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Analysis (Stress, Strain & Displacement) and Optimization of Connecting Rod using ALFA SiC 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 aluminum alloys are finding its application in connecting rod. In this work connecting rod is replaced by aluminum based composite material reinforced with silicon carbide and fly ash. And it also describes the modeling and analysis of connecting rod. First of all we made a model of connecting rod using Pro-E software with standard dimensions. FEA analysis was carried out by considering two materials, one is Aluminium-360 and another is ALFA-Sic composite. The parameter like von misses stress, von misses strain and displacement was obtained from ANSYS software. Compared to the former material the new material found to have less weight. It resulted in reduction of 46.35% of weight and it reduced the cost of connecting rod. The connecting rod is a major link inside of a combustion engine. It connect the piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it to the transmission. Connecting rods are widely used in variety of engines such as in-line engines, V-engine, opposed cylinder engines, radial engines and oppose-piston engines. [2]**

***Keywor*- ANSYS, Composite, Connecting Rod, Fly-ash, Pro-E, Silicon Carbide.**

I. INTRODUCTION

Connecting rod, automotive should be lighter and 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 aluminum connecting rods reinforced with steel continuous fibers. [2]

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 We described modeling and analysis of Connecting rod. In his project carbon steel connecting rod is replaced by aluminum boron carbide connecting rod. Aluminum 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%.

The connecting rod is a major link inside a combustion engine. It connects the piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it to the transmission. There are different types of materials and production methods used in the creation of connecting rods. The most common types of Connecting rods are steel and aluminum. The most common types of manufacturing processes are casting, forging and powdered metallurgy. Connecting rods are widely used in variety of engines such as, in-line engines, V-engine, opposed cylinder engines, radial engines and opposed piston engines. A connecting rod consists of a pin end, a shank section, and a crank-end. [2]

II. PROBLEM FORMULATION

Normally connecting rods are made of mild steel, cast iron, etc. which makes connecting rod very heavy. So now-a-days connecting rods are replaced by aluminum, silicon-carbides. It is now comparatively low in weight than mild steel, cast iron, etc. Considering the above facts we can use aluminum composites (ALFA Sic) to reduce almost 40% weight. [2]

III. OBJECTIVE

A. To reduce the weight of connecting rod by using ALFA

Sic composites.
B. To analyze and optimize the connecting rod.

IV. METHODOLOGY

A. CALCULATION OF CONNECTING ROD:

(a)- Pressure Calculation:

Assumptions:

(i)- Consider a 150cc engine
(ii)- Engine type air cooled 4-stroke, Bore × Stroke (mm) = 58.6×107.5

(iii)- Weight of reciprocating parts = Piston Weight + 0.33×Weight of connecting rod = 0.32 kg

(iv)- Displacement = 149.5CC

(v)- Maximum Power = 13.8bhp at 8500rpm

(vi)- Maximum Torque = 13.4Nm at 6000rpm

(vii)- Compression Ratio = 9.35/1

(viii)- Density of petrol at 274 K - 737.22×10^{-9} kg/mm^3

(ix)- Molecular weight M = 114.228 g/mole

(x)- Ideal gas constant R = 8.3143 J/mol.k

From gas equation,

$$PV = m\,.R_{specific}T \qquad (1)$$

& Mass = Density × volume

We found P = 14.63 MPa. [1]

(b)- Design Calculation of Connecting Rod:

Dimension and cross-section of the 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 forces, therefore the cross-section of the connecting rod is designed as a strut and the Rankine's formula is used [1]
According to Rankine's formula

Crippling load about X-axis $= F = (\sigma\times A) / [1 + a\,(L/ K_{xx})^2]$

$$F = (\sigma \times A)/ [1 + a\,(l/ K_{xx})^2] \qquad (2)$$

$L = \ell$ (for both end hinged)

Crippling load about Y-axis $(F) = (\sigma \times A)/ [1 + a\,(L/ K_{yy})^2]$

$$F = (\sigma \times A)/ [1 + a\,(\ell/2\, K_{yy})^2] \qquad (3)$$

$L = \ell/2$ (for both end hinged)

Where L = Equivalent length of the connecting rod.

& a = Constant

a = 1/500, for aluminum and aluminum composite

Crippling load about X-axis = Crippling load about Y-axis

$(\sigma\times A)/[1 + a(L/ K_{xx})^2] = (\sigma\times A)/[1 + a(L/2\, K_{yy})^2]$;

$K_{xx}^2 = (1/4)\, K_{xx}^2$

This implies that $4I_{yy} = I_{xx}$ [4]

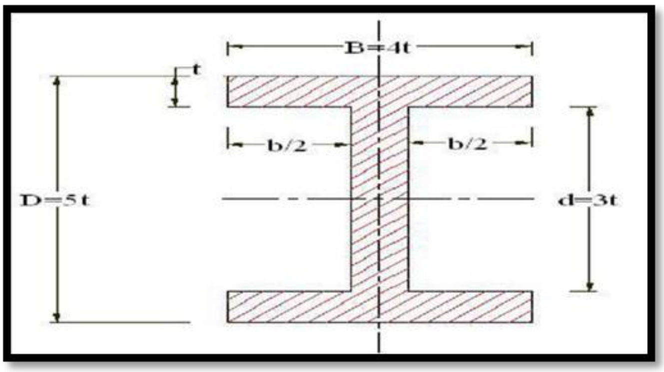

Figure 1. *Parameters of connecting rod*

(c)- Parameter of Connecting Rod:

Assumptions:

(i)- Thickness of the flange and web of the section= t
(ii)- Width of the section B=4t
(iii)- Depth or height of section H = 5t
(iv)- Area of the cross-section $A=2(3t\times t) + 3t\times t = 11t^2$
(v)- Moment of inertia of the section about x-axis

$I_{xx} = [3\,t\,(5t)^3 - 3t\,(3t)^3]/ 12 = 419t^4/12 = 34.9\, t^4$

(vi)- Moment of inertia about y axis

$I_{yy=} [2\times t / 12 \times (3t)\, 3 + (3t4) / 12] = 131t4 / 12 _= 10.91t^4$

Therefore $I_{xx} / I_{yy} = 3.2(4)$

Since the value of I_{xx}/I_{yy} lies between 3 and 3.5, therefore, I section chosen is quite satisfactory. After deciding the proportions for I-sections of the connecting rod, its dimensions are determined by considering the buckling of the rod about X-axis (assuming both ends hinged) and applying Rankine's formula. It is known that buckling load,

$$F= (\sigma\times A)/ [1+ a (L/ K_{xx})^2]$$

Now radius of gyration relation in term of t

$$K_{xx}^2=3.2\times K_{yy}^2$$

B. CACCULATION OF NET FORCE:

Length of the connecting rod (L) = 2 times the stroke
L = 215 mm

Total Force acting $F = F_p - F_i$ (5)

Where F_p = force acting on piston, F_i = force by inertia

$F_p = (\pi d^2/4) \times$ gas pressure (6)

$Fi = (F/g) \times (\omega^2) \times r [\cos\Theta + (r/l) \cos^2\Theta]$ (7)

Where, F = Weight of reciprocating parts

ω= angular velocity

r =crank radius

W_r = Weight of reciprocating parts = 0.32 ×9.81=3.1392N

r = stroke of piston / 2

θ = Crank angle from the dead center

l/r= length of connecting rod / crank radius = 4

g = acceleration due to gravity =9.81

v = crank velocity m/s

$w = 2\pi n/60$

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

$v= r\times w = 29.3e^3 \times 890.1179 = 26.08$

On substituting F_i=9285.54

Therefore F = 39473.1543 – 9285.5481= 30187.606

Taking factor of safety = 1.5

Hence net crippling load =30187.6062 ×1.5 = 46062.78 N

Now, According to Rankine's – Gordon formula,

$$F = \frac{f_c A}{1+a\,(\frac{l}{k_{xx}})} \quad (8)$$

Let,
A = Crossectional 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 &

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

1. For Aluminum 360:

On substituting to Rankine'S formula

$$46062.78 = \frac{170\times 11t^2}{1+0.002\,(\frac{215}{1.78t})^2} \quad (9)$$

t =7.5mm

There fore

Width B = 3t = 22.5mm

Height H = 5t = 37.5 mm

Area A = $11t^2$ = 618.45 mm^2

Height at the piston end H_1 = 0.5H to 0.9 H

H_1 = 0.64×37.5= 24 mm

Height at the crank end H_2 = 0.9H to 1.25 H

H_2 = 0.96×37.5= 36mm

2. For Aluminum 60619% SiC15% fly ash:

On substituting to Rankine's formula

$$46062.78 = \frac{170\times 11t^2}{1+0.002\,(\frac{215}{1.78t})^2} \quad (10)$$

t =5.17 mm

Therefore,

Width B = 4t = 20mm

Height H = 5t = 25mm

Area A = $11t^{2} = 275mm^{2}$

Height at the piston end $H_1 = 0.5H$ to 0.9 H

$H_1 = 0.64 \times 25 = 16mm$

Height at the crank end $H_2 = 0.9H$ to 1.25H

$H_2 = 0.96 \times 25 = 24.mm$

C. DESIGN OF ENDS:

$P = D_i \times D_o \times P_b$;

Where,

P = maximum gas load = $(3.14/4) \times 0.0586^2 \times 14.63 \times 10^6 = 39457.5$

L_c = length of crank pin (mm)

D_o = diameter of crank pin (mm)

P_b = allowable bearing pressure

1. For Aluminum 360:

From the formula $P = D_i \times D_o \times P_b$; (11)

We get,

(a)-Dimensions of big end:

P_b = allowable bearing pressure= ranges from 10 to 20 MPa

D_o = 57 mm

Inner diameter = 0.81 × Outer dia = 46.17 mm

D_i = 46.17 mm

Diameter of crank pin= 57 mm

Length of crank pin = 45 mm

(b): Design of small end:

P_b = allowable bearing pressure= ranges from 20 to 50 MPa

D_o= 36.26 mm

Inner diameter = 0.625 × Outer diameter =22.66 mm

D_i = 22.66 mm

2. For Aluminium6061-9%SiC-15%fly ash:

From the formula $P = D_i \times D_o \times P_b$;
We get,

(a)-Dimensions of big end:

P_b = allowable bearing pressure= ranges from 15 to 30 MPa

D_o = 54mm

Inner diameter = 0.81 × Outer diameter = 44 mm

D_i = 44 mm

Diameter of crank pin= 54mm

Length of crank pin = 44mm

(b)-Dimension of small end:

P_b = allowable bearing pressure = ranges from 30 to 60 MPa

D_o= 32 mm

Inner diameter = 0.625 × Outer diameter = 20 mm

D_i = 24mm

TABLE 1. MATERIAL PROPERTIES USED FOR ANALYSIS

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

D.CALCULATION OF VOLUME:

(a)- For aluminum 360:

Total volume = $\pi \times 46.17[57^2 - 46.17^2]/4 + A \times (215 - 28.5 - 18.13) + \pi \times 27.2[36.26^2 - 22.66^2]/4 = 161763.2\ mm^3$

Where, A is CS area = 618.45 mm^2

(b)- For aluminum 6061-9%SiC-15%fly ash:

Total volume = $\pi \times 44[54^2-44^2]/4 + A \times (215 - 27 - 16) + \pi \times 24[32^2-20^2]/4 = 92928.5 mm^3$

Where A is cross-sectional area area = 275mm^2

E. Weight of the Connecting Rod:

(a)- For aluminum 360:

The volume of the connecting rod used is 161763.2 mm^3. Therefore the mass of the connecting rod for respective materials are:

Weight = volume × density

= $161763.2 \times 2.8\ e^{-3}$ = 452.93 gm.

(b)- For aluminum 6061-9%SiC-15%fly ash:

The volume of the connecting rod used is 92928.5 mm^3. Therefore the mass of the connecting rod for respective materials are:

Weight = volume × density = $92928.5 \times 2.61161e^{-3}$ = 243 gm.

Therefore there is net difference of 209.9 grams in the new connecting rod for the same volume, i.e., is 46.35% reduction in weight.

V. IMPLEMENTATION

We have considered two different types of material-Aluminium360 and Aluminium60619% SiC15% flyash. Further a model is prepared using Pro-E software in same dimension and the model was analyzed for each material using ANSYS Software. [1]

TABLE 2.COMPARISON OF STRESS, STRAIN AND DISPLACEMENT FOR DIFFERENT MATERIALS

S. no	Material	Compressive load		
		Stress (MPa)	Displacement (mm)	Strain
1	Old material	74.48	0.0323	1.24×10^{-3}
2	Al6061-9% SiC-15% fly ash	167.5	0.0617	2.39×10^{-3}

VI. CONCLUSION

Weight can be reduced by changing the material of the current Al-360 connecting rod to hybrid ALFA-SiC composites. The optimized ALFA SiC connecting rod is 46.35% lighter than the current Al-360 connecting rod and the percentage Change in stress, strain and displacement are 55.53%, 47.65% and 48.11%.

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