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ANALYSIS AND OPTIMIZATION OF CONNECTING ROD USING ALFASiC COMPOSITES

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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 connecting rod is replaced by aluminium based composite material reinforced with silicon carbide and fly ash. And it also describes the modelling and analysis of connecting rod.

FEA analysis was carried out by considering two materials. The parameters like von misses stress, von misses strain and displacement were obtained from ANSYS software. Compared to the former material the new material found to have less weight and better stiffness. It resulted in reduction of 43.48% of weight, with 75% reduction in displacement.

Keywords: connecting rod, ANSYS, composite, silicon carbide, fly ash, analysis

I. INTRODUCTION

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. Connecting rod, automotives should be lighter and lighter, should consume less fuel and at the same time they should provide comfort and safety to passengers, that unfortunately leads to increase in weight of the vehicle. This tendency in vehicle construction led the invention and implementation of quite new materials which are light and meet design requirements.

Lighter connecting rods help to decrease lead caused by forces of inertia in engine as it does not require big balancing weight on crankshaft. Application of metal matrix composite enables safety increase and advances that leads to effective use of fuel and to obtain high engine power. Honda Company had already started the manufacturing of aluminium connecting rods reinforced with steel continuous fibers.

By carrying out these modifications to engine elements will result in effective reduction of weight, increase of durability of particular part, will lead to decrease of overall engine weight, improvement in its traction parameters, economy and ecological conditions such as reduction in fuel consumption and emission of harmful substances into atmosphere

K. Sudershan kumar [1] et al, described modeling and analysis of Connecting rod. In his project carbon steel connecting rod is replaced by aluminium boron carbide connecting rod. Aluminium boron carbide is found to have working factory of safety is nearer to theoretical factory of safety, to increase the stiffness by 48.55% and to reduce stress by 10.35%.

Vivek. C. Pathade [2] et al, he dealt with the stress analysis of connecting rod by finite element method using pro-e wild fire 4.0 and ansys work bench 11.0 software. And concluded that the stress induced in the small end of the connecting rod are greater than the stresses induced at the bigger end, therefore the chances of failure of the connecting rod may be at the fillet section of both end.

Pushpendra kumar Sharma [3] et al, performed the static FEA of the connecting rod using the software and said optimization was performed to reduce weight. Weight can be reduced by changing the material of the current forged steel connecting rod to crackable forged steel (C70). And the software gives a view of stress distribution in the whole connecting rod which gives the information that which parts are to be hardened or given attention during manufacturing stage.

Ram bansal [4] et al, in his paper a dynamic simulation was conducted on a connecting rod made of aluminium alloy using FEA. In this analysis of connecting rod were performed under dynamic load for stress analysis and optimization. Dynamic load analysis was performed to determine the in service loading of the connecting rod and FEA was conducted to find the stress at critical locations.

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II. THEORETICAL CALCULATION OF CONNECTING ROD

1. Pressure calculation:

Consider a 150cc 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

- Density of petrol at 288.855 K - $737.22*10^{-9}$ kg/mm^3
- Molecular weight M - 114.228 g/mole
- Ideal gas constant R – 8.3143 J/mol.k

From gas equation,
$PV=m.R_{specific}.T$
Where, P = Pressure
V = Volume
m = Mass
$R_{specific}$ = Specific gas constant
T = Temperature
But,
mass = density * volume
m =737.22E-9*150E3
m = 0.11 kg
$R_{specific} = R/M$
$R_{specific} = 8.3143/0.114228$
$R_{specific} = 72.76$
$P = m.R_{specific}.T/V$
P = 0.11*72.786*288.85/150E3
P = 15.4177 MPa
P ~ 16 MPA.

2. Design calculation of connecting rod:

In general

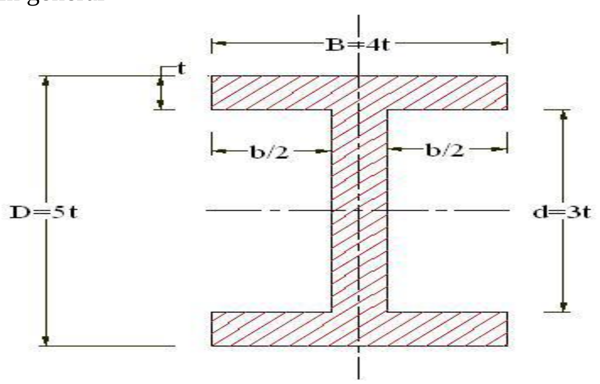

Fig 1: Standard Dimension’s of I Section

From standards,

- Thickness of flange and web of the section = t
- Width of the section B = 4t
- Height of the section H = 5t
- Area of the section $A = 11t^2$
- Moment of inertia about x axis $I_{xx}= 34.91t^4$
- Moment of inertia about y axis $I_{yy}= 10.91t^4$
- Therefore $I_{xx}/I_{yy} = 3.2$

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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 mm
Total Force acting $F = F_p - F_i$
Where F_p = force acting on piston
F_i = force by inertia
$F_p = (\pi d^2/4)$ * gas pressure
F_p = 39473.1543 N
$F_i = \frac{1000\,wr\,v^2}{gr} * cos\theta \pm \frac{\cos 2\theta}{n^l}$
Wr = weight of reciprocating parts
Wr = 1.6 * 9.81 = 15.696 N
r = crank radius
r = stroke of piston / 2
r = 58.6/2 = 29.3
θ = Crank angle from the dead center
θ = 0 considering that connecting rod is at the TDC position
n^1 = length of connecting rod / crank radius
n^1 = 117.2/29.3 = 4
g = acceleration due to gravity, 9.81
v = crank velocity m/s
w = $2\pi n/60$
w = $2\pi 8500/60$ = 890.1179
v = rw = 29.3e-3*890.1179 = 26.08
on substituting
F_i = 9285.5481
Therefore
F = 39473.1543 – 9285.5481
F = 30187.6062 N
According to Rankine's – Gordon formula,

$$F = \frac{f_c A}{1+a(\frac{l}{k_{xx}})}$$

Let,
A = C/s area of connecting rod,
L = Length of connecting rod
fc = Compressive yield stress,
F = Buckling load
Ixx and Iyy = Radius of gyration of the section about x – x and y – y axis respectively
and
Kxx and Kyy = Radius of gyration of the section about x – x and y – y axis respectively.

1. For aluminium 360

On substituting to rankine's formula

$$30187.6 = \frac{170 * 11t^2}{1+0.002(\frac{117.2}{1.78t})^2}$$

t = 4.7321
There fore
Width B = 4t = 18.9284 mm
Height H = 5t = 23.6605 mm
Area A = 11t = 246.32 mm^2
Height at the piston end H_1 = 0.75H – 0.9 H
H_1 = 0.75*23.66 = 17.745
Height at the crank end H_2 = 1.1H – 1.25H
H_2 = 1.1*23.66 = 26.026

2. For aluminium 6061-9%SiC-15%fly ash

On substituting to rankine's formula

$$30187.6 = \frac{363 * 11t^2}{1+0.002(\frac{117.2}{1.78t})^2}$$

t = 3.5658
There fore
Width B = 4t = 14.2632 mm

Height H = 5t = 17.829 mm
Area A = 11t = 139.8642 mm^2
Height at the piston end H_1 = 0.75H – 0.9 H
H_1 = 0.75*23.66 = 13.37
Height at the crank end H_2 = 1.1H – 1.25H
H_2 = 1.1*23.66 = 19.6119

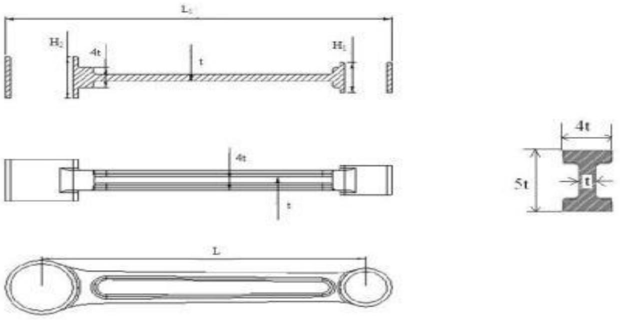

Fig.2: general dimensions of connecting rod

TABLE 1
MATERIAL PRORTIES USED FOR ANALYSIS

Sl no	Parameters	Old material (Al360)	New material (Al6061-9%SiC-15% flyash)
1	Ultimate tensile strength (MPa)	303	422
2	Yield strength (MPa)	170	363
3	Youngs modulus (GPa)	60	70
4	Poisson's ratio	0.33	0.33
5	Density (g/cm^3)	2.8	2.61161

III. FEA OF CONNECTING ROD

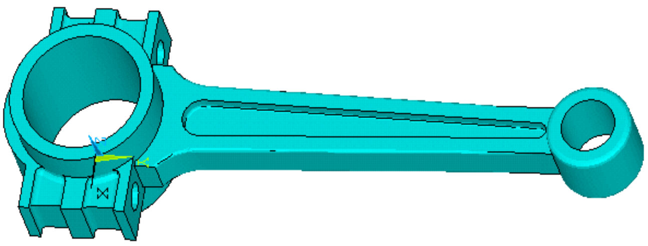

Fig.3: model of connecting rod

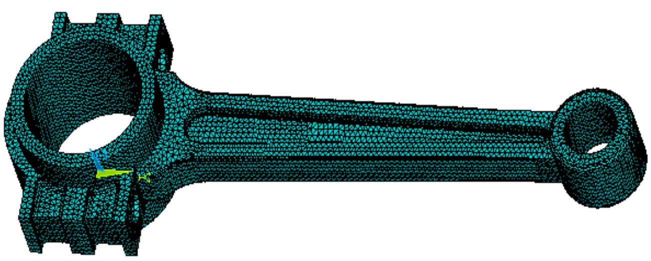

Fig 4: meshed model of connecting rod

Type of Element : solid 187
Number of Nodes : 117439

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Number of Elements : 69613

- Loads and constraints:

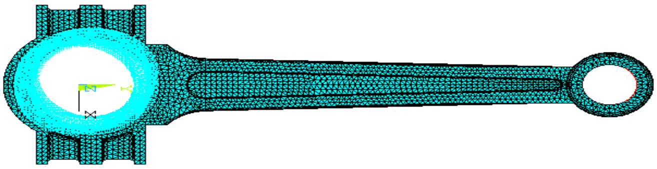

Fig 5: all DOF constrained at crank end

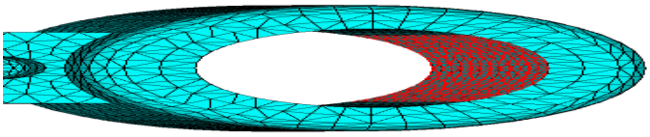

Fig 6: tensile load applied at the piston end

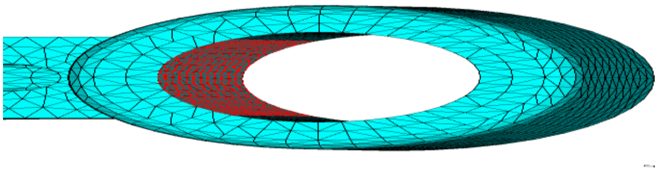

Fig 7: compressive load applied at the piston end

IV. RESULTS AND DISCUSSION

- ANALYSIS

For the finite element analysis 16 Mpa of pressure is used. The analysis is carried out using ANSYS software. The pressure is applied at the small end of connecting rod keeping big end fixed. The maximum and minimum von-misses stress, strain and displacement are noted from the ANSYS.

Table 2

COMPARISON OF STRESS, STRAIN AND DISPLACEMENT FOR DIFFERENT MATERIALS.

Sl no	Material	Tensile load			Compressive load		
		Stress (MPa)	Displacement (mm)	Strain (mm)	Stress (MPa)	Displacement (mm)	Strain (mm)
1	Old material	83.225	0.137925	0.002094	41.7163	0.088346	0.01048
2	Al6061-9% SiC-15% fly ash	124.837	0.034481	0.524e-3	62.5744	0.022087	0.262e-3
3	Percentage difference	49.99	75	74.97	49.99	74.99	97.5

1. VON-MISES STRESS PLOTS:

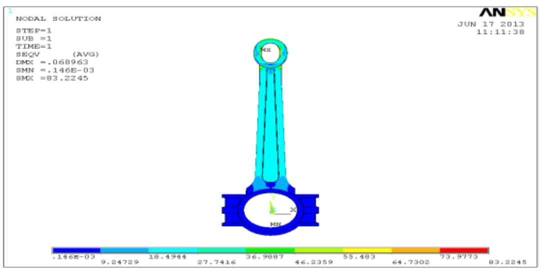

Fig 8: Von-Mises Stress For Tensile Load aluminium 360 material

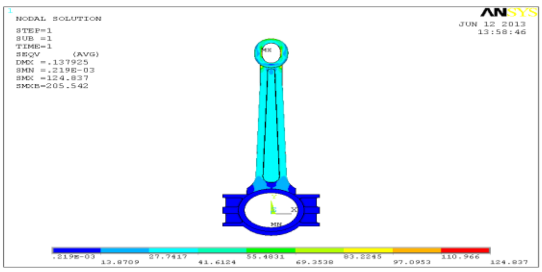

Fig 9: Von-Mises Stress For Tensile Load, aluminium 6061-9%SiC-15%fly ash material

From the fig 8 the maximum stress occurs at the piston end of the connecting rod is 83.2245 Mpa and minimum stress occurs at the crank end of the connecting rod is 0.146e-03 Mpa. From the fig 9 the maximum stress occurs at the piston

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end of the connecting rod is 124.837 Mpa and minimum stress occurs at the crank end of the connecting rod is 0.219e-03 Mpa.

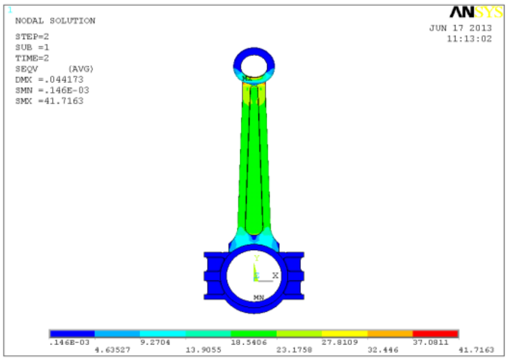

Fig 10: Von-Mises Stress For Compressive Load, aluminium 360 material

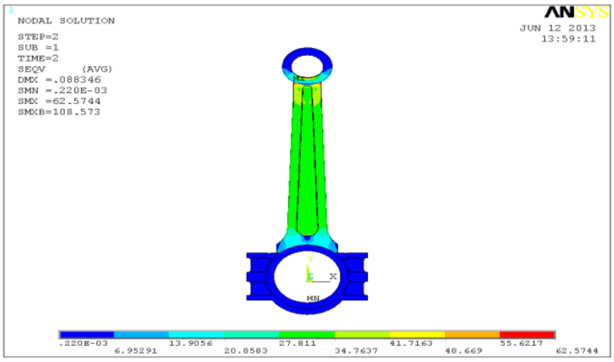

Fig 11: Von-Mises Stress For Compressive Load, aluminium 6061-9%SiC-15%fly ash

From the fig 10 the maximum stress occurs at the piston end of the connecting rod is 41.7163 Mpa and minimum stress occurs at the crank end of the connecting rod is 0.146e-3 Mpa. From the fig 11 the maximum stress occurs at the piston end of the connecting rod is 62.574 Mpa and minimum stress occurs at the crank end of the connecting rod is 0.220e-3 Mpa.

2. Displacement plots

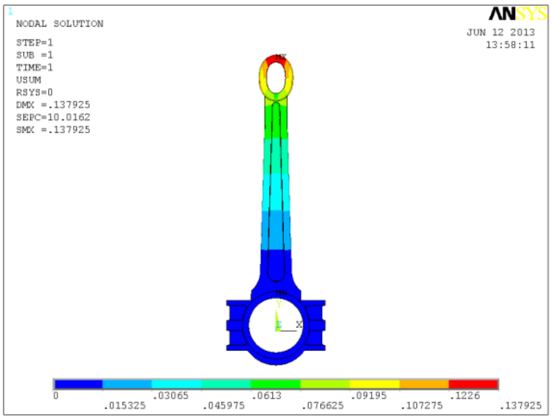

Fig 12: Displacement For Tensile Load, Al 360 Material

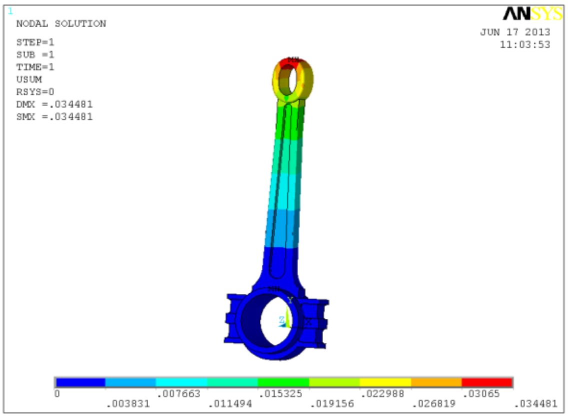

Fig13: Displacement For Tensile Load, Al6061-9%Sic-15% Fly Ash Material

From the fig 12 the maximum displacement occurs in the connecting rod is 0.137925 mm. From the fig 13 the maximum displacement occurs in the connecting rod is 0. 034481 mm.

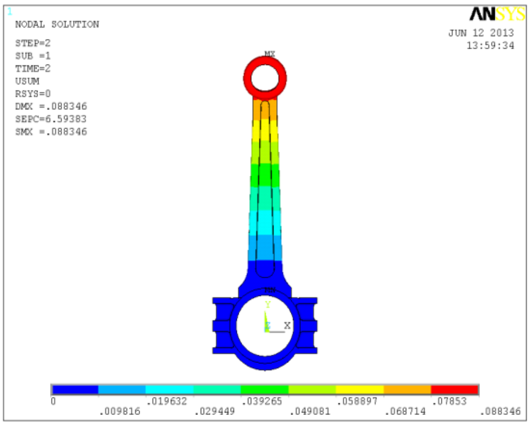

Fig 14: Displacement For Compression Load, Al 360 Material

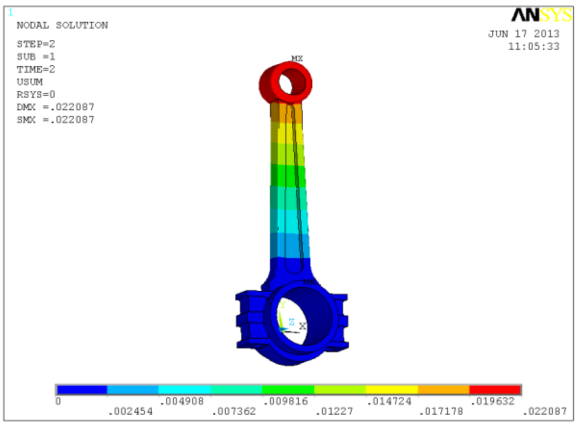

Fig 15: Displacement For Compressive Load, Al6061-9%Sic-15% Fly Ash Material

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From the fig 14 the maximum displacement occurs in the connecting rod is 0. 088346 mm. From the fig 15 the maximum displacement occurs in the connecting rod is 0. 022087 mm.

3. Von-mises Strain plots

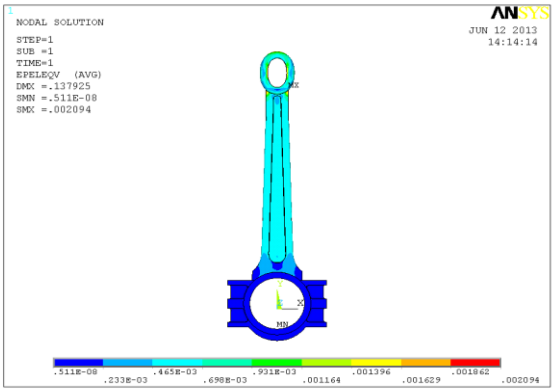

Fig 16: Von-Mises Strain For Tensile Load, Al 360 Material

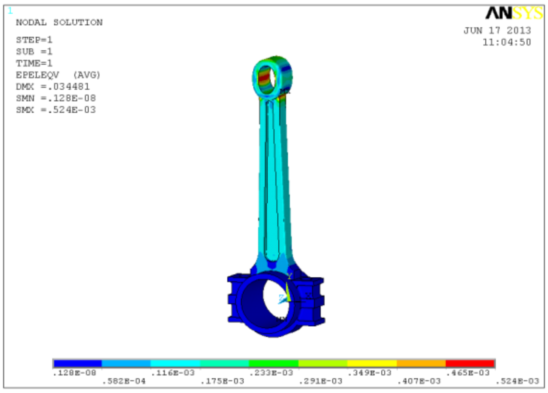

Fig 17: Von-Mises Strain For Tensile Load, Al6061-9%Sic-15% Fly Ash Material

From the fig 16 the maximum Von-mises strain occurs at the piston end of the connecting rod is 0.002094mm and minimum Von-mises strain occurs at the crank end of the connecting rod is 0.511e-08mm. From the fig 17 the maximum Von-mises strain occurs at the piston end of the connecting rod is 0.524e-03 mm and minimum Von-mises strain occurs at the crank end of the connecting rod is 0.128e-08mm.

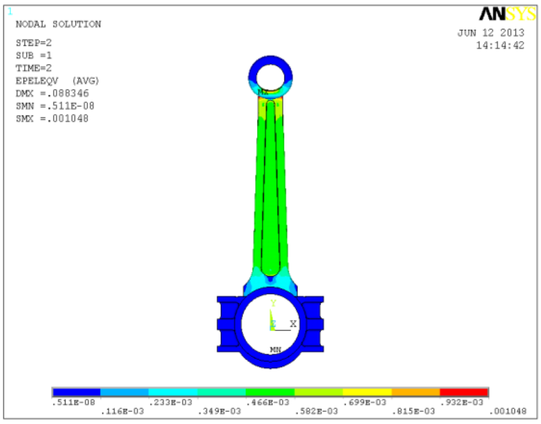

Fig 18: Von-Mises Strain For Compressive Load, Al 360 Material

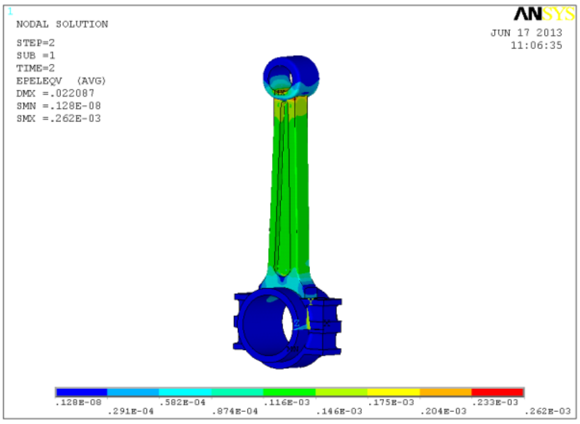

Fig 19: Von-Mises Strain For Compressive Load, Al6061-9%Sic-15% Fly Ash Material

From the fig 18 the maximum Von-mises strain occurs at the piston end of the connecting rod is 0.001048mm and minimum Von-mises strain occurs at the crank end of the connecting rod is 0.511e-08mm. From the fig 19 the maximum Von-mises strain occurs at the piston end of the connecting rod is 0.262e-03 mm and minimum Von-mises strain occurs at the crank end of the connecting rod is 0.128e-08mm.

4. VOLUME, WEIGHT AND STIFFNESS OF THE CONNECTING ROD.

a) Weight of the Connecting Rod.

- For aluminium 360:

The volume of the connecting rod used is 100829.348 mm^3. Therefore the mass of the connecting rod for respective materials are:

Weight = volume * density
Weight = 100829.348 * 2.63 e-3
Weight = 268.1811 grams

- For aluminium 6061-9%SiC-15%fly ash

The volume of the connecting rod used is 57472.72836 mm^3. Therefore the mass of the connecting rod for respective materials are:

Weight = volume * density
Weight = 57472.72836 * 2.637009e-3

Weight = 151.5555 grams

Therefore there is net difference of 116.6256 grams in the new connecting rod for the same volume, i.e., is 43.48 % reduction in weight.

b) Stiffness of the Connecting Rod

1. For aluminium 360
   Weight of the connecting rod = 268.1811
   Deformation = 0.137925
   Stiffness = weight / deformation
   Stiffness = 268.1811/0.137925
   Stiffness = 1944.39 g/mm

2. aluminium 6061-9%SiC-15%fly ash
   Weight of the connecting rod = 151.5555
   Deformation = 0.034481
   Stiffness = weight / deformation
   Stiffness = 151.5555/0.034481
   Stiffness = 4395.3336 g/m

V. CONCLUSION

- WEIGHT CAN BE REDUCED BY CHANGING THE MATERIAL OF THE CURRENT AL360 CONNECTING ROD TO HYBRID ALFASIC COMPOSITES.
- THE OPTIMISED CONNECTING ROD IS 43.48% LIGHTER THAN THE CURRENT CONNECTING ROD.
- THE NEW OPTIMISED CONNECTING ROD IS COMPARATIVELY MUCH STIFFER THAN THE FORMER.

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