Determination of Fatigue Life of a Connecting Rod of a Motor-Bike Using FEA

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Abstract: *The connecting rod is the most relevant part of an automotive engine. The connecting rod is subjected to an extremely complex state of loading. High compressive and tensile loads are due to the combustion of fuel and connecting rod's mass of inertia respectively. The objective of this dissertation is to investigate the fatigue life of connecting rod of motor bike. Static structural analysis using ANSYS and experimental analysis is conducted on connecting rod. The purpose of this is to Analyse Number of cycles of existing connecting rod under given different loading condition. After that the work is carried out for geometry change in existing connecting rod compared with Modified connecting rod. The Results of Finite Element Analysis is compared with the Experimental results.*

Keywords: *Connecting Rod (CR), Unigraphics, static structural analysis in ANSYS and Fatigue Life, Universal Testing Machine (UTM)*

1. INTRODUCTION:

Connecting rod is the intermediate link between the piston and the crank. And is responsible to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. For automotive it should be lighter should consume less fuel and at the same time they should provide comfort and safety to passengers, that 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.

Suraj Pal et al. "Design Evaluation and Optimization of Connecting Rod Parameters Using FEM". In this paper Finite element analysis of single cylinder four stroke petrol engines is taken for the study; Structural systems of Connecting rod can be easily analyzed using Finite Element techniques. So firstly a proper Finite Element Model is developed using Cad software. Then static analysis is done to determine the von Misses stress, shear stress, elastic strain, total deformation in the present design connecting rod for the given loading conditions using Finite Element Analysis Software ANSYS v 12.In the first part of the study, the static loads acting on the connecting rod, After that the work is carried out for safe design.

G. Naga Malleshwara Rao et al. "Design Optimization and Analysis of a Connecting Rod using ANSYS" The main Objective of this work is to explore weight reduction opportunities in the connecting rod of an I.C. engine by examining various materials such as Genetic Steel, Aluminium, Titanium and Cast Iron. This was entailed by performing a detailed load analysis. Therefore, this study has dealt with two subjects, first, static load and stress analysis of the connecting rod and second, Design Optimization for suitable material to minimize the deflection.

K. Sudershan Kumar et al. "Modelling and Analysis of Two Wheeler Connecting Rod" This paper describes modelling and analysis of connecting rod. In this project connecting rod is replaced by Aluminium reinforced with Boron carbide for Suzuki GS150R motorbike. A 2D drawing is drafted from the calculations. A parametric model of connecting rod is modelled using PRO-E 4.0 software. Analysis is carried out by using ANSYS software.

B. Anusha, C.Vijaya Bhaskar Reddy et al. "Modelling and Analysis of Two Wheeler Connecting Rod by Using Ansys" In this paper a static analysis is conducted on a connecting rod of a single cylinder 4-

stroke petrol engine. The model is developed using Solid modelling software i.e. PRO/E (creo-parametric) Further finite element analysis is done to determine the von-misses stresses shear stress and strains for the given loading conditions.

Vivek. C. Pathade et al. investigate the stress analysis of connecting rod by finite element method using pro-e wild fire 4.0 and ANSYS work bench 11.0 software. And concluded that the stress induced in the small end of the connecting rod are greater than the stresses induced at the bigger end, therefore the chances of failure of the connecting rod may be at the fillet section of both end.

H.B. Ramani et al. performed detailed load analysis of connecting rod., In order to calculate stress in Different part of connecting rod, the total forces exerted connecting rod were calculated. It was observed that maximum stresses in different parts of connecting rod were determined by Analysis. The maximum pressure stress was between pin end and rod linkages and between bearing cup and connecting rod linkage.

B. Anusha, Dr.C. Vijaya Bhaskar Reddy et al. "Comparison of Materials for TwoWheeler Connecting Rod Using Ansys" The modelled connecting rod imported to the analysis software i.e. ANSYS. Static analysis is done to determine von-misses stresses, strain, shear stress and total deformation for the given loading conditions using analysis software i.e. ANSYS. In this analysis two materials are selected and analyzed. The software results of two materials are compared and utilized for designing the connecting rod.

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.

Figure 1: connecting rod

2. CLASSIFICATION:

The classification of connecting rod is made by the cross sectional point of view i.e. I – section, H – section, Tabular section, Circular section. In low speed engines, the section of the rod is circular, with flattened sides. In high speed engines either an H – section or Tabular section is used because of their lightness. The rod usually tapers slightly from the big end to the small end.

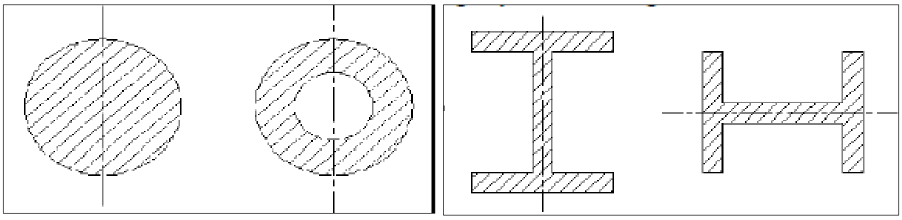


Figure 1.1: Different Cross sections of connecting rod

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 are,

- 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.

3. THEORETICAL CALCULATIONS OF CONNECTING ROD:

A connecting rod is a machine member which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile force, therefore the cross-section of the connecting rod is designed as a strut and the Rankine formula is used. A connecting rod subjected to an axial load F may buckle with x-axis as neutral axis in the plane of motion of the connecting rod, y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x axis and both ends fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis.

Let,

A = cross sectional area of the connecting rod.
L = length of the connecting rod.
σc = compressive yield stress.
F = crippling or buckling load.
Ixx and Iyy = moment of inertia of the section about x-axis and y-axis respectively.
Kxx and Kyy = radius of gyration of the section about x-axis and y- axis respectively.

Rankine's – Gordon formula,

Crippling or buckling load about x-axis = $\frac{(\sigma C \times A)}{4\,[\,1 + a\,\frac{L}{Kxx\;2}\,]}$

A) Specification of Existing Connecting Rod

Engine Specification

Engine type air cooled 4-stroke

- Bore = 56 mm
- Stroke = 60.7 mm
- Crank Throw r = 30.35 mm
- Peak Pr Pr = 72.5 Bar
- Engine speed @ Torque Pt N_{Torque} = 7500 rad/s
- Angular velocity @ Torque Pt V_{Torque} = 785.40 rpm
- Engine speed @ Peak Power N_{Power} = 8500 rad/s
- Angular velocity @ Peak Power V_{Power} = 890.12 rpm
- Engine speed @ Redline $N_{Redline}$ = 12500 rad/s
- Angular velocity @ Redline $V_{Redline}$ = 1309.00 rpm
- Compression Ratio = 9.5:1

B) Design Calculation

The standard dimension of I – Section are,

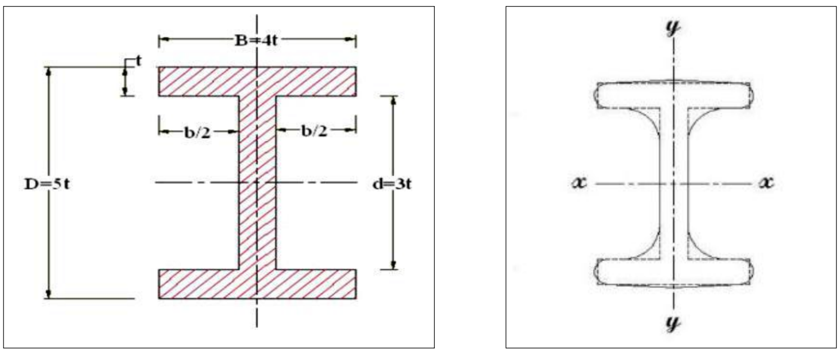


Figure 2. Standard Dimension of I – Section

Let us consider an I – section of the connecting rod as shown in figure, with the following proportions, so that the connecting rod to be equally resistant to buckling in either plane, the relation between moment of inertia must be, $I_{xx} = 4\,I_{yy}$.

C) Mathematical Calculation:

Maximum force on the piston due to pressure,

Gas Force = Pressure x Cross section area of piston

$F_G = P \times \frac{\pi}{4} \times D^2$

$= 7.25 \times \frac{\pi}{4} \times (56)^2 = 17856.81$ N

Calculations for other forces is given in the form of chart,

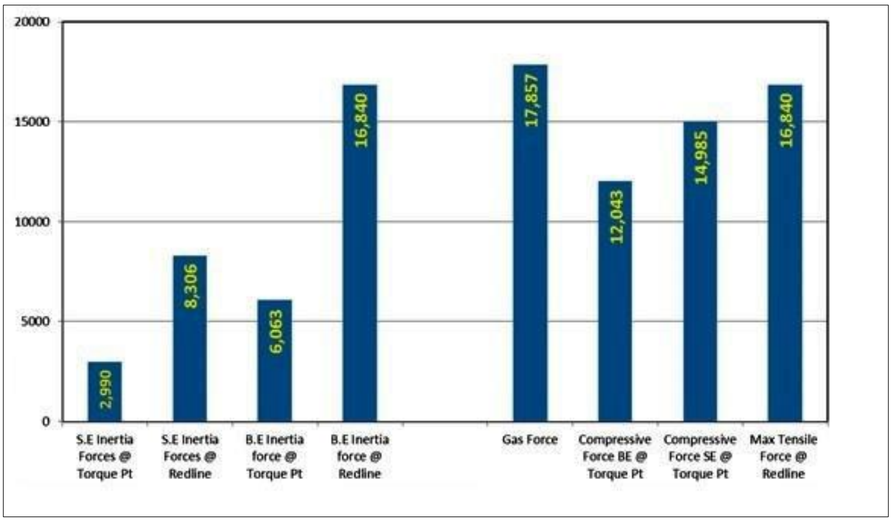


Figure 2.1: chart for Force Calculation of FEA

4. MODELING:

Connecting rod is modelled by taking the designed parameter of existing conrod with the help of Nx10 solid modeling software which is shown in Fig and saved in IGES format. Then this model is imported in ANSYS for further analysis.

Table I Dimensions of Connecting Rod

Sr.No.	Parameters		Value
1	Length of connecting rod	Lcr	104.5 mm
2	Outer Diameter of Big end		48 mm
3	Inner Diameter of Big end		38 mm
4	Outer Diameter of small end		25.8 mm
5	Inner Diameter of small end		17 mm
6	Mass of total piston assembly	Mp	0.124 kg
7	CG from Big end	X	34.395 mm
8	Total mass of CR	Mcr	0.150 kg
9	Reciprocating mass of CR	M_{cr} reci	0.049 kg
10	Rotary mass of CR	M_{cr} rot	0.101 kg

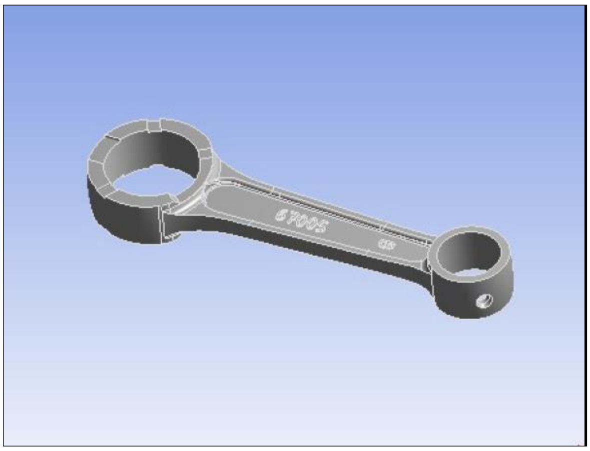


Figure 3: Model of Connecting Rod

A. Material Properties:

The connecting rod of internal combustion engines are mostly manufactured by drop forging. It should have adequate strength and stiffness with minimum weight. The materials of connecting rods range from mild or medium carbon steels to alloy steels. For connecting rods of low speed horizontal gas engines, the material may be sometimes steel casting. For high speed engines, the connecting rods may be made of duralumin and aluminum alloys.

Table II Material Properties

Selected Material	Structural Steel	Aluminum Alloy
Young's Modulus(E)	2.0 x10^5 MPa	71000 MPa
Poisson's Ratio	0.3	0.33
Density	7860 Kg/m^3	2260 Kg/m^3
Tensile ultimate Strength	460 MPa	572 MPa
Tensile Yield Strength	250 MPa	280 MPa
Compressive Yield Strength	250 MPa	280 MPa

B. Meshing

The next step after modeling is meshing of connecting rod model. The mesh model of present connecting rod is as shown in figure 3.1. Meshing is the initial step in the analysis of finite element method. Ansys creates the proper mesh of the total object for further analysis. Thus after meshing of connecting rod in the Ansys workbench 18.0 load and boundary conditions are applied.

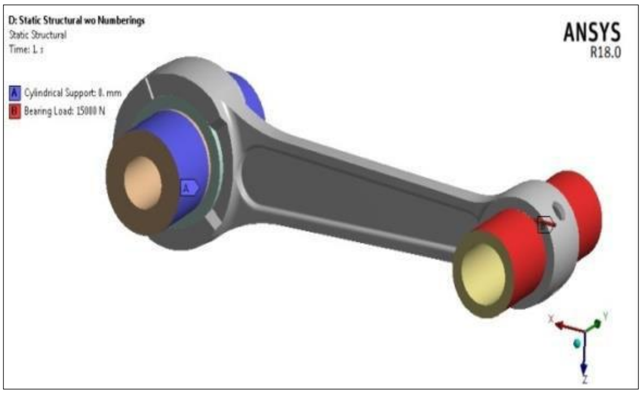
Nodes - 83435 Elements - 384648

Element Size - 1 mm

Figure 3.1: Mesh Model of connecting rod

C. Load and Boundary Condition of Connecting Rod

A model of connecting rod is created by Nx.10 is imported for analysis in ANSYS Workbench 18.0. Analysis is done with the given loading is applied at small end i.e. piston end of connecting rod by fixing the big end. Part A i.e. big end is fixed and at the part B i.e. small end force is applied on connecting rod as shown in figure 3.2.



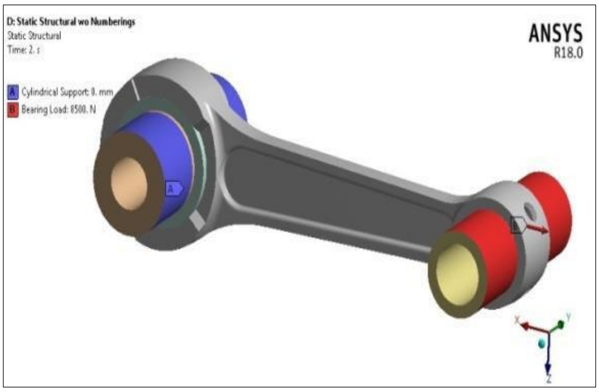


Figure 3.2: Loads & Boundary Condition

5. RESULTS AND DISCUSSIONS:

For the analysis of connecting rod the loading conditions are applied as per the numerical results obtained in the design calculations at small end keeping big end of connecting rod fixed. The analysis is done using software ANSYS workbench 18.0. The maximum and minimum values of parameters like von-mises stress, strain and deformation are noted in the present connecting rod analysis model.

A) Figure Shows Results of Existing connecting rod Analysis

Equivalent Stress

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

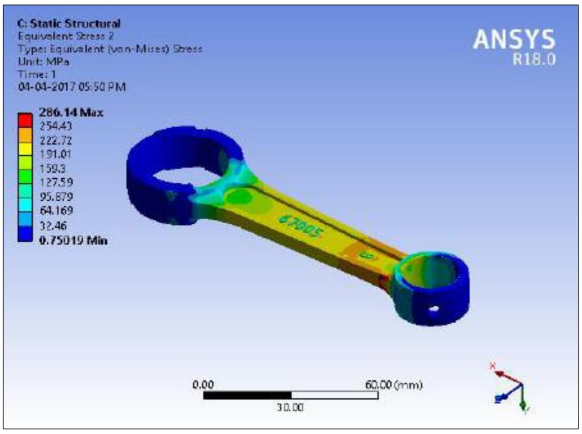


Figure 4: Equivalent Stress 1

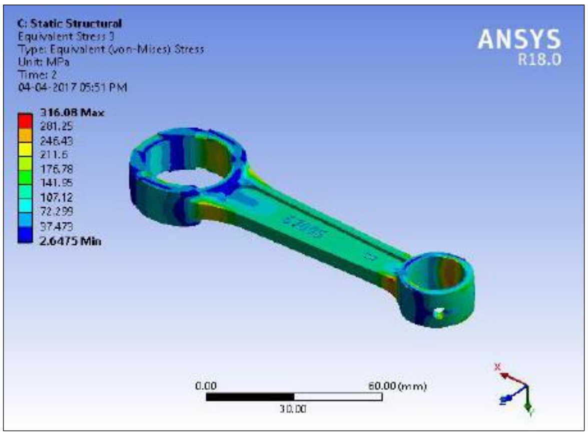


Figure 4.1: Equivalent Stress 2

From the fig 4 the Equivalent von Mises stress occurs at the piston end of the connecting rod is 286.61 MPa and minimum stress occurs at the crank end of the connecting rod is 0.79236 MPa.

From the fig 4.1 the Equivalent von Mises stress occurs at the piston end of the connecting rod is 309.83 MPa and minimum stress occurs at the crank end of the connecting rod is 3.404 MPa.

Total Deformation

It is combined measure of deformation is seen from Figure 7.8 & Figure 7.9 that deformation goes on increasing from fixed support end to free end.

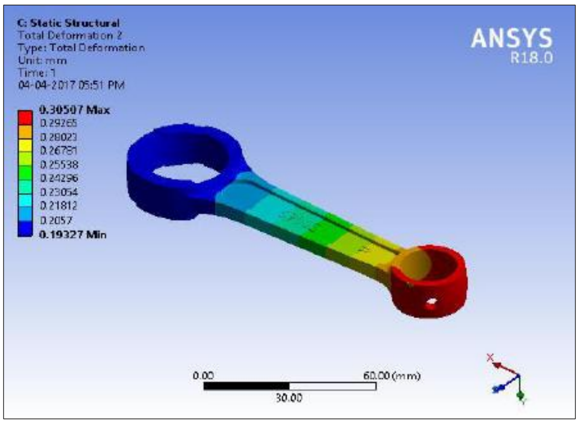


Figure 4.2: Total Deformation1

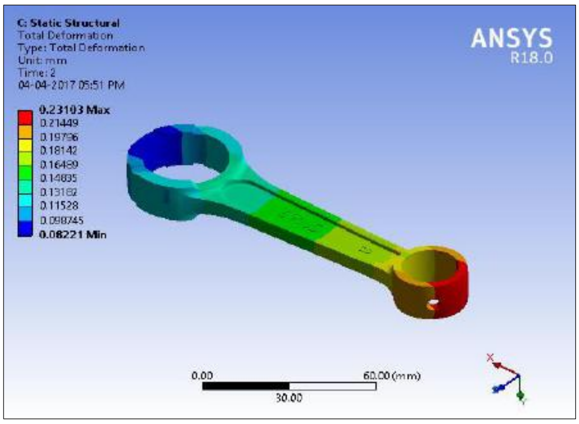


Figure 4.3: Total Deformation 2

From the fig 4.2 the maximum total deformation occurs at the piston end of the connecting rod is 0.3058 mm and minimum total deformation occurs at the crank end of the connecting rod is 0.19397 mm.

From the fig 4.3 the maximum total deformation occurs at the piston end of the connecting rod is 0.23032 mm and minimum total deformation occurs at the crank end of the connecting rod is 0.081685 mm.

Fatigue Analysis

Life

It is number of cycles conrod can withstand before any sign of failure occurs.

Damage

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

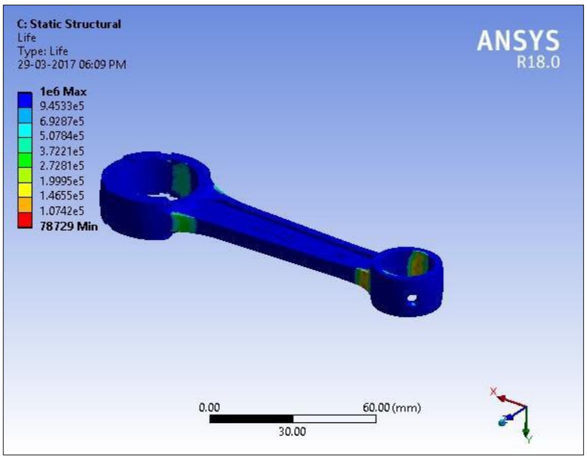


Figure 4.5: Life

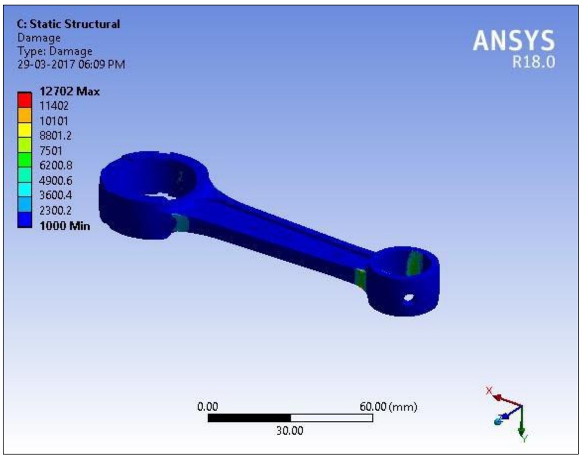


Figure 4.6: Damage

Safety Factor

It is measure of factor of safety for design. Safety factor is Maximum15 is recorded and minimum 0.59368 is recorded. In between moderate FOS is present.

Biaxility Indication

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

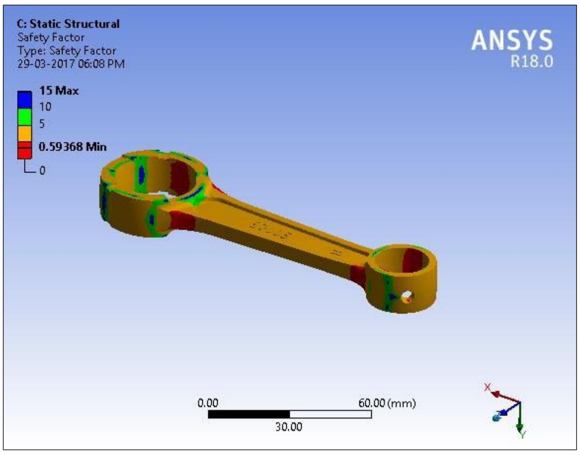


Figure 4.7: Safety Factor

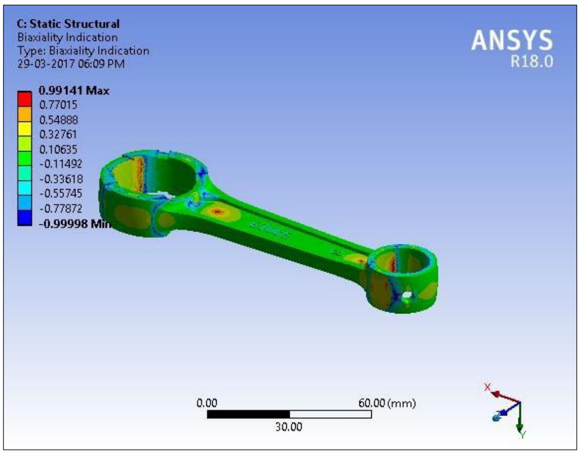


Figure 4.8: Biaxility Indication

Results for Static Loading at Small end with Big end fixed

Table 3: Maximum and Minimum Values of Stress Parameters

Parameter	Time	**Structural Steel**	
		Max	Min
Equivalent Stress (MPa)	Time 1	286.14	0.75019
	Time 2	316.08	2.6475
Total Deformation (mm)	Time 1	0.30507	0.19327
	Time 2	0.23103	0.08221

Fatigue Tool Results

Table 4: Maximum and Minimum Values of Fatigue Parameters

Parameter	Structural Steel	
	Max	Min
Life	1 e^6	78729
Damage	12702	1000
Safety Factor	15	0.59368
Biaxility indication	0.99141	-0.99998

6. CONCLUSION:

The research presented in this thesis has mainly concerned to find a superior alternative to existing connecting rod i.e by modifying geometry. The chapter summarizes the main conclusions from this work and discusses possible improvements.

In this dissertation work, the element stress analysis of connecting rod covers the maximum stresses and structure is expected to sustain, without fatigue failure. The connecting rod is analysed under the load.

- The existing connecting rod is modelled and with the help of fatigue tool a fatigue life is carried out. The modified connecting rod is analysed for same boundary conditions and its mechanical performance is numerically and experimentally evaluated.
- In fatigue we can determine that the minimum and maximum number of cycles can withstand a given connecting rod.
- Maximum stress values observed in the existing and modified connecting rod are 286.14 MPa, 316.08 MPa and 283.23 MPa, 310.62MPa respectively.

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