Design, Analysis And Manufacturing of 150cc IC Engine Connecting Rod Using Composite Material

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Abstract- *Connecting rod interconnects piston to crankshaft and it is responsible for transferring power from piston to the crankshaft and sending it to the transmission. Advance materials application in automotive industries shows that Connecting Rods can be manufactured using composite materials to enhance its strength and reduce the weight without compromising its strength. The Objective of this project work is, to analyze the performance of connecting rod when it is made of E Glass, S Glass and Carbon epoxy Composite in terms of stress and Deformation. Connecting rod of Honda Unicorn 150cc engine is considered. Theoretical designing of connecting rod is done as per standard connecting rod design procedure. 3D modeling is done using Solidworks 2018 software and Finite Element analysis software ANSYS Workbench 18.2 is used. Connecting rod was analyzed for stress and Deformation using FEA using E Glass, S Glass and Carbon epoxy Composite and Results were compared with AISI 4340 Steel. The results of Finite element analysis shows that S-Glass Composite material will perform better compared to Other Composite materials. FOS is also higher when connecting rod is made of S-Glass Composite where as AISI 4340 designed only for FOS 2. Hence S-Glass will be the best competitive material for manufacturing of Connecting Rod.*

Keywords- Connecting Rod, Composite Materials, FEA, FOS.

I. INTRODUCTION

A connecting rod is a major link inside combustion engine. It connects the piston to a crankshaft and is responsible to transfer power from the piston to a crankshaft and sending it to the transmission. There are different types of materials and production methods are used in the creation of connecting rods. The most common types of materials used for connecting rods is steel and aluminium.

Connecting rod interconnects the piston and the crank shaft and transmits the gas forces from the piston to the crankshaft. Without Connecting rod it is difficult to convert the reciprocating motion of the piston into rotary motion of the crankshaft. Connecting rod is subjected to the complex state of loading. Rod undergoes high cyclic loads of the order 10^8 to 10^9 cycles, which ranges from high compressive loads due to the combustion, to high tensile loads due to the inertia. Therefore, durability of this Connecting Rod is critical importance. Typical parts of connecting rod are as shown in fig.

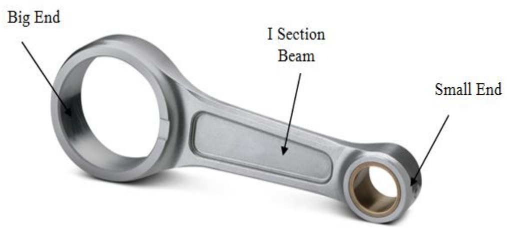

Figure 1. Basic parts of Connecting Rod

It consists of three main part

1. A pin End (Small end)
2. A Shank Section (Middle)
3. A Crank End (Big end).

Whereas bending stresses are caused due to the Centrifugal effects. To provide the maximum rigidity with minimum weight, the cross section of a connecting rod is made as and I – section end of the rod is a solid eye or a split eye this end holding the piston pin.

The big end works on a crank pin and is always split. In some connecting rods, the hole is drilled between two ends to carry lubricating oil from big end to small end for the lubrication of piston and the piston pin.

II. LITERATURE REVIEWS

Arshad Mohamed Gani P, Vinithra Banu T.

The aim of this project work is to design and Analyze a connecting rod of the two wheeler SUZUKI BIKE of 150cc. An attempt is made to replace currently used material i.e.

carbon steel by Aluminium reinforced boron silicide. 3D Modelling is done by CATIA V5 Software and Finite Element analysis for static strength calculation is done using ANSYS workbench software. The results shows that Aluminium reinforced boron silicide used for manufacturing of connecting rod reduces the weight by 50% and also increase in the fatigue life.

Sushant, Victor Gambhir:

The author has studied the performance of the connecting rod made of two different materials i.e. Carbon 70 steel and Aluminum 7068. Analytical calculations are done to find the thickness of the connecting rod and other parameters are calculated by using the pressure of gas on the piston. FEA software ANSYS Workbench 14.0 is used to study the nature of the connecting rod made of two different materials in terms of stress, deformation and strain. We concluded that connecting rod made of aluminum 7068 perform better as compared to carbon 70 steel.

Prateek Joshi, Mohammed Umairzaki

The objective of the paper is to find out the load, strain & stress analysis of the crank end of the connecting rod of different materials such as High Strength Carbon Fiber, Stainless Steel and Aluminium Alloy. The result can be used for optimization for weight reduction and for design modification of connecting rod. It was concluded that High Strength Carbon Fiber can be used for connecting rod but due to very high manufacturing cost it is effective to use stainless steel or Aluminum Alloy.

III. OBJECTIVE AND PROBLEM DEFINITION

3.1 Objective

- To Design a Connecting Rod using E-Glass, S-Glass and Carbon Glass composting materials
- To analyze the performance of the connecting rod made of composite material in terms of strength using finite element analysis with Steel Connecting Rod
- To manufacture and test the Rod to validate the experimental results with simulation values

3.2 Problem Definition

Existing design of connecting rods are manufactured using most commonly used steel materials. These materials have high density and less resistance to High temperature, resulting in Recent Advancement in Composite material will help the design engineers to think beyond the boundaries to design and manufacture existing automotive parts using new composite materials.

IV. METHODOLOGY

Designing of Connecting rod is a very critical task in internal combustion Engine design. It requires Study of working conditions of the engine. This includes Stroke length, Gas pressure after combustion which acts on the piston, Piston Diameter etc. Designing of connecting rod starts with the pressure which acts on the piston which is converted in terms of force on the piston. This force is the design parameter for connecting rod design. This force which tends the rod to buckle in motion because of its other fixed end condition.

Using this buckling load other design parameters are calculated i.e. diameter of large and, diameter of smaller end, Web thickness and distance between the two ends. Once the all the design parameters are calculated using standard design proportions 3D modeling is done using CAD software. Solid works 2018 is used for 3D modeling of the component because of its comfortable GUI.

Existing Connecting rods are made of commonly used materials. In this project composite materials are studied and best suited metal matrix composite is selected for the manufacturing point of view. Selection of composite out of number of available composite material is made using weighted residual method.

Finite element method was used to study the working nature of the connecting rod for exiting and advance composite materials. ANSYS 18.2 was used to simulate its working nature and Stress and deformation values are calculated. ANSYS results are compared with theoretical values to calibrate the results. Theoretical calculation is done using basic fundamentals of engineering. It also finds the amount of weight reduced and saving in the cost so the composite can be referred in place of metals in the design of composite

V. PROPERTIES OF MATERIAL USED

Sr. No.	Properties	AISI 4340	E-glass FRP	S-glass FRP	Carbon Epoxy
1	Density	7850 Kg/m3	2100 kg/m3	2490 kg/m3	1600 Kg/m3
2	Young Modules in Axial Direction	205GPa	45GPa	55GPa	140Gpa
3	Young Modules in Transverse Direction	205GPa	12GPa	16GPa	10Gpa
4	Poisons ratio	0.285	0.28	0.27	0.27
5	Ultimate Strength	415MPa	2275MPa	3970MPa	1900Mpa

VI. DESIGN FOR CONNECTING ROD PARAMETERS

6.1 specifications of engine considered.

Consider a 150cc Honda Unicorn Engine

Engine type air cooled 4-stroke
Bore × Stroke (mm) = 57×58.6
Displacement = 149.5CC
Maximum Power = 13.8bhp at 8500rpm
Maximum Torque = 13.4Nm at 6000rpm
Compression Ratio = 9.35/1

6.2 properties of petrol and buckling load calculation for connecting rod

Density = 737.22 × 10-9kg/mm3
Molecular weight = 114.228 g/mole
Ideal gas constant of air = 8.3143 J/mol k
Rsp Gas constant = R/M
= 8.3143/0.114228
= 72.79 J/kg k
Pressure of petrol acting on the piston due to combustion is calculated by Ideal Gas Equation

From gas equation,

PV=m.Rspecific.T

Where, P = Pressure, V = Volume, m = Mass

Rspecific = Specific gas constant

T = Temperature Mass = density * volume,
m=737.22E-9*150E3; m = 0.11 kg
Rspecific = R/M
Rspecific = 8.3143/0.114228
Rspecific = 72.76
P = m.Rspecific.T/V
P = 0.11*72.76*288/150E3
P = 15.45 MPa

Force acting on connecting rod is due to gas pressure which is called as gas force

Gas force = Area × Pressure

Gas force = ∏ /4 x D^2 x P
= 39429.78 N

System always design for max force hence buckling force acting on connecting rod is given by,
Buckling force Wb = Gas force × FOS
Assuming FOS= 2
Wb = 39429.78 × 2= 78859.56 N

6.3 Design calculations for Connecting Rod

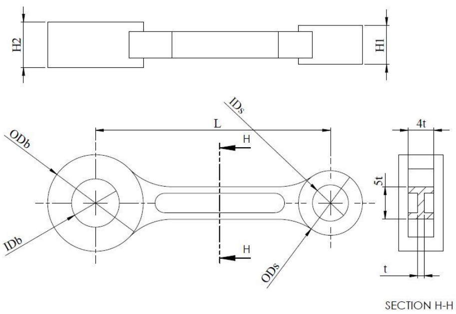

Figure 2 Standard Dimensions for Connecting Rod

For AISI 4340
Yield Stress σ c = 415 N/mm2
Young Modules E = 2.15 × 105 N/mm2

$$78859.57=\frac{415\times 11t^2}{1+\frac{415}{2.15\times 10^5}\times\frac{0.0319\times(2\times 58.6)^2}{t^2}}$$

$$78859.57=\frac{4565t^2}{1+\frac{0.8457}{t^2}}$$

$$78859.57=\frac{4565t^4}{t^2+0.8457}$$

$$4565t^4-78859.57t^2-66691.59=0$$

t2 = 18.08
t = 4.25 mm
Width B = 4t = 17 mm
Height H = 5t = 21.25mm
Area A = 198.68 mm2

Height at big end H_1 = (1.1 to 1.25) H
= 1.1 H = 23.77 mm
Height at small end H_2 = (0.75 to 0.9) H
= 0.85 H = 18.06 mm
Outer diameter of smaller end = $d_1 + 2t_b + 2t_m$
Where,
t_b=Thickness of bush = 2 to 5 mm

Inner diameter of small end

$$d_1 = \frac{F_g}{P_b \times l_1}$$

Where F_g = Gas force

P_b = bearing pressure for small end = (12.5 to 15) N/mm^2

Assume P_b = 15 N/mm^2

l_1 = length of piston pin = (1.5 to 2) d_1

Take $l_1 = 2d_1$

$$d_1 = \frac{39429.78}{15 \times 2d_1}$$
$$= 36.25mm$$

Assume, t_b = 2mm
Marginal thickness = 5 to 15 mm
Assume, t_m = 5mm

Outer dia. of smaller end = 36.25 + 2×2 +2×5
= 50.25 mm
Inner diameter of big end

$$d_2 = \frac{F_g}{P_b \times l_2}$$

Where,
Pb= (10.8 to 12.6) N/mm2
Assume, Pb = 12.6N/mm2
l_2 = (1 to 1.25) d_2
Take $l_2 = 1.25d_2$

$$d_2 = \frac{39429.78}{12.6 \times 1.25}$$
$$= 50.03mm$$

Outer diameter of Larger End = $d_2 + 2t_b + 2t_m$
= 50.03+ 2×2 + 2×5
= 64.03 mm

Similarly by using material properties of all other materials their respective dimensions are calculated. Their dimensions are as follows.

Specifications of the connecting rod	AISI 4340	E-glass	S-glass	Carbon Epoxy
Thickness of the connecting rod	4.25 mm	3.1733 mm	2.91mm	2.64mm
Width of the section	17 mm	12.69 mm	11.64mm	10.56mm
Height of the section	21.25 mm	15.86 mm	14.55mm	13.2mm
Height at the big end	23.77 mm	17.45 mm	16.005mm	14.52mm
Height at the small end	18.06 mm	13.48 mm	12.36mm	9.9mm
Inner diameter of the small end	36.25 mm	36.25 mm	36.25 mm	36.25 mm
Outer diameter of the small end	50.25 mm	50.25 mm	50.25 mm	50.25 mm
Inner diameter of the big end	50.03 mm	50.03 mm	50.03 mm	50.03 mm
Outer diameter of the big end	64.03 mm	64.03 mm	64.03 mm	64.03 mm

6.4 cad model prepared using solidworks software

3D Modelling of Connecting rods as per Design Calculations in Solidworks 2018

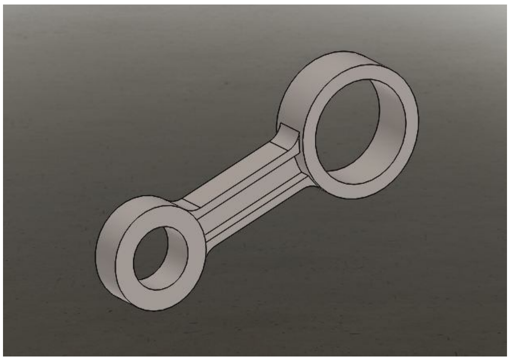

Figure 3 CAD Model for AISI 4340

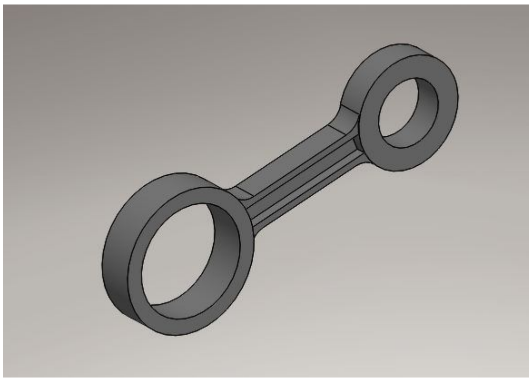

Figure 4 CAD Model for E-Glass

Figure 5 CAD Model for S-Glass

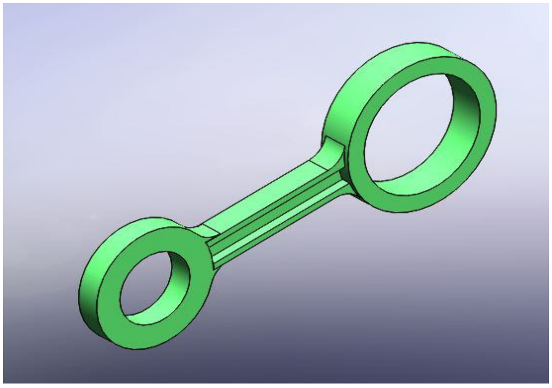

Figure 6 CAD Model for Carbon Epoxy

VII. FEA SIMULATION FOR CONNECTING ROD

ANSYS Workbench 18.2 is used for FEA.
Mesh size is 2 mm.
Automatic mesh is used.
ANSYS simulation is done for four materials.

7.1 Boundary Conditions

Connecting rod is assumed to be fixed at small end and subjected to compressive bearing load at the Big end.

- Fixed support at small end
- Load of 39430N in x-direction at big end

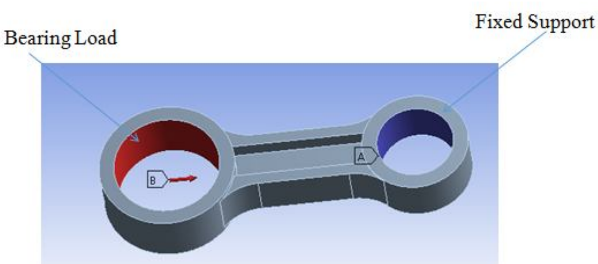

Figure 7 Boundary Conditions for FEA Analysis

7.2 Meshing

Mesh size is 2 mm.
Automatic mesh is used.

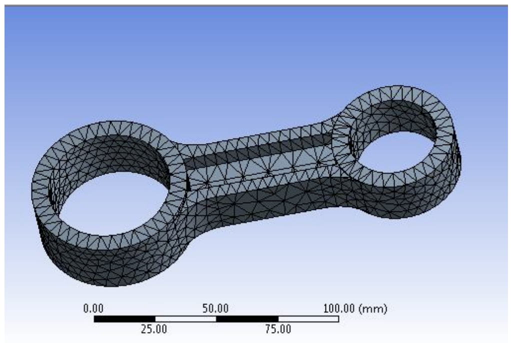

Figure 8 Meshing

Details of mesh are as given below
No of Nodes = 7185
No of Elements = 3802

7.3 FEA Simulation Results for connecting Rod

7.3.1 Equivalent Stresses

Equivalent stresses for connecting Rod made of different materials are as follows

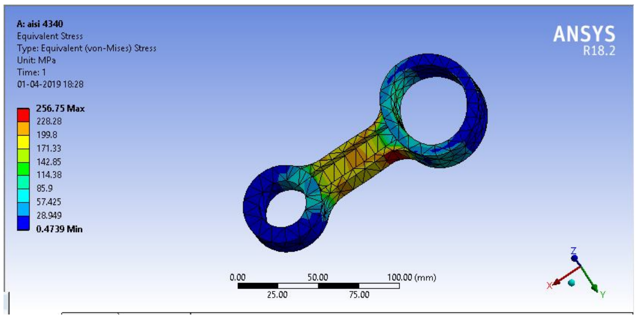

Figure 9 Equivalent Stresses for AISI 4340

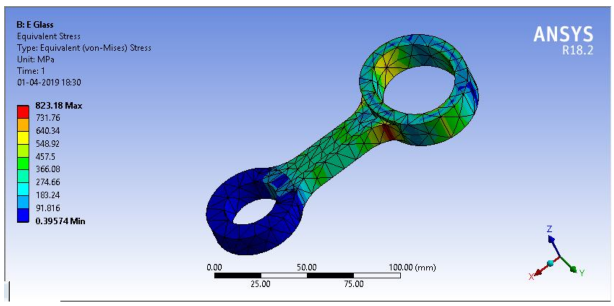

Figure 10 Equivalent Stresses for E-Glass

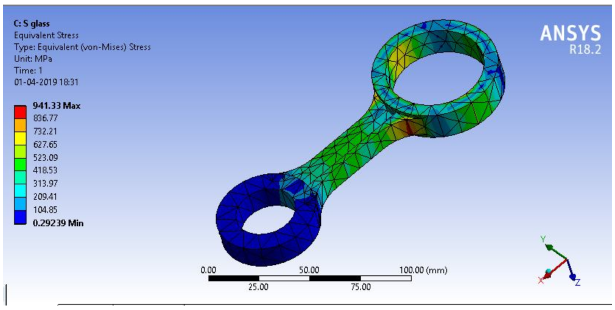

Figure 11 Equivalent Stresses for S-Glass

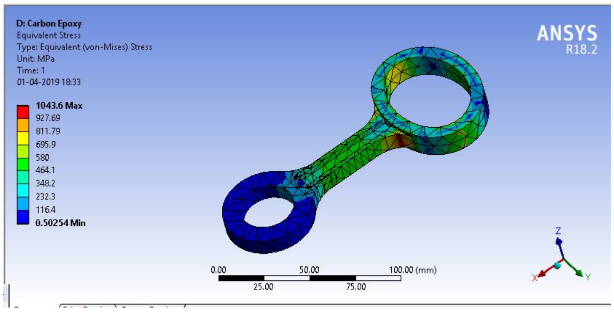

Figure 12 Equivalent Stresses for Carbon Epoxy

7.3.2 Total Deformation

Total Deformation for connecting Rod made of different materials are as follows

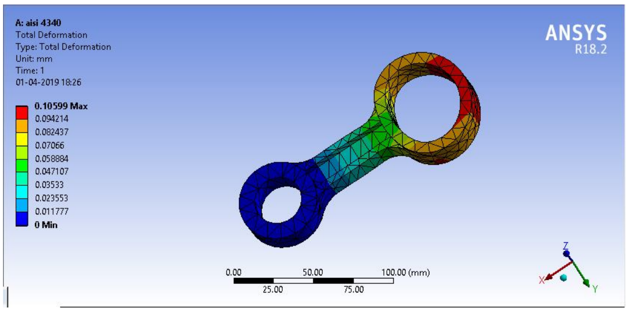

Figure 13 Total Deformation for AISI 4340

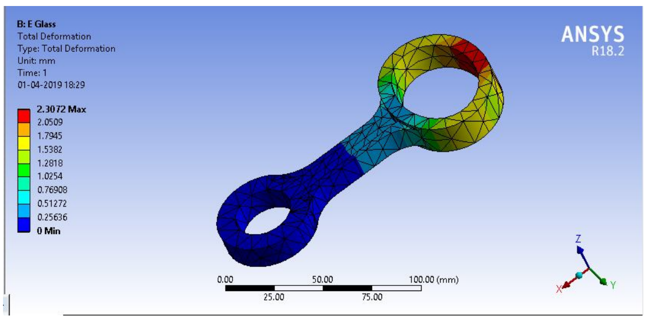

Figure 14 Total Deformation for E-Glass

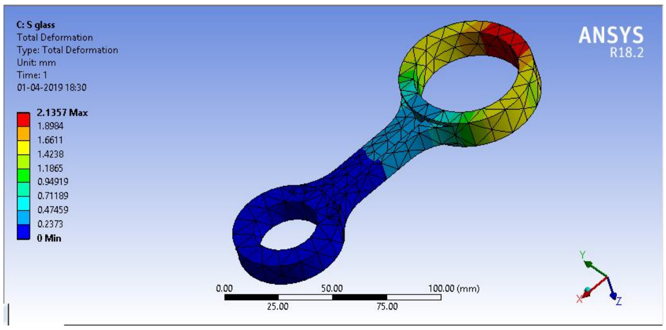

Figure 15 Total Deformation for S-Glass

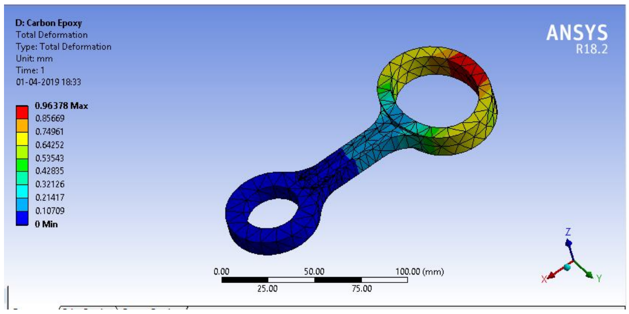

Figure 16 Total Deformation for Carbon Epoxy

7.3.3 Fatigue Analysis for connecting Rod made of S- Glass Material

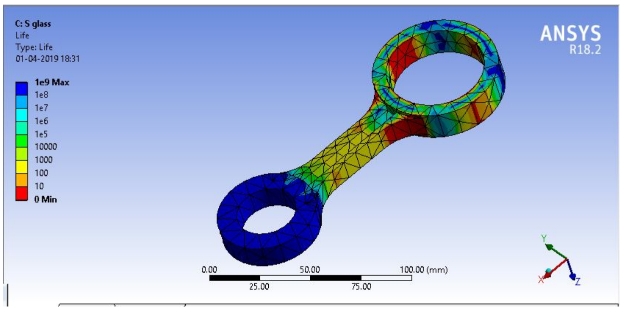

Figure 17 Total Life Distribution for Connecting rod made up of S Glass

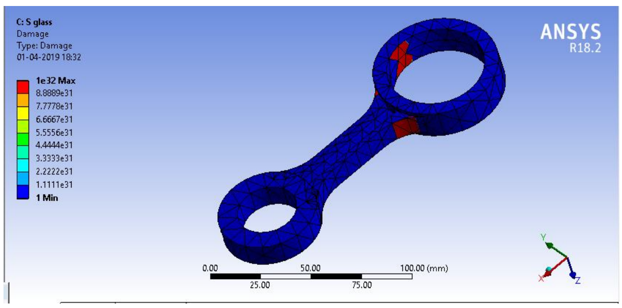

Figure 18heDamage Factor for Connecting rod made up of S Glass

7.4 Results

FEA Results for stress analysis using ANSYS softwrae is as follows

Material	Max . Stress	Max. Deformation	FOS	Weight, gms
AISI 4340	256.69MPa	0.1056mm	1.62	522.71
E-glass	823.18MPa	2.3072 mm	2.76	99.16
S Glass	941.33 MPa	2.1357 mm	4.21	106.72
Carbon Epoxy	1043.6 MPa	0.9637mm	1.821	56.62

VIII. CONCLUSION

- Gas pressure was calculated by given details and accordingly other values were founded. Based on these Dimensions a CAD model was prepared for different materials like HCS AISI4340, E-Glass, S-Glass & Carbon Epoxy.
- Analysis of these files was performed on ANSYS Workbench 18.2 and the results concluded were as stated.
- Different composites were used and according to material density, deformation and stress analysis material with optimum property is selected.
- From the FOS table it was found that all the Three selected composite materials can be used for the manufacturing of connecting rod because stress induced in all the materials are within the yield strength of the material.
- But Out off four materials, S Glass is having more safer range as compared to other composite materials and FOS safety is also more.
- Hence S Glass can be prepared for the manufacturing of Connecting rod for high strength.

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