IJAET International Journal of Application of Engineering and Technology ISSN: 2395-3594

Vol.1 No.1

OPTIMIZATION OF CONNECTING ROD USING CAE TOOLS

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ABSTRACT

Aim of this work is to optimize weight and reduce inertia forces on the existing connecting rod, which is obtained by changing such design variables in the existing connecting rod design. In this project material of connecting rod is replaced by Aluminum with some modifications and finite element analysis of the single cylinder four stroke petrol engine connecting rod of Hero Honda Splendor Pro motorbike is considered as case study. The Von Mises stress, strain and total deformation determined for the same loading conditions and compared with the existing results. Based on the observation of static FEA and the load analysis result, the load for the optimization study was selected same as on existing connecting rod. A parametric model of connecting rod and Analysis is carried out by using ANSYS software. Finite element analysis of connecting rod is done by considering two materials ,viz..Carbon steel and Aluminum 360. The current work consists of static structural analysis.

***Keywords:* -** Connecting rod, Finite Element Analysis, Optimization, ANSYS workbench Static analysis, Carbon steel, Aluminum 360

I. INTRODUCTION

The connecting rod is used to transfer linear, reciprocating motion of the piston into rotary motion of the crankshaft. The maximum stress occurs in the connecting rod near the piston end due to thrust of the piston. The tensile and compressive stresses are produced due to the gas pressure, and bending stresses are produced due to centrifugal effect. From the viewpoint of functionality, connecting rods must have the highest possible rigidity at the lowest weight. So the connecting rods are designed generally of I-section to provide maximum rigidity with minimum weight. The maximum stress produced near the piston end could be decreased by increasing the material near the piston end. 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 is used because of their lightness. The rod usually tapers slightly from the big end to the small end.

Mr.Pranav G Charkha and Dr Santosh B Jajucarried out the Finite Element Analysis and optimization of connecting rod using ANSYS work bench 9. The study consists of two types of analysis, static analysis and fatigue analysis.The main objective of this study was to explore weight reduction opportunities for a production forged steel connecting rod. The study was performed on four stroke petrol engine connecting rod which is made up of forged steel. The weight reduction is achieved by static analysis under static load conditions, and 9.24% weight is reduced as compared to the existing connecting rod. Pravardhan S. Shenoy and Ali Fatemi presented the FE analysis procedure for optimization for connecting rod weight and cost reduction. A study was performed on a forged steel connecting rod with a consideration for improvement in weight and production cost. Weight reduction was achieved by an iterative procedure. This study results in an optimized connecting rod that was 10% lighter and 25% less expensive, as compared to the existing connecting rod. A. Mirehei et al. [3] carried out the fatigue analysis of connecting rod of universal tractor (U650). The objective of the research was to determine the lifespan of connecting rod due to cyclic loading. The numbers of critical points were also located from where the crack propagation initiates. Allowable number of load cycles and using fully reverse Loading was gained 10^8. It was suggested that the results obtained could be useful to bring about modifications in the process of connecting rod manufacturing. Vasile George Cioata,Imre Kiss presented a method used to verify the stress and deformation in the connecting rod using the finiteelement method with Ansys v.11. The study only analysestheconnecting rod foot. Theobtained

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results provided by this method were compared to the results obtained by classic calculation, in similarconditions of application, and after wards conclusions weredrawn.

Figure:1 Schematic diagram of connecting rod

II. OBJECTIVES

The objective of the present work is to design and analyse connecting rod made of Aluminum 360. Steel and aluminum materials are used to design the connecting rod. In this project the material (carbon steel) of connecting rod replaced and modified with Aluminum 360. Connecting rod was created and analyzed in ANSYS 13. After analysis a comparison is made between existing steel and aluminum connecting rod in terms of weight, factor of safety, deformation and stress.

III. MATERIAL OF CONNECTING ROD

Automotive companies are continuously searching for new and better cost effective ways to manufacture connecting rods. The common process technologies for the bulk production of connecting rods are drop-forged, casting, and powder-forged.

Table: Material properties of connecting rods

Material selected	Carbon steel
Young's Modulus,(E)	2.0 X 10^5MPa
Poisson's Ratio	0.30
Tensile strength	540MPa
Yield strength	415 MPa
Density	7850kg/m3
Behavior	Isotropic

MANUFACTURINGPROCESSES

2.1 DROP-FORGED

Forging is a plastic deformation process in which the work piece is compressed between two dies, using either impact or gradual pressure to form the part. This process is used to shape metal objects that must withstand great stress.

2.2 POWDER FORGING

Powder forging is a process in which powders such as iron and copper are compacted, heated and forged so that their density increases up to that of wrought steel.

2.3 DIE- CASTING

Die-casting is accomplished by forcing molten metal under high pressure into reusable metal dies.

FINITE ELEMENT MODELLING

The model of connecting rod was generated in Ansys 13.0 as shown in figure.

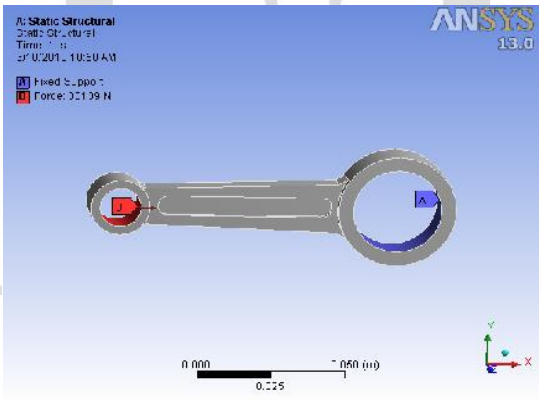

Figure:2 CAD model of connecting rod

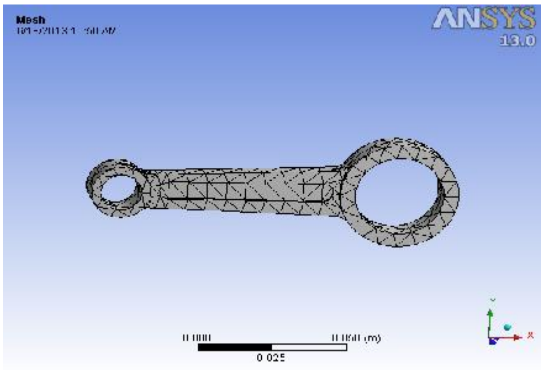

Figure :3 Meshed model of connecting rod

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CASE STUDY OF & THEORETICAL CALCULATIONS

1 1SPECIFICATION DATA FOR97.2CC ENGINE

(Hero Splendor Pro)

2. PRESSURE CALCULATION ON

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 W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod, {or} 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.

Wcr =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 formula = (Ixx=4Iyy).

Specifications

Engine type air cooled 4-stroke

Bore × Stroke (mm) = 50 X 49.5

Displacement = 97.2 CC

Maximum Power = 5.74 Kw @ 7500 rpm

Maximum Torque = 8.04 Nm @ 4500 rpm,

Compression Ratio = 9 : 1,

Density of Petrol C_8H_{18} = 737.22kg/m3

= 737.22E-9kg/mm3

Temperature = 60F = 288.855K

Mass = Density × Volume = 737.22E-9×97.2E3 = 0.071Kg

Molecular Weight of Petrol 114.228 g/mole

From Gas Equation,

PV=MRt,

R = R*/Mw = 8.3143/0.114228 = 72.78

P = (0.071x72.786x288.85) / 97.2 E^3

P = 15.35 Mpa.

Piston Bore Dia (D) = 50 mm

Force acting on the connecting rod

(F) = $(\frac{\pi D^2}{4})$x P = 30139 N= 30.1 KN

3 DESIGN CALCULATION FOR CARBON STEEL

Thickness of flange & web of the section = **t**

Width of section **B= 4t**

Height of section H=5t

Area of section A= 2(4t×t) +3t×t

A=11t²

MI of section about x axis:

Ixx=1\12 (4t $(5t)^3$-3t $(3t)^3$) = 419\12t^4

MI of section about y axis:

IYY = (2+1\12t$(4t)^3$+1\12(3t) t^3) = 131\12 t^4

IXX\ IYY= 3.2

Length of connecting rod (L) = 2 times the stroke

L = 2 x 49.5 mm = 99 mm

Buckling load W_B= maximum gas force × F.O.S

= 30139 x 6 = 180834 N

The dimensions of cross-section are calculated by applying Rankine's formula for bucking of connecting rod in the plane of rotation or about the XX-axis. According to this formula,

$W_B = \frac{\sigma_C \text{ X } A}{1+a(L\backslash K_{XX})^2}$= 180834 N

Where

W_B = critical buckling load (N)

σ_C =compressive yield stress (N/mm^2)

A = cross-sectional area of connecting rod (mm^2)

a = constant depending upon material and end fixity coefficient

L= length of connecting rod (mm)

K_{XX}= radius of gyaration (mm)

For a connecting rod made of forge steel,

σ_C = compressive yield stress = 415MPa

K_{XX} = 1.78t

a= $\sigma_C \backslash \pi^2 E$

a = 0.0002

By substituting σ_C, A, a, L, K_{XX} on W_B then

$$\frac{180834}{415 \text{ X } 11} = \frac{t^2}{1+0.0002(\frac{115.6}{1,78t})^2}$$

t^4-39.61t^2-24.5 =0

t^2 = 40.21

t= 6.3 mm

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Width of section B = 4t =25.2 mm

Height of section H = 5t = 31.5 mm

Area A = $11t^2$ = 436.6mm2

Height at the big end (crank end) = H_2 = 1.1H to 1.25H

H_2=37.8mm

Height at the small end (piston end) = 0.9H -0,75H

H_1 =26.7mm

4.4DESIGN CALCULATION FORALUMINUM 360.

For a connecting rod made of Modified aluminium 360

σ_C = compressive yield stress = 172MPa
K_{XX} = 1.78t
a= σ_C \$\pi^2$E
a = 0.0002

By substituting σ_C, A, a, L, K_{XX} on W_B then

$$\frac{180834}{172\ X\ 11} = \frac{t^2}{1+0.0002(\frac{115.6}{1.78t})^2}$$

t^4-95.57t^2-59.12 =0
t^2 =96.18
t=9.8 mm

Width of section B = 4t =39.2 mm

Height of section H = 5t = 49mm

Area A = $11t^2$ = 1056mm2

Height at the big end (crank end) = H_2 = 1.1H to 1.25H

H_2=58.8mm

Height at the small end (piston end) = 0.9H -0,75H

H_1 =41.6mm

STRUCTURAL ANALYSIS

5.1 EXISTING CARBON STEEL:

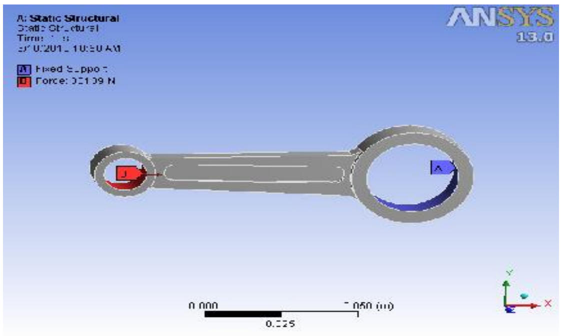

Figure :4 loads and boundary conditions applied to the model of connecting rod.

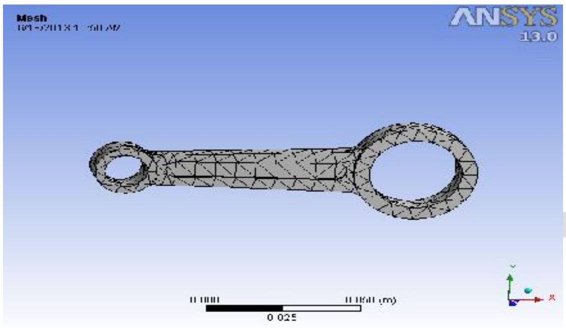

Figure:5 Mesh of carbon steel.

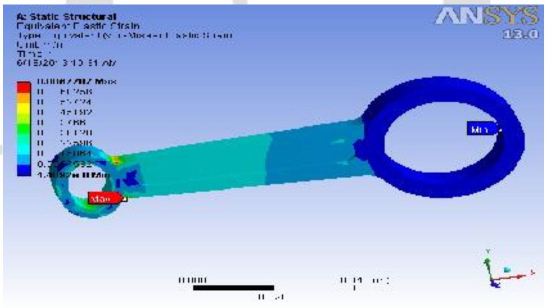

Figure:6 von- mises strain of carbon steel.

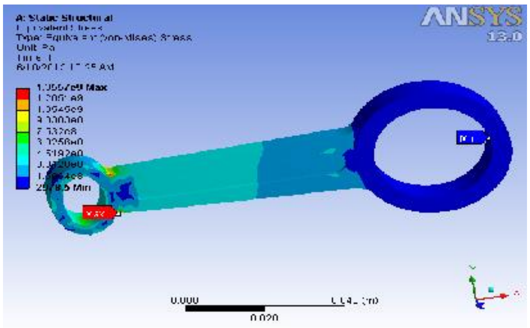

Figure: 7von-mises Stress for carbon steel.

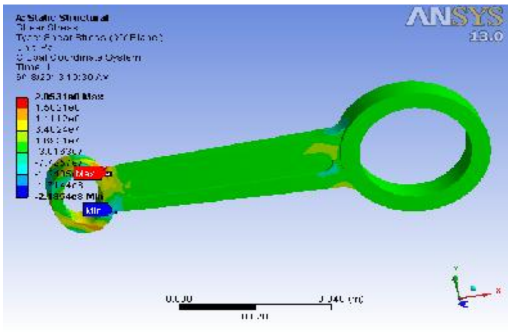

Figure:8 Shear stress for carbon steel.

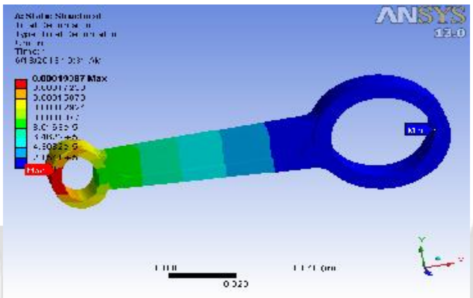

Figure: 9 Displacement of carbon steel.

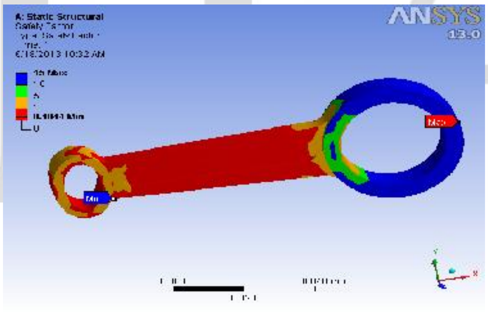

Figure:10 Factor of safety of carbon steel.

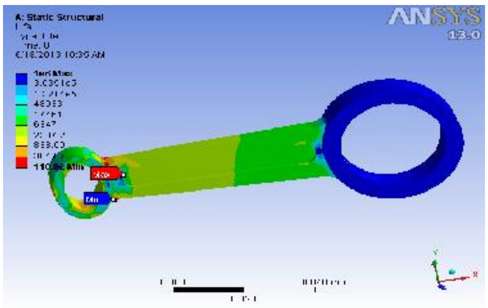

Figure: 11 Life carbon steel.

5.2 MODIFIED ALUMINUM 360

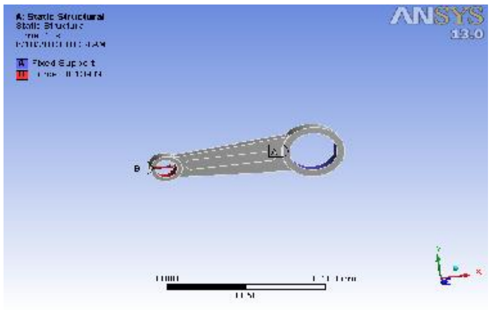

Figure: 12 loads and boundary conditions applied to the model of connecting rod.

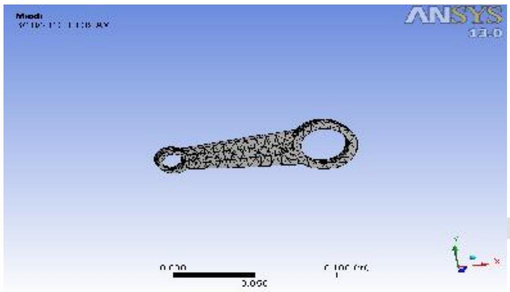

Figure: 13 Mesh of modified aluminium 360

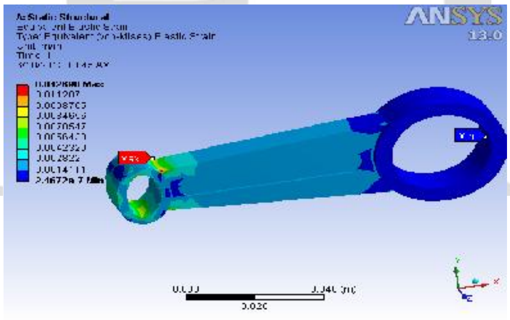

Figure: 14 von misses strain of modified aluminium 360.

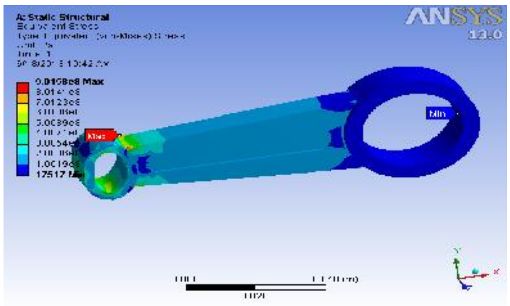

Figure: 15 Von misses Stress for modified aluminium 360.

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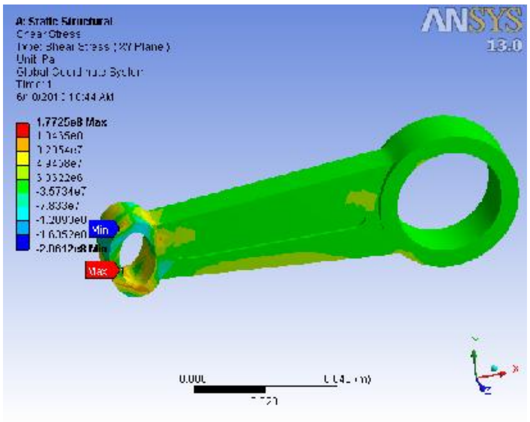

Figure: 16 Shear stress for modified aluminium 360.

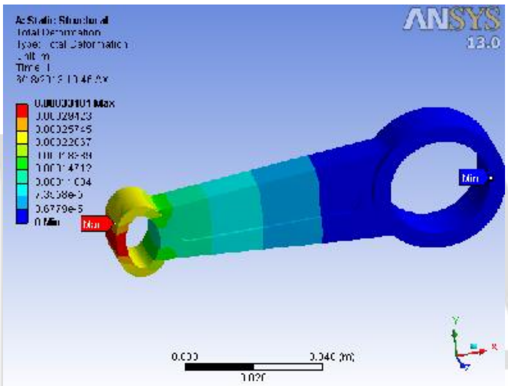

Figure :17 Displacement of modified aluminium 360.

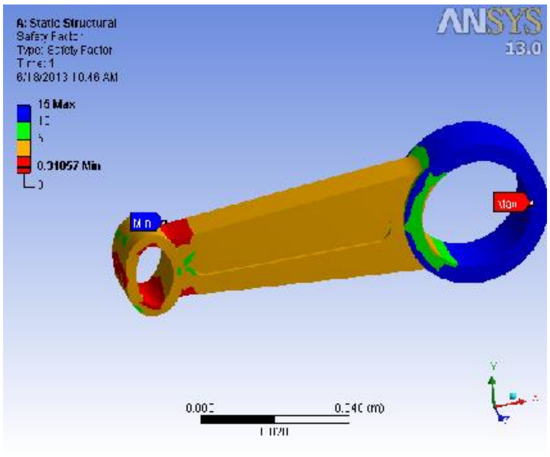

Figure :18 Factor of safety of modified aluminium 360.

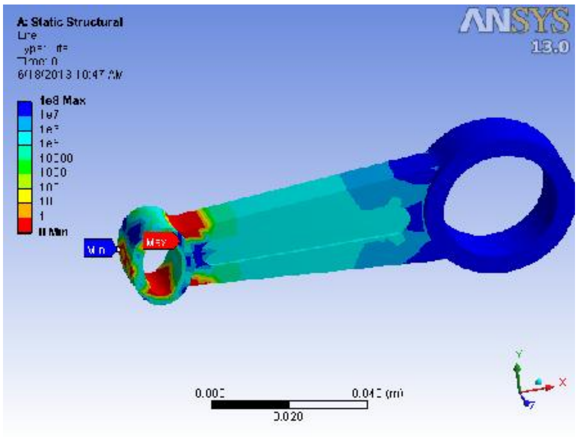

Figure: 19 Life modified aluminum 360.

IV. RESULTS

1. COMPARISON OF EXISTING AND OPTIMIZED DESIGN

The following data given below has been taken from ANSYS 13 software for making the comparison of existing and optimized design.

Table: Comparison table for materials.

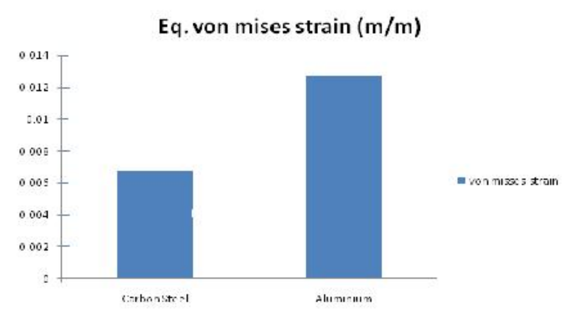

Figure : 20 Von-Misses Strain for two materials

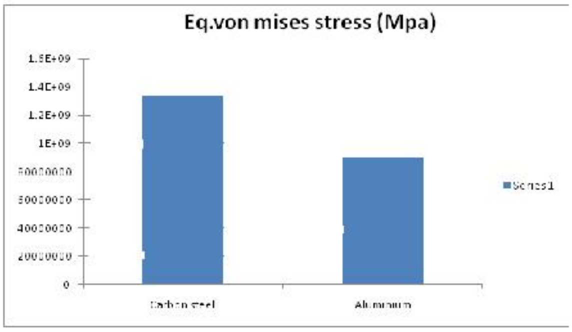

Figure :21 Von-Misses Stress for two materials

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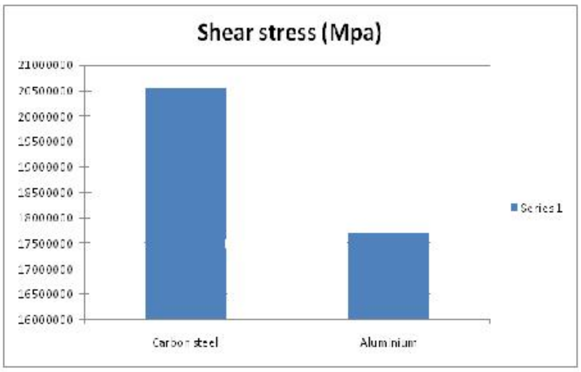

Figure : 22 Shear Stress for two materials

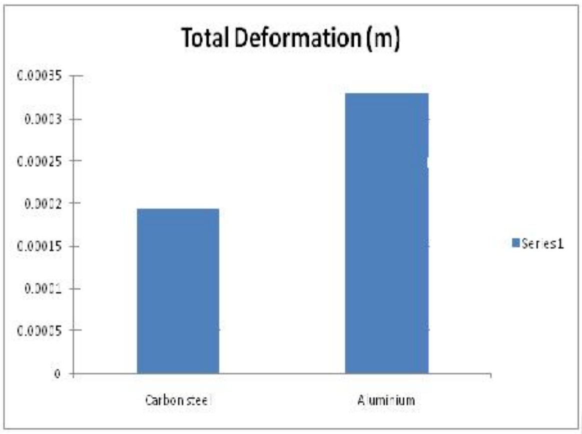

Figure :23 Displacement for two materials.

2. RESULT FOR WEIGHT OF CONNECTING ROD

The optimization task was to minimize the mass of the connecting rod under the effect of a load range for two extreme loads, the peak compressive gas within the limits of the allowable stresses. The result of weight reduction for optimized connecting rod is given below in table 6.

1. Density of Carbon steel = 7.87e-6 Kg/mm3
Volume of connecting rod = $1.6489\times10^{-5}m^3$
Weight of connecting rod = Density × Volume
=7.87e-6×1.6489×10^{-5} = 0.129 kg

2. Density of Al 360 =2.685e-6 kg/mm3
Volume of connecting rod =$2.3713\times10^{-5}m^3$

Weight of connecting rod =Density × Volume = 0.065 kg

Percentage of reduction in weight = W of Carbon steel-W of Al 360 / W of Carbon steel =0.129-0.065/0.129 =0.49

Table-7. For weight optimization

ORIGINAL	OPTIMIZED	REDUCTION (PERCENTAGE)
0.129 kg.	0.065 kg.	49 %

6.3. RESULT FOR PERCENTAGE OF STRESS REDUCTION:

If Carbon Steel is changed by Aluminum 360 =1.3xe^9- 9.01xe^8/ 1.3xe^9 =0.306(i.e.~ 30%)

V. CONCLUSIONS

According to the results, it can be concluded that the weight of optimized design is 49% lighter. Stiffness and stress are reduced in aluminum 360 as shown by the results. The stress was found maximum at the piston end. This can be reduced by increasing the material near the piston end.Optimization was performed to reduce weight of the existing connecting rod. This optimization can also be achieved by changing the current forged steel connecting rod into some other materials such as Magnesium, Titanium, Micro alloyed steel etc.

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ISSN 2395-3594