DESIGN ANALYSIS OF CONNECTING ROD FOR WEIGHT REDUCTION IN CASE OF A CI ENGINE

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Abstract—**Every vehicle equipped with internal combustion engine and every Internal Combustion engine has connecting rod. The main idea of this study is to analyze the connecting rod and explore weight reduction opportunities of connecting rod by examining connecting rod with two new materials, glass fiber and carbon fiber. In this study CI engine connecting rod is selected for analysis. Therefore this study deals with two subjects first static stress analysis of existing connecting rod and second optimization of rod for weight reduction by experimenting it with two new materials. In this study after knowing dimensions of connecting rod appropriate 3D model is prepared using CATIA, the model is imported in ANSYS software. Static analysis is done by fixing small end force is applied at big end, and by fixing big end force is applied at small end. Static stress analysis is carried out for compressive as well as tensile loading. And von-misses stresses and deformations were found in existing connecting rod for given loading conditions. The same work was done for same design and same loading conditions for two selected new materials. After optimization with new materials it is observed that Stress induced in composite materials was reduced. And weight of connecting rod also reduced.**

***Keywords*—Finite Element Analysis, CATIA, ANSYS, Static Stress Analysis, Connecting Rod**

I. INTRODUCTION

Connecting rod is a crucial moving component of a reciprocating internal combustion (I.C.) engine. It is the intermediate linkage between piston and crankshaft. And its primary function is to transmit the thrust of piston to crank shaft. Connecting rods are subjected to the forces generated by mass and fuel combustion which results axial and bending stresses in connecting rod. Therefore a connecting rod must withstand for transmitting axial tension, axial compression occurred due to the thrust and pull of the piston.

The connecting rod consist of two ends small end and big end small end of connecting rod is attached to piston pin and piston assembly and crank end is connected to the crankshaft, it experiences pure reciprocating motion where as big end attached to crank pin experiences pure rotary motion and only the shank of connecting rod experiences both motions. During working the connecting rod is under tremendous stress due to reciprocating load represented by the piston, actually it is stretching and being compressed with every rotation, and the load on rod increases to the square of the engine speed increase.

Automobile should be light in weight to consume less fuel, at the same time they should provide comfort and safety to passengers, unfortunately which leads to increase weight of the vehicle, implementation of new materials which are light and meet design requirements can solve this problem. Weight optimization of connecting rod reduces the stresses over the rod. As connecting rod is manufactured in large volume production, logically optimization of the connecting rod for its weight or volume will result large scale savings. Also it can achieve objective of reducing weight of the engine component, thus it will reduce inertia loads on rod. By reducing engine weight, increasing demand of fuel economy can be achieved.

An automobile industry always require cost efficient and high quality product, therefore it gives opportunity to study various parts of engine. To avoid time spend on trial and error method of analysis computational and Finite Element Method is used for model analysis. Structural analysis gives best idea about stress distribution at different loading conditions. Accuracy stress analysis result is depends on type of mesh selected determination of best mesh is also a critical part.

II. LITERATURE REVIEW

[1] Durgesh Yadav, Mr. Avinash Nath Tiwari(august 2017): analyse the stresses developed in connecting rod of four stroke petrol engine under static loading conditions, Then optimised it for various materials like Al360, carbon steel and cast iron. They measured dimensions of Hero Splendor 100cc bike connecting rod and prepared model in CATIA V5 and analysed model by using ANSYS software. At final concluded that stress developed and weight of Al 360 connecting rod were minimum as compared with cast iron connecting rod

[2] Satish Wable, Dattatray S.Galhe(March 2016) : analysed two wheeler pulsar 180cc IC engine connecting rod .They developed the CAD model of connecting rod in CATIA for Carbon steel and Aluminium MMC and analysis is carried out in ANSYS software. And by comparing von mises stress and deformation, concluded that less amount of stresses were developed in aluminium MMC connecting rod as compared with existing carbon steel connecting rod. Also it was light in weight as compared with carbon steel connecting rod.

[3] Prateek Joshi, Mohammad Umair Zaki (May - June 2015) : did analysis of connecting rod for various materials and compared analysis results of high strength carbon fiber with stainless steel and aluminium alloy. And shows that Aluminium Alloy has higher intensity of Stress and Strain induced as compare to Connecting Rod made up of Carbon Fiber, Also connecting

rod made up of High Strength Carbon fiber help in reducing weight of engine, thus increase fuel economy. Hence concluded that carbon fiber can be the future material for the Connecting Rod.

[4] S. Aishwarya, V. V. Ramanamurthy: (June 2015) presented paper on modified design of Cast Iron connecting rod in Hero Honda Splendor plus motorbike. Modified design is modelled using Modelling software CATIA and various parameters are obtained and the results are taken and compared. From analysis it is observed that strain obtained by the modified design is less When compared to the existing design. They showed weight reduction clearly in the Comparison graph. They analyzed modified truss design for different composite materials also and concluded that modified design was much better than existing solid design

[5] G.M Sayeed Ahmed, Sirajuddin Elyas Khany, Syed Hamza Shareef(Oct 2014): undertaken the work to replace the existing connecting rod made of forged steel which is broken for LML Freedom with aluminium and carbon fiber connecting rod they prepared prototype for both materials and tested it with piston assembly. Finally they replaced connecting rod made of forged steel is with Aluminium alloys and Carbon Fiber and suggested carbon fiber connecting rod are the best to be used as they with stand the forces but epoxy in carbon fiber melts due to heat and this can be eliminated with better epoxy which can withstand at high temperatures also

[6] Leela Krishna Vegi and Venu Gopal Vegi(June 2013) : presented paper on design and analysis of connecting rod using forged steel By checking and comparing the results of two materials. In analysis results they obtained equivalent stress for the both the materials are same. For the forged steel material factor of safety and stiffness is increased compared to existing carbon steel. The weight of the forged steel material is less than the existing carbon steel. By comparing both the materials, forged steel is cheaper than the existing connecting rod material.

III. Objective

The main objective of this study is to design and analyse the existing connecting rod and suggest weight reduction opportunity by analysing with two new materials. In this study two most critical areas are considered for study, that is small end and big end of connecting rod. Analysis is done by using four boundary conditions as mentioned below. Same amount of load is applied on both ends for all conditions.

i. Compressive load applied on big end while small end fixed.
ii. Tensile load applied on big end while small end fixed
iii. Compressive load applied on small end while big end fixed
iv. Tensile load applied on small end while big end fixed.

For analysis we considered force acting on connecting rod is equals to force which is acting on the piston due to the pressure exerted by the gas. Force acting on piston due to gas pressure is calculated as (F = 16231N).

IV. Methodology

A. Specifications of connecting rod

By using standard design procedure we designed connecting rod. Following chart shows the specifications of connecting rod.

TABLE I

SPECIFICATIONS OF CONNECTING ROD

Parameters	Dimensions
Length of the connecting rod (L)(mm)	112
Thickness of the connecting rod (t) (mm)	4.847
Outer diameter of the big end(mm)	56
Inner diameter of the big end(mm)	44
Outer diameter of the small end(mm)	34
Inner diameter of the small end(mm)	20
Width of the section (B) (mm)	19.389
Height of the section (H) (mm)	24.237

B. Modelling

According to above dimensions we have prepared 3D model of connecting rod by using CATIA software and then it is imported in ANSYS workbench. After successful import of model material properties are defined. This existing connecting rod was made by cast iron therefore we assigned cast iron properties in ansys. With same dimensions and same procedure two more 3D models are prepared for Carbon Fiber and Glass Fiber materials. Fig 1 shows 3D model of connecting rod.

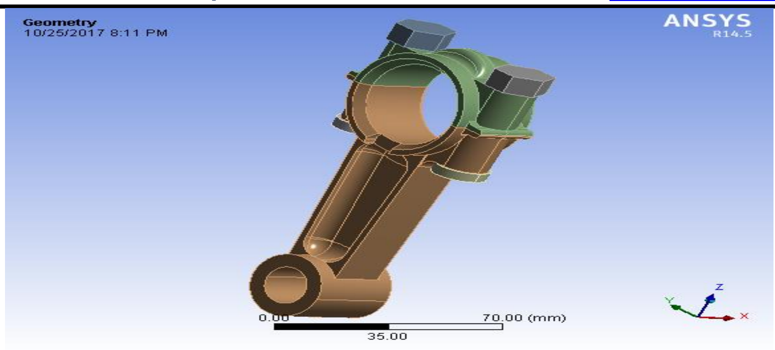

Fig. 1 3D Model of connecting rod

C. Materials of connecting rod

Widely used materials in manufacturing of connecting rod are carbon steel, Aluminium alloys, Steel alloys. Connecting rods are typically manufactured by forging or powder metals. Most common process for the bulk production of connecting rods are closed die drop-forging and powder-forging. In the Present study we used Cast iron, Carbon fiber and Glass fiber Materials. Following are the selected mechanical properties of selected materials.

TABLE III

PROPERTIES OF CAST IRON

Properties	Values
Young's modulus (Pa)	1.1E+11
Bulk modulus (Pa)	8.3333E+10
Shear Modulus (Pa)	4.2969E+10
Poison's ratio	0.28
Ultimate tensile strength (Pa)	2.4E+08
Ultimate compressive strength (Pa)	8.2E+08
Density (Kg m^3)	7200

TABLE III

PROPERTIES OF GLASS FIBER AND CARBON FIBER

Properties	Values (Glass Fiber)	Values (Carbon Fiber)
Young's modulus along X direction (MPa)	43000	177000
Young's modulus along Y direction (MPa)	6500	10600
Young's modulus along Z direction (MPa)	6500	10600
Shear modulus XY (MPa)	4500	7600
Shear modulus YZ (MPa)	2500	2500
Shear modulus XZ (MPa)	2500	2500
Poisson's ratio XY	0.27	0.27
Poisson's ratio YZ	0.06	0.02
Poisson's ratio XZ	0.06	0.02
Density (Kg mm3)	2E-6	1.6E-6

V. ANALYSIS OF CONNECTING ROD

A. Meshing

The next step was meshing before the analysis we must mesh the model. By comparing results, number of nodes and elements we finalised Fine mesh. Table III shows number of nodes and elements used in fine mesh. Mesh is generated with 108976 Number of Nodes and 35244 Numbers of Elements. Fig. 2 shows meshed model of connecting rod with fine mesh.

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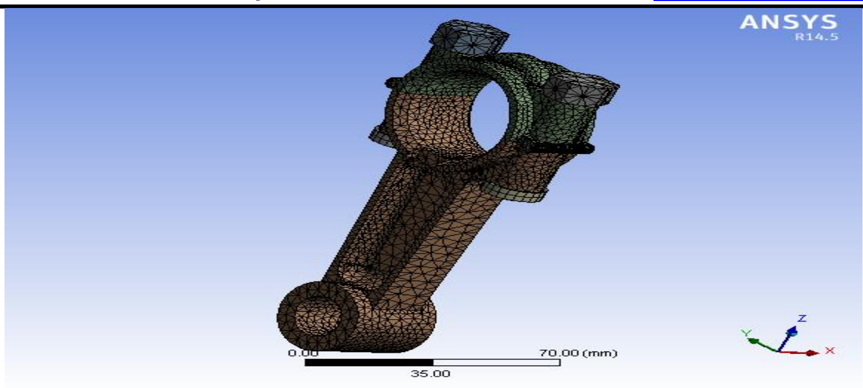

Fig. 1 Meshed model of connecting rod

B. Load and boundary conditions

Analysis is done with Force on piston due to gas pressure equal to 16231N. Static load was applied on connecting rod with four boundary conditions as

- Small end fixed compressive load applied on big end.
- Small end fixed tensile load applied on big end.
- Big end fixed compressive load applied on small end.
- Big end fixed tensile load applied on small end

Fig 3 and 4 shows, small end fixed with load applied on big end and Big end fixed with load applied on small end respectively

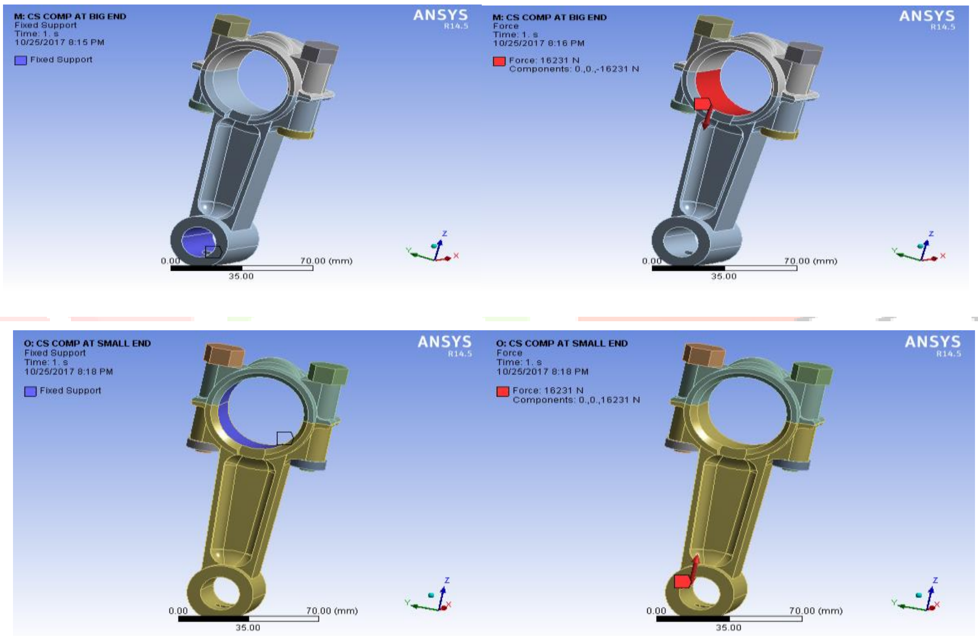

Fig 4

VI. **RESULTS AND DISCUSSION**

Maximum vonmises stress and deformation was found out using static structural analysis in ANSYS for compressive as well as tensile loading on small end and big end of connecting rod

A. Cast iron connecting rod.

Fig 5 and 6 shows results for compressive load applied on big end with small end fixed. Fig 7 and 8 shows results for compressive load applied on small end with Big end fixed.

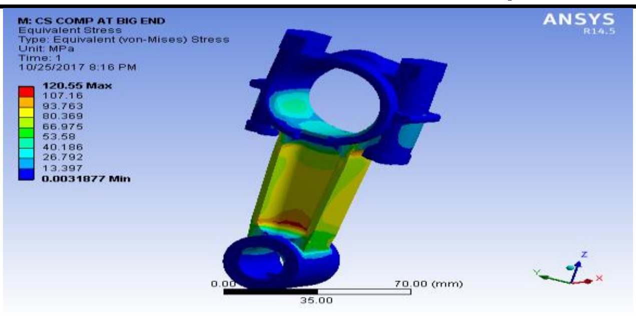

Fig. 5 Equivalent stresses

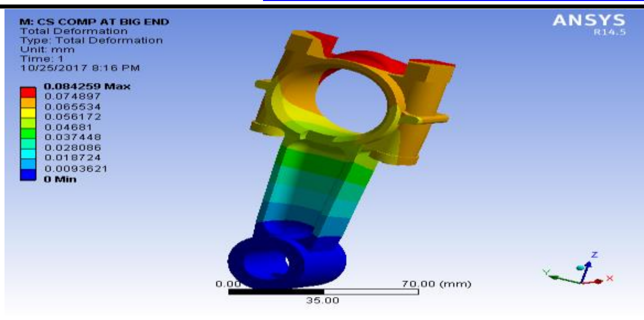

Fig 6 Total deformation

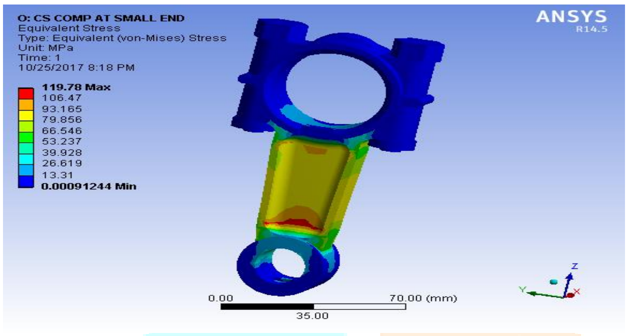

Fig 7 Equivalent stresses

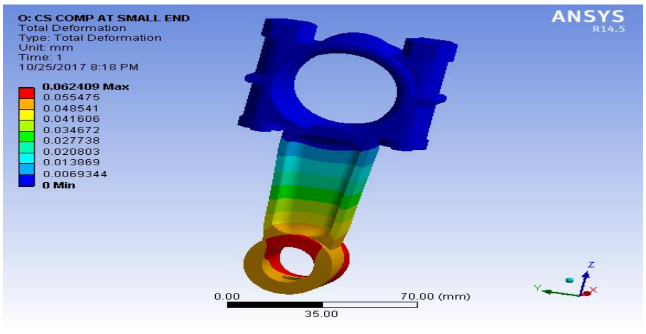

Fig. 8 Total deformation

B. Carbon fiber connecting rod.

Fig 9 and 10 shows results for compressive load applied on big end with small end fixed. Fig 11 and 12 shows results for compressive load applied on small end with Big end fixed.

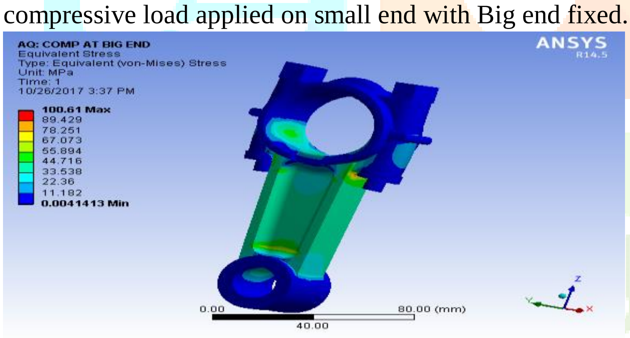

Fig 9 Equivalent stresses

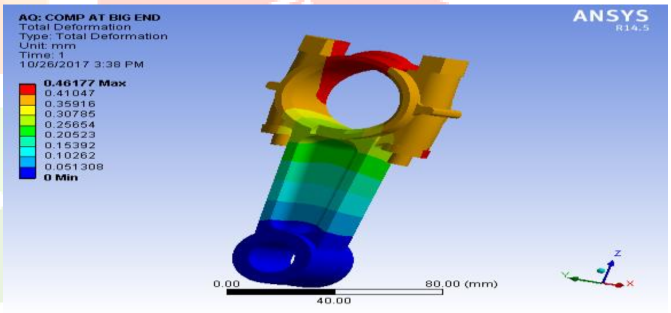

Fig. 10 Total deformation

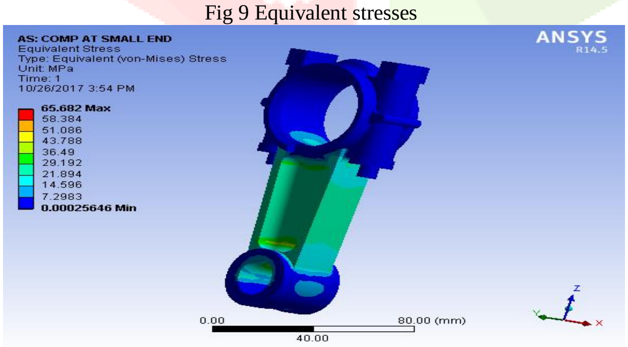

Fig 11 Equivalent stresses

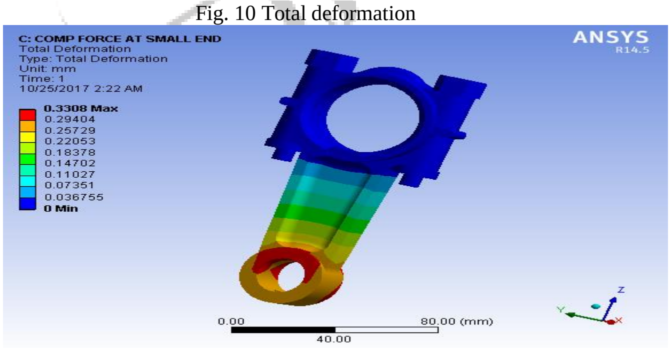

Fig. 12 Total deformation

C. Glass fiber connecting rod.

Fig 13 and 14 shows results for compressive load applied on big end with small end fixed. Fig 15 and 16 shows results for compressive load applied on small end with Big end fixed.

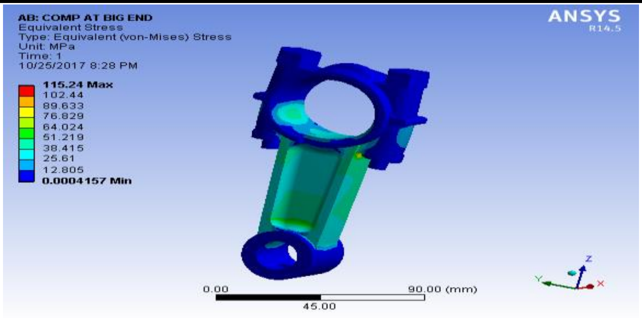

Fig 13 Equivalent stresses

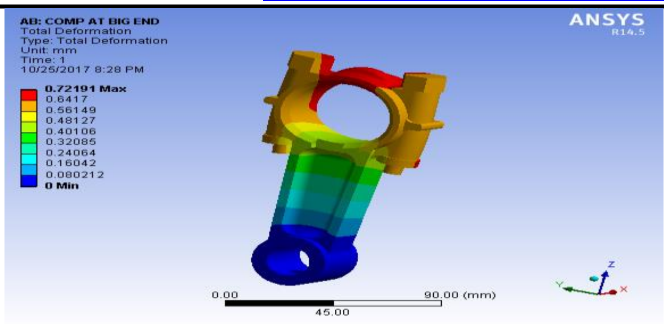

Fig. 14 Total deformation

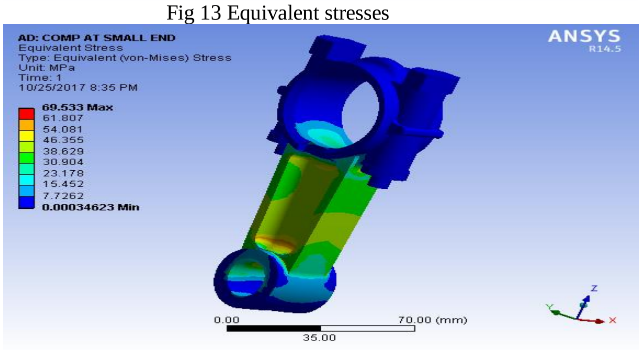

Fig 15 Equivalent stresses

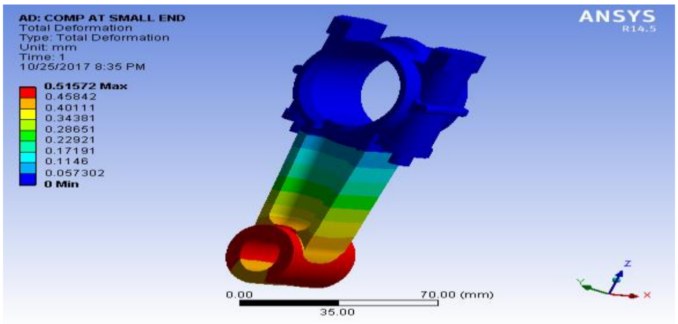

Fig. 16 Total deformation

TABLE V

RESULTS OF STATIC STRUCTURAL ANALYSIS

Pressure applied	Result for	Type of loading	Cast iron	Carbon Fiber	Glass Fiber
Big end	Stress	Compressive	120.53	100.61	115.24
		Tensile	191.53	191.74	183.07
Small end	Stress	Compressive	119.78	65.682	69.533
		Tensile	189.4	185.94	178.85

Weight comparison of connecting rod with cast iron, Carbon Fiber and Glass Fiber composite is shown in Table VI.

TABLE VIII
WEIGHT COMPARISON

Material Name	Cast iron	Carbon Fiber	Glass Fiber
Weight (Kg)	0.583221	0.163232	0.20404

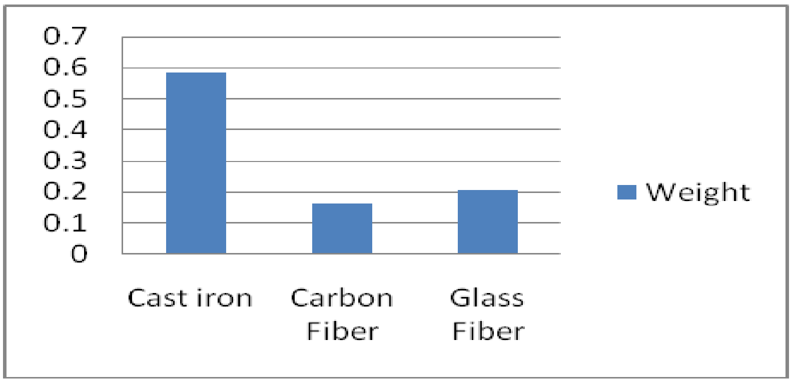

Fig. 15 Weight comparison graph

Weight comparison graph (Fig 15) for three materials Cast Iron, Carbon Fiber and Glass Fiber shows that with the use of carbon fiber maximum amount of weight can be reduced.

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VII. CONCLUSION

- From static structural analysis for compressive and tensile loading conditions it is observed that stress induced in composite materials is less as compared with Cast Iron. Comparing between three materials, with Carbon Fiber material minimum stresses are observed at big end as well as at small end with compressive loading.
- With the use of composite material deformation of connecting rod is slightly increased than cast iron but it is within acceptable limit.
- Weight obtained of Cast Iron, Carbon Fiber and Glass Fiber is 0.5832 Kg, 0.1632 Kg, and 0.2040 Kg respectively. Therefore it is observed that with carbon fiber maximum amount of weight can be reduced.
- After optimisation of connecting rod by using composite materials of Carbon Fiber and Glass Fiber it is observed that stress induced in composite materials is less, also weight is reduced up to 70%. Therefore from above result we can conclude that, we can use carbon fiber material for Connecting rod in diesel Engine.

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