fatigue analysis the forged steel material is used.

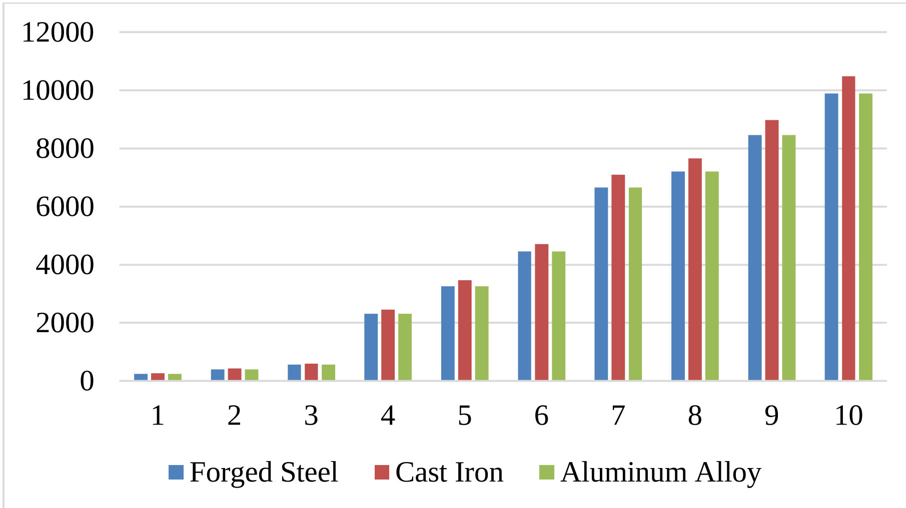

Figure 8. Comparison of natural frequencies (aluminium alloy, cast iron, forged steel)

From the above Figure it is observed that, the Aluminum alloy have less vibration as compare to the cast iron but very similar to the forged steel material. The aluminum alloy has less strength and more expensive than forged steel material so in stress analysis and the fatigue analysis the forged steel material is used.

3.4 Prediction of Life Span of the Connecting Rod by Using Fatigue Life Method

The life span of the connecting rod is evaluated as shown Figure 9. It observed that the forged steel connecting rod has maximum fatigue life that is 10^6 cycle.

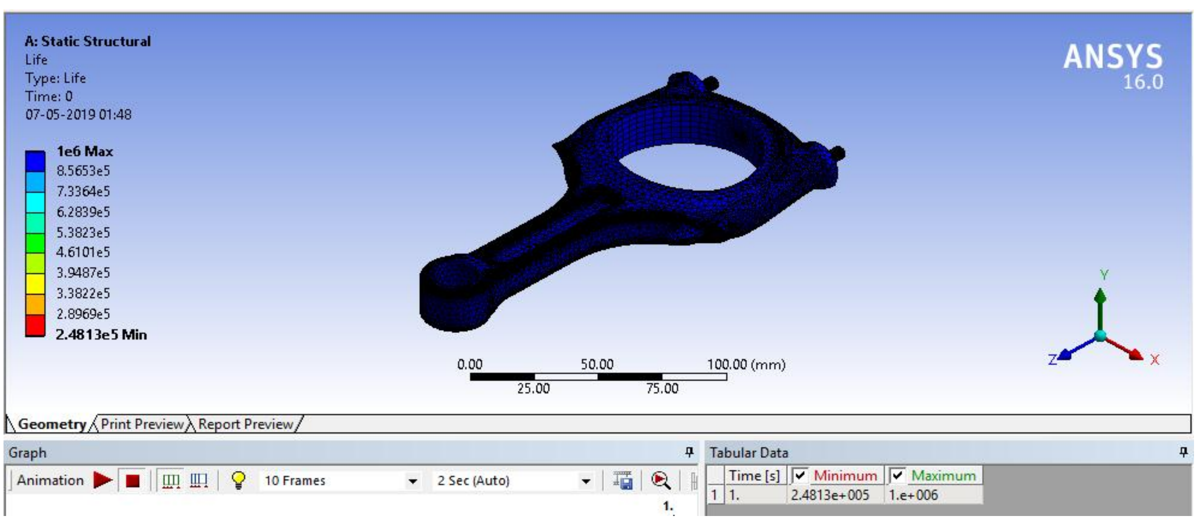

Figure 9. Lifespan of the connecting rod

3.5 Damage of the Connecting Rod

In this section the damage growth of the connecting rod is analyzed. It is found that the maximum cyclic damage occurs to the connecting rod during the fatigue analysis is 0.002 as shown in Figure 10.

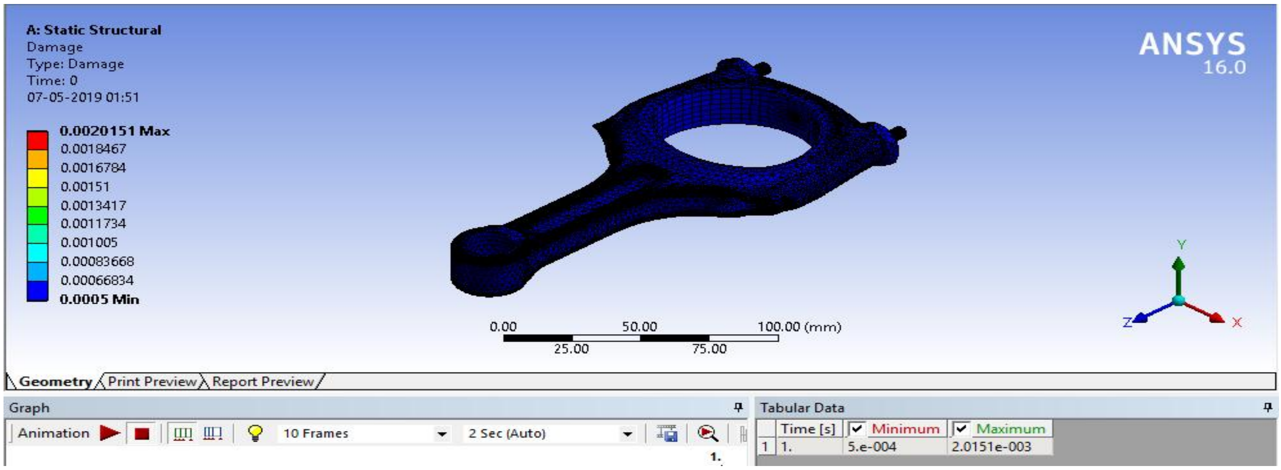

Figure 10. Damage of the connecting rod

4. CONCLUSION

The connecting rod model was safe during the analysis providing a factor of safety more than one for all of the materials considered for the Analysis. These studies consider the stress, vibration and fatigue analysis of the connecting rod which is made up of forged steel material. In stress analysis, the model is analyzed in FEM. For the vibration analysis there is a comparison between three materials (Aluminium alloy, cast iron, and Forged steel) and considering which material is giving less frequency. Due to the fatigue analysis, the lifetime and the deformation is determined for the connecting rod. From the present analysis, the following conclusions are made:

1. Stress, strain, deformation, life, damage, etc. have been studied and analysed to get the good design parameters with taking into account the safe permissible stresses and factors which would have affected the design if not taken into account.
2. From the stress analysis of connecting rod with different materials, the forged steel has less stress and less deformation as compared to the aluminum alloy and cast iron.
3. In free vibration analysis, forged steel has less frequency as compared to the other two materials. From the fatigue analysis of the connecting rod the life span is 10^6 determined.

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