

Design, Analysis and Optimization of I.C. Engine Connecting Rod ALFASiC Material Using Finite Element Analysis

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ABSTRACT: 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. Generally connecting rods are manufactured using carbon steel and in recent days aluminium alloys are finding its application in connecting rod. In this work the connecting rod material is replaced by aluminium based composite material reinforced with silicon carbide and fly ash (ALFASiC). For present investigation the designed connecting rod is modeled using solid modeling software i.e. PRO/E. The modeled connecting rod imported to the analysis software i.e. ANSYS. Finite Element Analysis are carried out by considering two materials (Forged Steel and ALFASiC). The parameters like von misses stress, von misses Strain, and displacement were obtained from ANSYS software. Comparing the results and percentage of weight reduction is calculated.

KEYWORDS: Connecting rod, ANSYS, Composite, Silicon Carbide, fly ash, Forged Steel, Analysis

I. INTRODUCTION

In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminum (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters. The small end attaches to the piston pin, gudgeon pin (the usual British term) or wrist pin, which is currently most often press fit into the con rod but can swivel in the piston, a "floating wrist pin" design. The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the third power with increasing engine speed. Failure of a connecting rod, usually called "throwing a rod" is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance or from failure of the rod bolts from a defect, improper tightening, or re-use of already used (stressed) bolts where not recommended. Despite their frequent occurrence on televised competitive automobile events, such failures are quite rare on production cars during normal daily driving. This is because production auto parts have a much larger factor of safety, and often more systematic quality control. When building a high performance engine, great attention is paid to the connecting rods, eliminating stress risers by such techniques as grinding the edges of the rod to a smooth radius, shot peening to induce compressive surface stresses (to prevent crack initiation), balancing all connecting rod/piston assemblies to the same weight and Magnafluxings to reveal otherwise invisible small cracks which would cause the rod to fail under stress. In addition, great care

is taken to torque the con rod bolts to the exact value specified; often these bolts must be replaced rather than reused. The big end of the rod is fabricated as a unit and cut or cracked in two to establish precision fit around the big end bearing shell. Recent engines such as the Ford 4.6 liter engine and the Chrysler 2.0 liter engine have connecting rods made using powder metallurgy, which allows more precise control of size and weight with less machining and less excess mass to be machined off for balancing. The cap is then separated from the rod by a fracturing process, which results in an uneven mating surface due to the grain of the powdered metal. This ensures that upon reassembly, the cap will be perfectly positioned with respect to the rod, compared to the minor misalignments which can occur if the mating surfaces are both flat. A major source of engine wear is the sideways force exerted on the piston through the con rod by the crankshaft, which typically wears the cylinder into an oval cross-section rather than circular, making it impossible for piston rings to correctly seal against the cylinder walls. Geometrically, it can be seen that longer connecting rods will reduce the amount of this sideways force, and therefore lead to longer engine life. However, for a given engine block, the sum of the length of the con rod plus the piston stroke is a fixed number, determined by the fixed distance between the crankshaft axis and the top of the cylinder block where the cylinder head fastens; thus, for a given cylinder block longer stroke, giving greater engine displacement and power, requires a shorter connecting rod (or a piston with smaller compression height), resulting in accelerated cylinder wear.

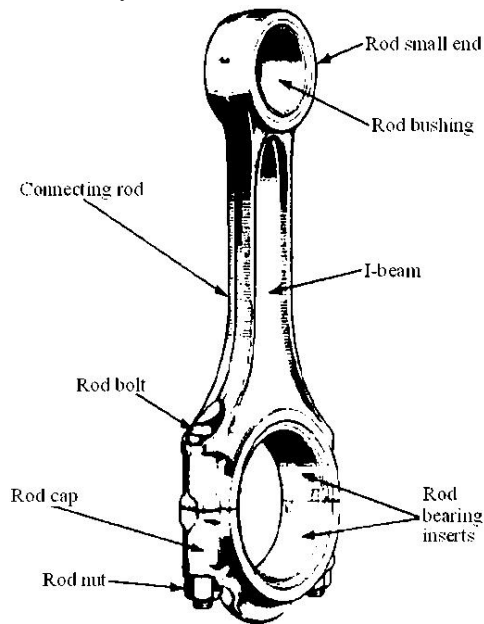


Figure 1: Connecting Rod Nomenclature

II. PRESSURE CALCULATION FOR 150CC ENGINE

Engine type air cooled 4-stroke
Bore x Stroke (mm) = 57×58.6
Displacement = 149.5 CC
Maximum Power = 13.8 bhp @ 8500 rpm
Maximum Torque = 13.4 Nm @ 6000 rpm

Compression Ratio = 9.35/1
Density of Petrol C₈H₁₈ = 737.22 kg/m³

$$= 737.22E-9 \text{ kg/mm}^3 \text{ Temperature} = 60^\circ \text{ F}$$

$$= 288.855^\circ \text{ K}$$

Mass = Density \times Volume

$$= 737.22E-9 \times 149.5E3$$

$$= \mathbf{0.11kg}$$

Molecular Weight of Petrol 114.228 g/mole

From Gas Equation,

$$PV = Mrt R$$

$$= RxMw$$

$$= 8.3143/114228$$

$$= 72.76$$

$$P = (0.11 \times 72.786 \times 288.85) / 149.5 = 3$$

$$\mathbf{P = 15.5 MPa.}$$

III. DESIGN CALCULATION OF CONNECTING ROD

In general From standards,

Width of the section B = 4t

- Thickness of flange and web of the section = t
- Height of the section H = 5t |
- Area of the section A = 11t² |
- Moment of inertia about x axis I_{xx} = 34.91t⁴ |
- Moment of inertia about y axis I_{yy} = 10.91t⁴ |
- Therefore I_{xx}/I_{yy} = 3.2

So, in the case of this section (assumed section) proportions shown above will be satisfactory. Length of the connecting rod (L) = 2 times the stroke

$$L = 117.2 \text{ mm}$$

Total Force acting F = F_p-F_i Where F_p = force acting on piston F_i = force by inertia

$$F_p = (\pi d^2/4) * \text{gas pressure} F_p = 39473.1543 \text{ N}$$

$$F_i = 1000wrv^2 * \pm \cos 2 \text{ } W_r = \text{weight of reciprocating parts} W_r = 1.6 * 9.81 = 15.696 \text{ N}$$

r = crank radius

$$r = \text{stroke of piston} / 2 \text{ } r = 58.6/2 = 29.3$$

= Crank angle from the dead center

= 0 considering that connecting rod is at the TDC position n1 = length of connecting rod / crank radius

$$n1 = 117.2/29.3 = 4$$

g = acceleration due to gravity, 9.81 v = crank velocity m/s
w = 2 /60

$$w = 2 \cdot 8500/60 = 890.1179$$

$$v = rw = 29.3e-3 \cdot 890.1179 = 26.08 \text{ on substituting}$$

$$F_i = 9285.5481 \text{ Therefore}$$

$$F = 39473.1543 - 9285.5481$$

$$F = 30187.6062 \text{ N}$$

According to Rankine's – Gordon formula,

Let,

A = C/s area of connecting rod, L = Length of connecting rod f_c = Compressive yield stress, F = Buckling load

I_{xx} and I_{yy} = Radius of gyration of the section about x – x and y – y axis respectively and

K_{xx} and K_{yy} = Radius of gyration of the section about x – x and y – y axis respectively.

A. FOR ALUMINIUM 6061-9%SiC-15%FLY ASH (ALFASiC)

On substituting to rankine's formula $t = 3.5658$

There fore

$$\text{Width } B = 4t = 14.2632 \text{ mm}$$

$$\text{Height } H = 5t = 17.829 \text{ mm Area } A = 11t = 139.8642 \text{ mm}^2$$

$$\text{Height at the piston end } H_1 = 0.75H - 0.9 H \quad H_1 = 0.75 \cdot 23.66 = 13.37 \text{ mm}$$

$$\text{Height at the crank end } H_2 = 1.1H - 1.25H \quad H_2 = 1.1 \cdot 23.66 = 19.6119 \text{ mm}$$

B. FOR FORGED STEEL

On substituting to rankine's formula $t = 2.5966 \text{ mm}$

There fore

$$\text{Width } B = 4t = 10.3864 \text{ mm Height } H = 5t = 12.983 \text{ mm Area } A = 11t = 74.1656 \text{ mm}^2$$

$$\text{Height at the piston end } H_1 = 0.75H - 0.9 H \quad H_1 = 0.75 \cdot 23.66 = 9.73725 \text{ mm}$$

$$\text{Height at the crank end } H_2 = 1.1H - 1.25H \quad H_2 = 1.1 \cdot 23.66 = 14.2813 \text{ mm}$$

C. DIMENSIONS OF CONNECTING ROD

Inner diameter of the small end $d_1 =$ ×
 $= 6277.16712.5 \times 1.5d_1$

$= 17.94\text{mm}$

Where,

Design bearing pressure for small end $p_{b1} = 12.5$ to 15.4N/mm^2

Length of the piston pin $l_1 = (1.5 \text{ to } 2) d_1$

Outer diameter of the small end $= d_1 + 2t_b + 2t_m$

$= 17.94 + [2 \times 2] + [2 \times 5]$

$= 31.94\text{mm}$

Where,

Thickness of the bush (t_b) = 2 to 5 mm Marginal thickness (t_m) = 5 to 15 mm

Inner diameter of the big end $d_2 = F_g P_{b2} \times l_2 = 6277.16710.8 \times 1.0d_1$

$= 23.88\text{mm}$

Where,

Design bearing pressure for big end $p_{b2} = 10.8$ to 12.6N/mm^2

Length of the crank pin $l_2 = (1.0 \text{ to } 1.25) d_2$

Root diameter of the bolt $= ((2F_{im})(\pi \times St))^{1/2}$

$= (2 \times 6277.167 \pi \times 56.667)^{1/2}$

$= 4\text{mm}$

Outer diameter of the big end $= d_2 + 2t_b + 2d_b + 2t_m$

$= 23.88 + 2 \times 2 + 2 \times 4 + 2 \times 5$

$= 47.72\text{mm}$

Where,

Thickness of the bush [t_b] = 2 to 5 mm Marginal thickness [t_m] = 5 to 15 mm

Nominal diameter of bolt [d_b] = 1.2 x root diameter of the bolt = $1.2 \times 4 = 4.8\text{mm}$

Table 1: Mechanical properties of Forged Steel and ALFASiC

S.No	Mechanical Property	Forged Steel	ALFASiC
1	Yield Strength (MPa)	415	363
2	Ultimate Strength (MPa)	625	422
3	Modulus of Elasticity (GPa)	221	70
4	Density (g/cc)	7.7	2.61161
5	Poisson's Ratio	0.29	0.33

IV. MODELLING OF CONNECTING ROD



Figure 2: Pro E model of Connecting Rod

V. ANALYSING OF CONNECTING ROD

5.1. MESHING OF CONNECTING ROD

Relevance	: 100
Relevance Center	: Fine
Minimum Edge Length	: 1.60 mm

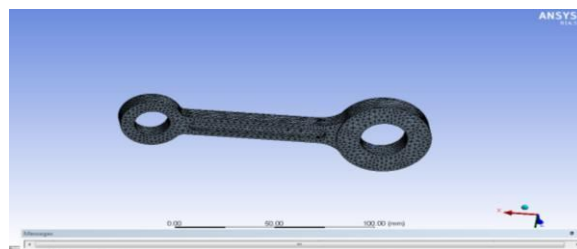


Figure 3: Meshing

5.2. LOADS AND CONSTRAINTS

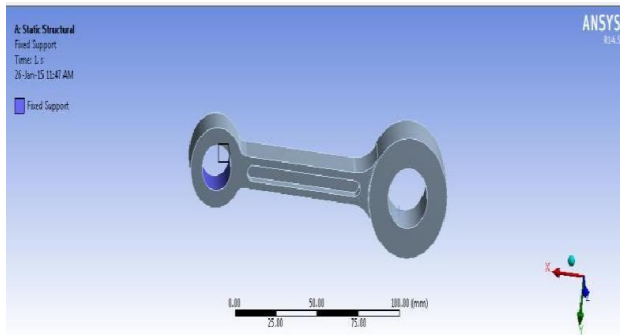


Figure 4: Small eye end fixed (Mpa)

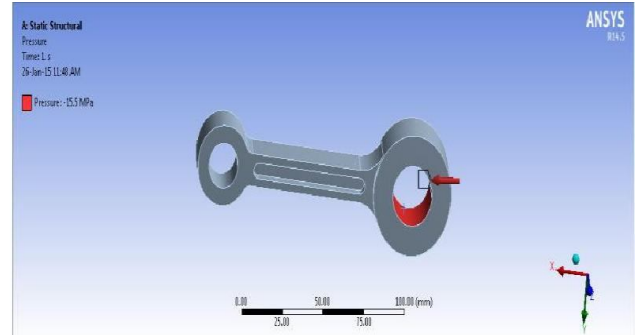


Figure 5: Big eye end (Pressure – 15.5 Mpa)

5.3 ANALYSIS OF FORGED STEEL

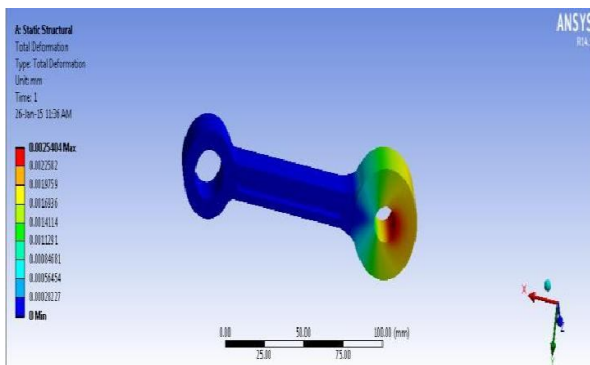


Figure 6: Total Deformation (axis)

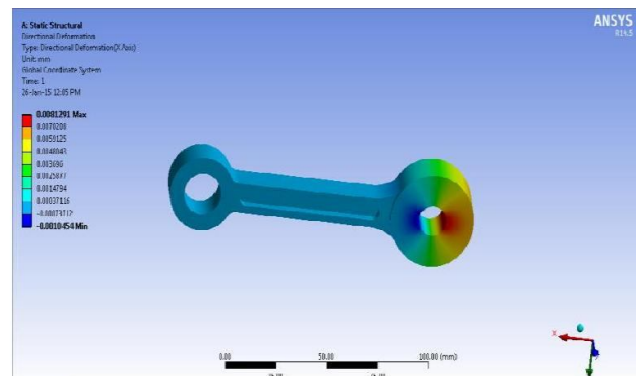


Figure 7: Directional Deformation (x axis)

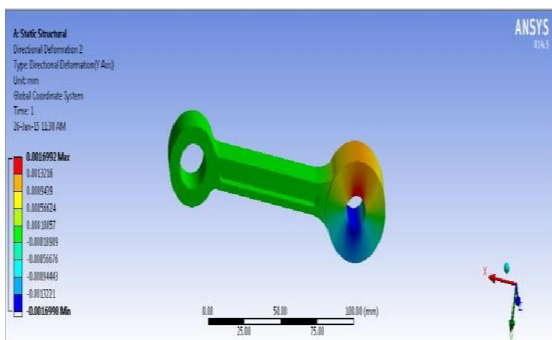


Figure 8: Directional Deformation (y axis)

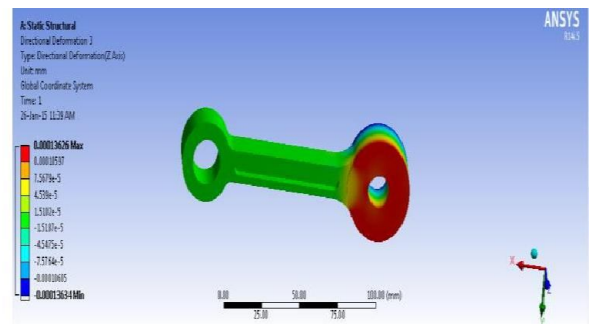


Figure 9: Directional Deformation (z axis)

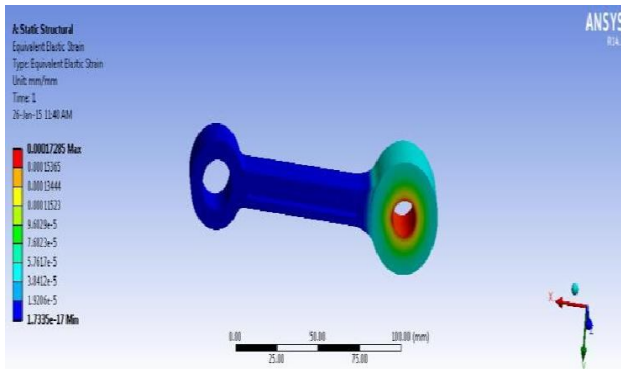


Figure 10: Equivalent Strain Moises)

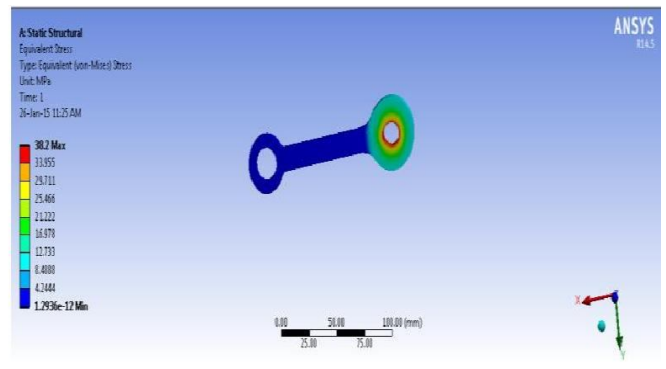


Figure 11: Equivalent Stress (Von

5.4. ANALYSIS OF ALFASiC

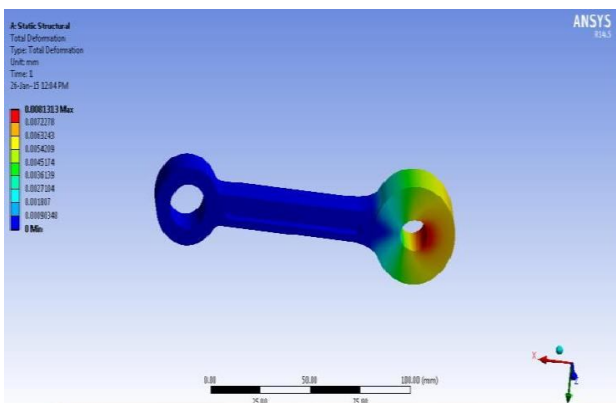


Figure 12: Total Deformation axis)

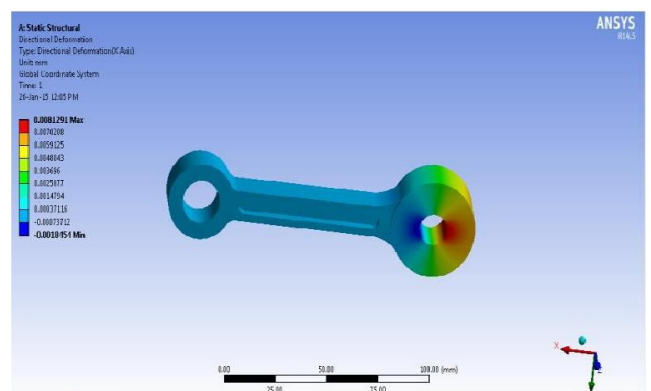


Figure 13: Directional Deformation (x

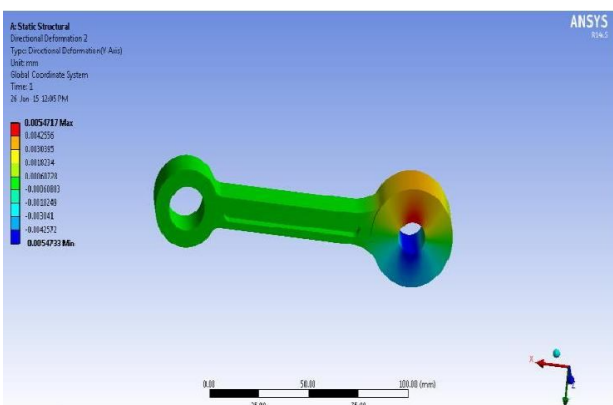


Figure 14: Directional Deformation (y axis) axis)

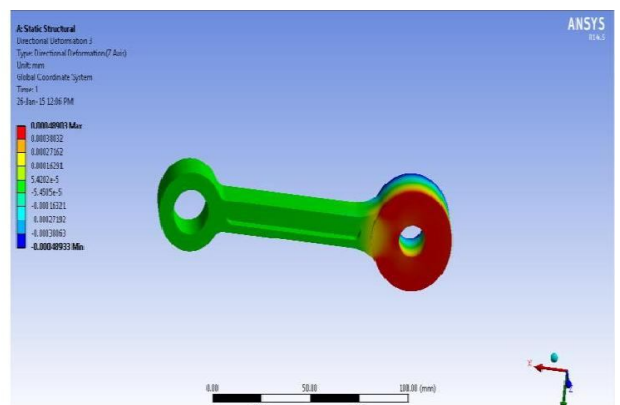


Figure 15: Directional Deformation (z

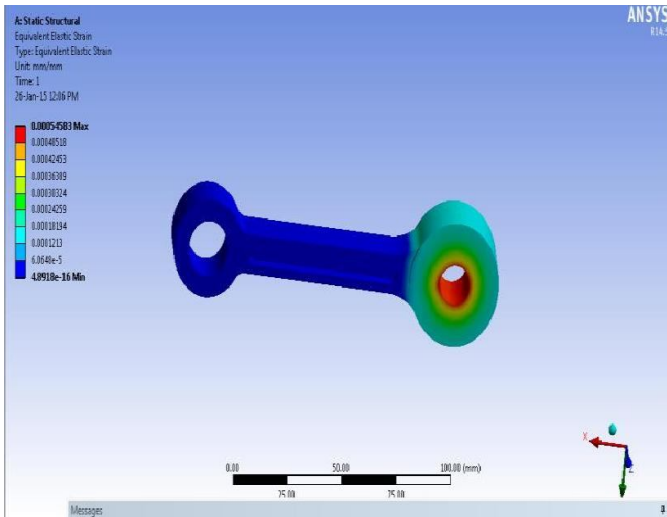


Figure 16: Equivalent Strain Moises)

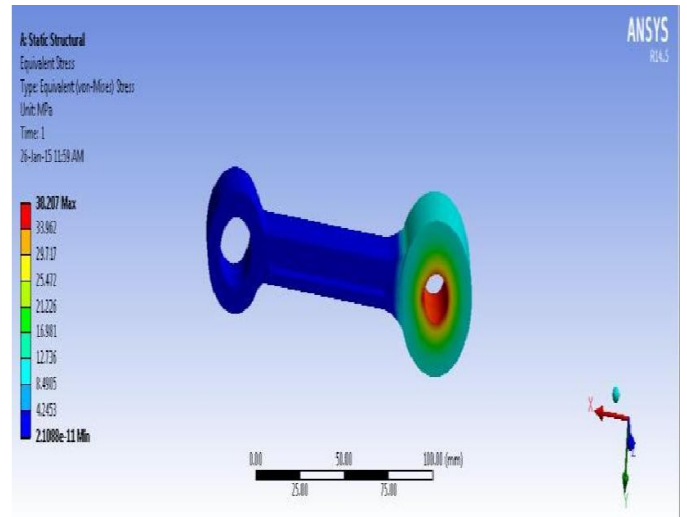


Figure 17: Equivalent Stress (Von

VI. RESULTS

Table 2: ANSYS Results for Connecting Rod (Forged Steel and ALFASiC)

S.No.	Solution Information	Forged Steel	ALFASiC
1	Total Deformation (mm)	0.0025404	0.0081313
2	Directional Deformation (x axis) (mm)	0.00254	0.0081291
3	Directional Deformation (y axis) (mm)	0.0016992	0.0054717
4	Directional Deformation (z axis) (mm)	0.00013626	0.00048903
5	Equivalent Stress (Von Moises) (MPa)	Max: 38.2 Min: 1.2936e-12	Max: 38.207 Min: 2.1088e-11
6	Equivalent Strain (mm/mm)	Max: 0.00017285 Min: 1.7335e-17	Max: 0.00054583 Min: 4.8918e-16
7	Weight (Kgs)	0.31	0.1072

6.1 Percentage of weight reduction:

Weight of connecting Rod (Forged Steel) = 0.31 Kg

Weight of connecting Rod (ALFASiC) = 0.1072 Kg

Percentage reduction of weight = 65.4194%

6.2 Percentage of Total Deformation

Total Deformation (Forged Steel) = 0.0025404 mm

Total Deformation (ALFASiC) = 0.0081313 mm

6.3 Stiffness of Connecting Rod a.

Forged Steel

Weight of Connecting Rod = 0.31 kg

Deformation = 0.0025404mm Stiffness =

122.028 Kg/mm

Percentage of Total Deformation = -220.0677 %

b. ALFASiC

Weight of Connecting Rod = 0.1072 kg Deformation = 0.0081313mm Stiffness = 13.1836 Kg/mm

VII. CHEMICAL COMPOSITION

a. Forged Steel

Forged Steel 0.61-0.68%C, 0.2-0.4%S, 0.5-1.2%Mn, 0.04%S, 0.04%P, 0.9-1.2%Cr b. ALFASiC

Al6061-9%SiC-15% flyash

VIII. CONCLUSION

- Weight can be reduced by changing the material of the current Forged Steel connecting rod to hybrid ALFASiC composites.
- Due to weight reduction in ALFASiC Connecting Rod, Engine Performance will be better.
- ANSYS Equivalent Stresses Induced on both the connecting rod (Forged Steel and ALFASiC) are nearly same.
- But the deformation and Stiffness of the Connecting Rod (Forged Steel) is better than the Connecting Rod (ALFASiC).

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