Design Optimization of Connecting Rod for Static Loading Condition

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Abstract - *The automobile engine connecting rod is a high quantity manufacturing, an important aspect. It connects the reciprocating piston to the rotating crankshaft, transmitting the thrust of the piston to the crankshaft. Each vehicle that uses an internal the primary goal of this project is performing the static and dynamic load analysis, and to explore the weight reduction opportunity of connecting rod. This Has been executed through two cases. The first case includes static load stress analysis and material optimization by looking at the possible weight reduction of connecting rod. Second case includes dynamic load mode frequencies. The geometric Modeling of connecting rod is performed with the aid of using Solidworks. And imported to Ansys work bench R1. The connecting rod analyzed for various stress by applying load and boundary condition. Finite detail analysis of connecting rod is done three materials, finally results are obtained for applied load of connecting rod to check the strength and reduction of weight through material optimization of connecting rod. Modeling of connecting rod is executed by using optimization of the connecting rod is performed under equal boundary and loading conditions combustion engine calls for as a minimum one connecting rod depending upon the range of cylinders.*

Key Words*: *Connecting Rod, SolidWorks, Ansys, Static loading

1. INTRODUCTION

The automobile engine connecting rod is a crucial component that is manufactured in large quantities. It links the revolving piston to the spinning crankshaft, transferring piston thrust to the crankshaft. Depending on the number of cylinders in the engine, any vehicle that uses an internal combustion engine needs at least one connecting rod leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow. A connecting rod can also be used to convert rotational motion into reciprocating motion, which is what it was designed for in the first place. Earlier devices, such as the chain, should only be used for pulling. Because connecting rods are stiff, they can only transfer push or pull, allowing the rod to rotate the crank by half a turn. The connecting rod is the only item that needs to be pushed in certain two-stroke engines. connecting rod is well-known for its usage in internal combustion piston engines, such as those seen in automobiles. These are very different from the connecting rods They were originally utilized in locomotives and steam engines The connecting rod connects the piston to the crank or crankshaft in a reciprocating piston engine. For the most part, connecting rods in contemporary car internal combustion engines are made of metal, but they can also be constructed of aluminium or titanium (for lightness and the ability to absorb excessive stress at the price of sturdiness) (for a mixture of electricity and lightness at the fee of affordability). For high-performance engines and motorbikes and scooters, forged iron is used.

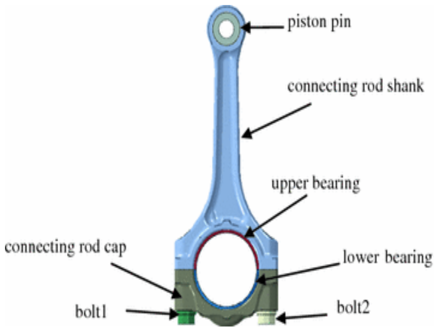

Fig - 1: Basic component of connecting rod

Figure [1] shows basic component of connecting rod which include piston pin, connecting rod shank, upper bearing, lower bearing, connecting rod cap and bolts.

1.1 The Piston Pin

Fig - 2: The piston pin

Also known as a gudgeon pin or wrist pin shown in Figure.2 The piston pin, is press-fit into the tiny end. into the connecting rod but may spin inside the piston, creating a "floating wrist pin" configuration. The reciprocating force produced by the piston puts immense strain on the connecting rod, which honestly extends and compresses with each round, and the load grows to the third power as engine speed increases.

1.2 Upper bearing and Lower bearing

Fig - 3: Upper and lower bearing

piston pin here are two sections: upper and bottom. Connecting rod bearings allow the crank pin to rotate within the connecting rod, shows fig.3: upper and lower bearing transmitting the cycle stresses to the piston. Connecting rod bearings are installed in the connecting rod's big end. The detachable portion of a two-piece connecting rod that serves as a bearing surface.

2. LITERATURE REVIEW

The ANSYS simulation tool was used to examine the connecting rod fatigue of a universal tractor (U650) and predict its lifespan. The purpose of this study was to demonstrate how fatigue phenomena caused by cyclic loadings impact connecting rod behaviour and to use the findings to save time and money, which are two extremely important factors in manufacturing. The findings show that completely reverse loading may be used to predict the lifespan of a connecting rod as well as identify crucial places where fracture development is more likely to begin. Furthermore, the maximum number of load cycles allowed was increased to 108 by adopting completely reverse loading. It is proposed that the findings might be used to make changes to the production process for connecting rods. Mirehei et al. [1] Mercedes-Benz employs a detailed studies on computational method that makes use of motor component examples. According to them, 2D FE models may be used to get fast pattern proclamations, while 3D FE models can be used for more precise inspection. The many individual loads following up on the associated pole were used for replication, and actual pressure dispersion was obtained via superposition. The piles comprised latency weight, firing load, bearing shell press assault, and bolt powers. There were no discussions about streamlining or weakening in particular. Balasubramaniam et al. [2] The stress version of the connecting rod was measured at the column center and bottom, as well as the bending strain at the column middle. The maximum tensile stress does not occur at 360-degree crank angle or top useless center at higher engine speeds, as indicated by the values 1.5 and 1.6. It was also observed that the r ratio varies with location, and that it also varies with engine speed at a particular place. At 12000 rev/min, at the column center, the greatest bending strain significance was determined to be around 25% of the maximum tensile pressure during the same cycle (0-to-720-degree crank angle) Ishida et al. [3]. The experiments included specimens that had been subjected to stress. Checking using specimens derived from connecting rods and stress-controlled bench testing of connecting rods In monotonic and cyclic deformations, stress and deformation behavior are studied. The controlled fatigue properties of several materials are investigated and compared. The stress attention factors were calculated using FEA, and the mean pressure impact was accounted for using the modified Goodman equation. An internal combustion engine (ICE) is a type of internal combustion engine that uses the connecting rod is the most strained component. Various strains appear on it during its functioning. Because of fuel stress and whipping stress, the impact of compressive strain is enhanced Afzal et al. [4]. In his study, he changed the size of an existing tractor engine connecting rod arrangement. This analysis is performed under static and fatigue loads. For validation of a few strain and fatigue parameters, optimization was performed under equal boundary and loading conditions. The critical areas below static and fatigue analyses are identified and upgraded. The connecting rod was designed and improved for weight reduction, increased longevity, and manufacturability. The material was maintained same, and a massive trade was discovered in von Mises strain. Under static stress circumstances, 9.4 percent less strain was discovered at a critical location. Only five grammes of weight were lost, which is extremely little. As a result, we may conclude that not only chemicals, but also layout factors, can be taken into account for optimization. The fatigue behavior of forged metallic and powder steel connecting rods were addressed Gupta [5]. The 3-D finite element technique was used to analyses the stress distribution, safety component, and fatigue lifestyles cycle of a connecting rod. The results show that at maximum compression, the exposed destructive function became the transition region of the small end and connecting rod shank. The maximum stress was increased to 303 MPa. Safety concerns emerged 1.24. At maximum extend, the revealed unfavorable function became i-fashioned pass-through at enormous give-up. The majority of pressures rose to 118 MPa. The safety factor was 3.19. And the structure of the connecting rod evolved. The connecting rod's protection component and fatigue lifestyles cycle will be extended. Maximum stress reduces during structural development, and both the protective thing and the fatigue lifestyles cycle grow Yongqi et al. [6].

3. OBJECTIVE OF STUDY

The purpose of this study was to optimize the material of the connecting rod for its weight. The process of optimization starts with determining the appropriate load conditions and magnitudes. By eliminating material from areas with lower stress concentration. Industrial software, such as Ansys Workbench 19.2, is used to solve problems using the finite element method and to model them using Solidworks.

1. View may be used to get variation values such as compression load. However, in most cases, the

worst-case load is taken into account throughout the design process.

2. According to a review of the literature, scientists utilize the maximum One extreme load is the inertia load of the piston assembly mass. related to the compression weight.
3. Static linear analysis is used to determine the structural safety.

4. METHODOLOGY

This chapter explains about the step-by-step methods which are carried out to accomplish this study. Using Solidworks solid mode l of connecting rod Geometric Modeling. The three-dimensional model produced using 3D software is exposed to stress conditions and strain displacements in this case. Finite Element Model The three-dimensional model produced in Solidworks is imported into the FE programme ANSYS and meshed, and this model is referred to as a Finite elemental model.
Suitable Boundary Conditions (sensitivity analysis) Ansys is used to do sensitivity analysis on the meshed model after it has been exposed to specific boundary conditions.
FEM Procedural Steps

- Modeling
- Continuum Description
- Choosing an appropriate interpolation model
- The creation of an element stiffness matrix
- Putting together element equations to get the equilibrium equations
- Applying the boundary condition
- Solution of a system equation to obtain nodal displacement values
- Elements strains and stresses are computed.

5. MATERIALS AND METHODS

5.1 Stainless steel

Table -1: Stainless steel chemical composition

Material	In %
Carbon	0.12
Manganese	7.5/10
Silicone	0.9
Chromium	14/16
Nickel	0.5/2.0
Molybdenum	0.2
Phosphorus	0.06
Nitrogen	0.25

Table 2: Mechanical Properties of Stainless steel

Properties	MPa
Tensile Strength	505
Yield Strength	215
Elongation	55
Modulus of Elasticity	200+3
Poisson's Ratio	0.3

5.2 Aluminium 360

Table - 3. Aluminium 360 chemical compositions

Alloy composition	In %
Silicon	9.5-10.5
Iron	1.30
Copper	0.60
Manganese	0.35
Magnesium	0.4-0.6
Nickel	0.50
Zinc	0.50
Tin	0.15
Others	0.25
Aluminium	Balance

Table - 4: Mechanical properties

Properties	Values
Tensile Strength (MPa)	317.159
Yield Strength (MPa)	165.474
Elongation (%)	3.50
Hardness (HB)	75
Shear Strength (MPa)	179.264
Fatigue Strength (MPa)	124.106

Density	0.095

5.3 E- Glass epoxy

Table - 5: Mechanical properties

Properties	Values
Compressive strength-longitudinal (MPa)	301
Compressive strength –transverse (MPa)	416
Density (g cm-3)	1.9
Tensile strength-longitudinal (MPa)	495

5.4 Engine Specification and Calculations

1) Engine Capacity: 109.20 cc
2) Power developed: 5.910kw @ 700rpm
3) Torque developed: 8.940 Nm @ 5500 rpm
4) Stroke: 55.60 mm
5) Bore: 50 mm
6) Compression ratio: 9.5:1
7) Density of petrol: =737.220kg/m3=737.220E-9 kg/mm3
8) Flash point for petrol (Gasoline) Flash point = -43°c (-45°F)
9) Auto ignition temp. = 280°c (536°F) = 553° k
10) Mass = Density x volume = 737.22E-9 x 109.1E3 = 0.08kg
11) Molecular weight of petrol = 114.2280 g/mole = 0.114230 kg/mole

From gas equation, PV=m * R specific * T Where, P = Pressure, MPa V = Volume m = Mass, kg R specific = Specific gas constant T = Temperature, °k R specific = R/M R specific = 8.31430/0.1142280 R specific = 72.760 Nm/kg K
P = m. R specific. T/V
P = (0.08 x 72.7570 x 553) / 109.2e3 = 29.47710 MP

5.5 Geometry

In the figure 4 show the dimension of the connecting rod where inner diameter of small end 18mm outer diameter of small end 30mm inner diameter of big end 30mm outer diameter of bib end 50mm

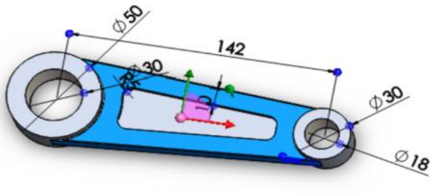

Fig - 4: Dimension of connecting rod

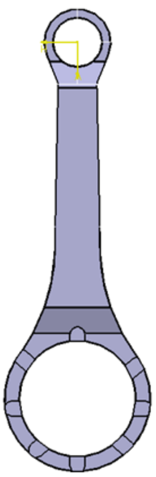

Fig - 5: without cutout

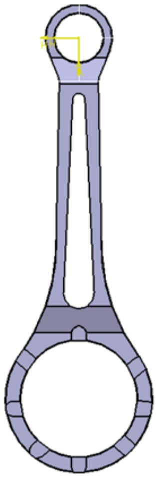

Fig - 6: with cutout

In the figure 5 and 6 shows without cutout of connecting rod and with cutout of connecting rod.

5.7 Meshing

Fig – 7: Meshing connecting rod with cutout

The above fig 7shows the Connecting Rod Meshed Model, has the Maximum number of elements (262888) as shown in figure.

Table – 6 Type of element and tetrahedrons

Particulars	Values
Type of element	Tetrahedrons
No of element	262888
No of nodes	56800
Aspect Ratio	2.6

5.8 Boundery Conditions

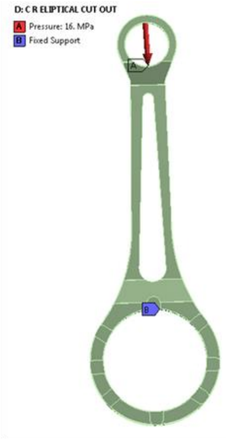

Fig – 8: Boundery Conditions of connecting rod

Fig [8]. Connecting rod with cut out. Pressure of 16 MPa is applied at small end and the bigger end is fixed. The Pressure of 16 MPa is exerted by the piston during combustion of fuel inside the engine cylinder.

6. RESULT AND ANALYSIS USING ANSYS

6.1 Static Analysis of Stainless Steel

a) Equivalent Stress

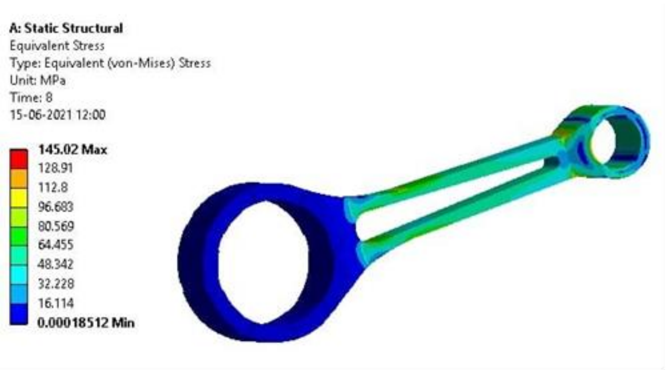

Fig – 9: Linear Von-Mises stress is 145.02MPa

Fig [9]: linear Von-mises connecting rod. From the fig it is observed that connecting rod the Von-mises stress is found to be maximum at the small end is equal to 145.02 MPa.

b) Minimum Principal Stress

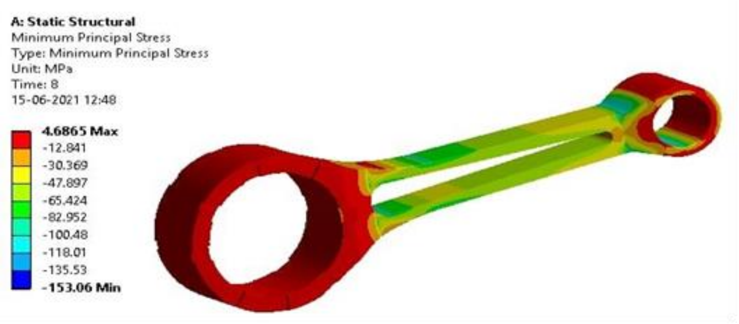

Fig – 10: Minimum principal stress is 4.6865 MPa

Fig [10] shows minimum principal stress for FEA results of Connecting rod. Due to the load and its boundary conditions, the minimum principal stress found at 4.6865 MPa.

b) Maximum Principal Stress

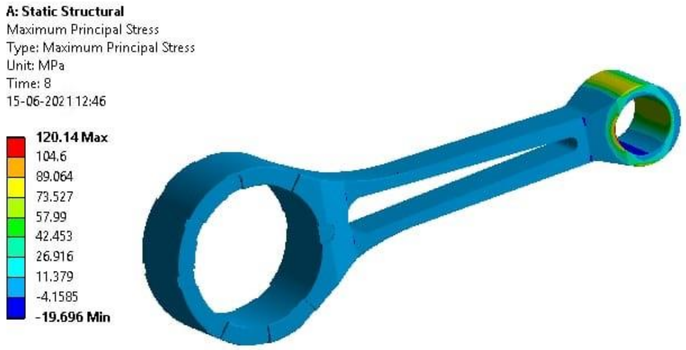

Fig – 11: Maximum principal stress is 120.14 MPa

Fig [11] shows Maximum principal stress for FEA results of Connecting rod. Due to the load and its boundary conditions, the Maximum principal stress found at 120.14 MPa.

c) Total Deformation

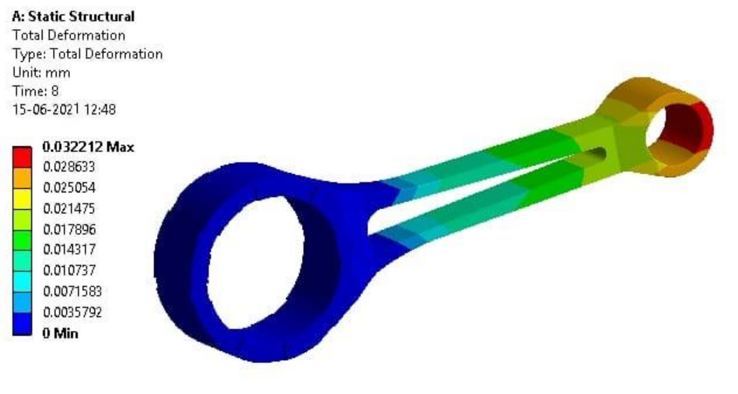

Fig – 12: Total deformation is 0.032212

Fig [12]: Total deformation obtained is 0.032212 mm for the applied load condition and boundary conditions.

6.2 Aluminium 360

a) Equivalent stress

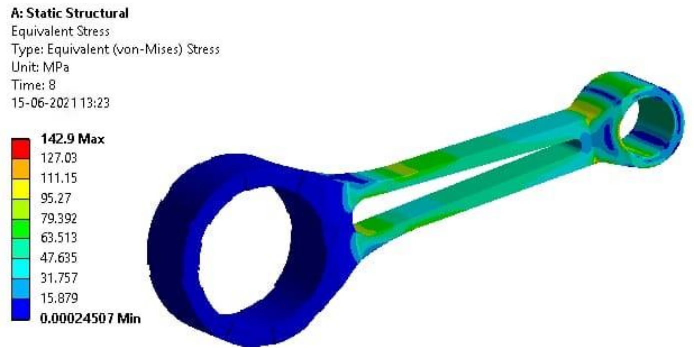

Fig – 13: Linear Von-Mises stress is 142.9 MPa

Fig [13]: linear Von-mises connecting rod. From the fig it is observed that connecting rod the Von-mises stress is found to be maximum at the small end is equal to 142.9 MPa.

b) Minimum Principal Stress

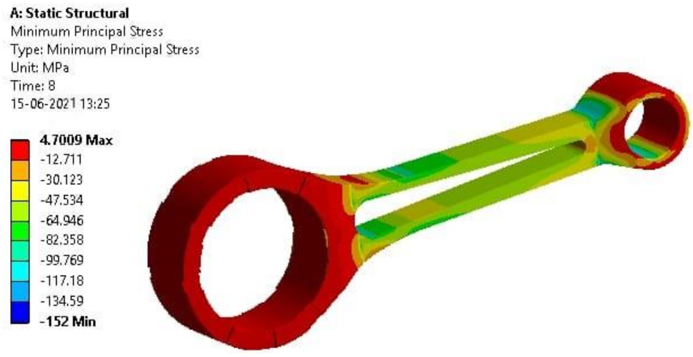

Fig – 14: Minimum principal stress is 4.7009 MPa

Fig [14] shows minimum principal stress for FEA results of Connecting rod. Due to the load and its boundary conditions, the minimum principal stress found at 4.7009 MPa.

b) Maximum Principal Stress

Fig – 15: Maximum principal stress is 120.22 MPa

Fig [15] shows Maximum principal stress for FEA results of Connecting rod. Due to the load and its boundary conditions, the Maximum principal stress found at 120.22 MPa.

c) Total deformation

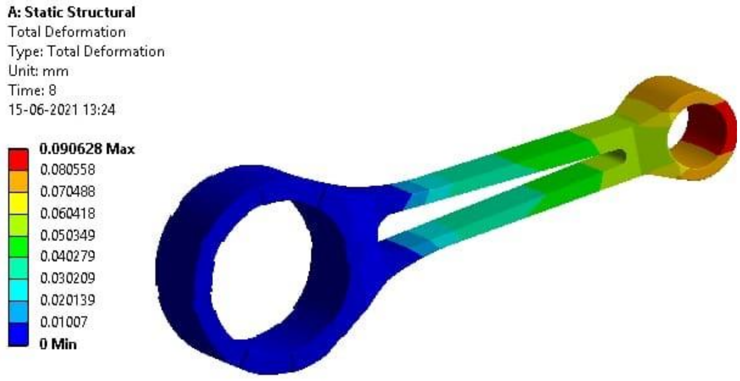

Fig – 16: Total deformation is 0.090628

Fig [16]: Total deformation obtained is 0.032212 mm for the applied load condition and boundary conditions.

6.3 E- Glass Epoxy

a) Equivalent Stress

Fig – 17: Linear Von-Mises stress is 143.88 MPa

Fig [17]: linear Von-mises connecting rod. From the fig it is observed that connecting rod the Von-mises stress is found to be maximum at the small end is equal to 143.88 MPa.

b) Maximum Principal Stress

Fig – 15: Maximum principal stress is Mpa

Fig [18] shows Maximum principal stress for FEA results of Connecting rod. Due to the load and its boundary conditions, the Maximum principal stress found at 127.34 MPa

c) Minimum Principal Stress

Fig – 16: Minimum principal stress is 5.7023 MPa

Fig [16] shows minimum principal stress for FEA results of Connecting rod. Due to the load and its boundary conditions, the minimum principal stress found at 5.7023 MPa.

d) Total deformation

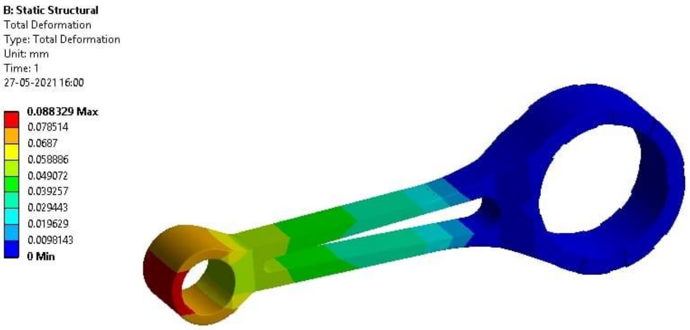

Fig – 17: Total deformation is 0.0088329

Fig [17]: Total deformation obtained is 0.0088329mm for the applied load condition and boundary conditions.

7. RESULTS AND DISCUSSIONS

7.1 Static Analysis of Stainless steel

CASE1: When loads are applied to the body of a connecting rod, the body deforms and the load effect is conveyed throughout the small end and big end. Internal forces and reactions are induced by external loads, bringing the body into stability. Static analysis is carried out for the connecting rod pressure applied for small end and static analysis calculates displacement, maximum stress, minimum stress and equilibrium stress and the readings are tabulated in the table [7]

Table - 7. Results of Static Analysis of Stainless steel

Material Stainless steel	
Weight KG	1.500
Total deformation mm	0.033199
equivalent Stress MPa	145.02
Maximum stress MPa	121.66
Minimum stress MPa	5.7427

7.1 Static Analysis of Aluminium 360

CASE 2: When loads are applied to the body of a aluminium360 connecting rod, the body deforms and the load effect is conveyed throughout the small end and big end. Internal forces and reactions are induced by external loads, bringing the body into stability. Static analysis is carried out for the connecting rod pressure applied for small end and static analysis. calculates displacement, maximum stress, minimum stress and equilibrium stress and the readings are tabulated in the table [8]

Table - 8. Results of Static Analysis of Aluminium 360

Material Aluminium 360	
Weight KG	1.201
Total deformation mm	0.090628
equivalent Stress MPa	142.9
Maximum stress MPa	120.22
Minimum stress MPa	4.7009

7.1 Static Analysis of E Glass

CASE3: When loads are applied to the E Glass body of a connecting rod, the body deforms and the load effect is conveyed throughout the small end and big end. Internal forces and reactions are induced by external loads, bringing the body into stability. Static analysis is carried out for the connecting rod pressure applied for small end and static analysis calculates displacement, maximum stress, minimum stress and equilibrium stress and the readings are tabulated in the table [9]

Table - 9. Results of Static Analysis of E Glass

Material E Glass	
Weight KG	0.72145
Total deformation mm	0.088329
equivalent Stress MPa	143.88
Maximum stress MPa	127.34
Minimum stress MPa	5.7023

- Connecting rod structure of an engine was analyzed using FEM technique to verify structural strength.
- It is observed from FEM analysis, that the stress and deflection values are within the permissible limits and meets requirement of the specification

8. CONCLUSIONS

Existing design of connecting rod is re-optimized by considering same boundary and loading conditions under static and fatigue loading. The maximum stress, strain, and deformation in the connecting rod were estimated using linear static structural analysis. Peak stress of 143.88 Mpa and total deformation of 0.088329 mm are achieved. Weight of 0.72154 kg in connecting rod, which is optimized to improve efficiency and longevity the optimization of connecting rod, is improved significantly.

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