Stress Analysis & Weight Optimization of Connecting Rod using Al Based Composites – FEA Approach

Laxman Khose[1] Navalkant Konda[2]
[1,2]Assistant Professor
[1,2]D. Y. Patil College of Engineering, Savitribai Phule Pune University, Pune, India

Abstract— The automobile engine connecting rod is a major link inside of an internal combustion engine. It is the intermediate member between the piston and the crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crankpin and thus convert the reciprocating motion of the piston into rotary motion of the crank. Previously connecting rods are manufactured using cast iron but now days AL based alloys finds wide application in manufacturing the connecting rod. In the present study, FEM analysis is carried out by considering two materials viz. cast iron and Al based composite material reinforced with the boron carbide with addition of some amount of fly ash. The parameters like von misses stress, strain and displacements were obtained from ANSYS software. Compared to cast iron the new material found to have less weight (reduction of 70-75%), with more stiffness and 75-80% reduction in displacement.

Key words: Connecting Rod, Composite Material, ANSYS, Boron Carbide, Fly Ash, CATIAV5R19

I. INTRODUCTION

As we know well, the primary function of the connecting rod is to transmit the push and pull from the piston pin to the crank pin and thus converts the reciprocating motion of the piston into rotary motion of the crank. There are different types of materials and production methods used for the manufacturing of connecting rods. The most common types of connecting rod are made up of cast iron, steel etc. Hero Honda Company had already started the manufacturing of aluminum connecting rods reinforced with steel continuous fibers. The major stresses induced in the connecting rod are a combination of axial and bending stresses in operation. The axial stresses are produced due to cylinder gas pressure (compressive only) and the inertia force arising in account of reciprocating action (both tensile as well as compressive), whereas bending stresses are caused due to the centrifugal effects. It consists of a long shank, a small end and a big end. The cross-section of the shank may be rectangular, circular, tubular, I-section or H-section. Generally circular section is used for low speed engines while I-section is preferred for high speed engines. The most common type of manufacturing processes is casting, forging, and powdered metallurgy. Connecting rod is subjected to a complex state of loading. It undergoes high cyclic loads of the order of 10^8 to 10^9 cycles, which range from high compressive loads due to combustion, to high tensile loads due to inertia. Vivek. c. pathade et al [1] performed stress analysis of I.C Engine connecting rod by finite element method. They modeled connecting rod using pro/E Wildfire 4.0 and ANSYS Workbench 11.0 software. They reported from the theoretical and finite element analysis then the stresses induced in the small end of the connecting rod are greater than the stress induced at the big end. K.surdershn Kumaret al [2], reported on modeling and analysis of two wheeler connecting rod. In this connecting rod is replaced by aluminum reinforced with boron carbide for Suzuki GS150R motor bike. A parametric model of connecting rod is modeled using pro/E Wildfire 4.0. Analysis is carried out by using ANSYS software. They presented the results of materials and reported that the working factor of safety is nearer to theoretical factor of safety in aluminum boron carbide. Anil Kumar et al [3], presented the optimization of connecting rod parameters using CAE tools. They reported on optimizing weight and reducing inertia forces on the existing connecting rod, which is obtained by changing design variables in the existing connecting rod design. The model was developed in pro/E Wildfire 5.0 and then imported as a Para solid from in ANSYS Workbench. The stress was found maximum at the piston end. This can be reduced by increasing the material near the piston end. The weight of the connecting rod was also reduced by 0.004kg which was not significant but reduces the inertia *forces*. Suraj pal et al [4], reported on design evaluation and optimization of connecting rod parameters using Finite element method. Proper finite element model is developed using pro/E Wildfire 4.0. The weight of the connecting rod is also reduced by 0.477g. The stress is found maximum at the piston end so that material is increased in the stressed portion to reduce stress.

II. MODELING

Connecting rod of Honda CBZ unicorn (150cc) is selected for the present investigation. Two materials namely cast iron and aluminum alloy composite reinforced with boron carbide by addition of some amount of fly ash are used for the manufacturing of connecting rod. This manufactured connecting rod is analyzed by ANSYS software to determine the von misses stress, strain and displacement.

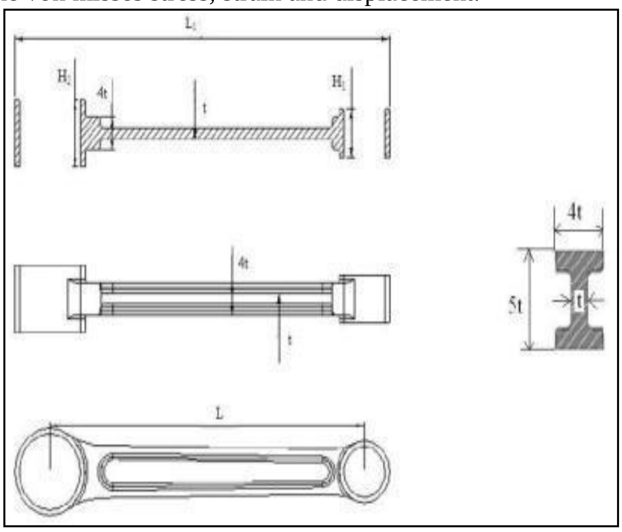

Fig. 1: General Dimensions of the Connecting Rod

Parameters	Old Material (Cast iron)	New material (Al6061-10%BC-15%fly ash)
Ultimate tensile strength	150-200 Mpa	420 Mpa
Yield strength	550 Mpa	360 Mpa
Young's modulus	178 Gpa	85 Gpa
Poisson' ratio	0.3	0.33
Density	7.2 g /cc	2.8 g/cc

Table 1: Material Properties for Analysis

In I.C. Engines , the most widely used section of rod is I due to its easiness as it will keep the inertia forces small and can withstand the high gas pressures also. The dimensions of the selected connecting rod are found using vernier calipers, screw gauge. The properties of the old and new material are tabulated in the Table 1.According to the dimensions as shown in Table 2. The model of the connecting rod is developed using CATIA V5 R19, the modeled connecting rod is the imported in to design modeler of ANSYS workbench.

Sr.No.	Parameters	Values
1.	Length of connecting rod	117.2mm
2.	O.D. of big end	39.05mm
3.	I.D. of big end	30.20mm
4.	O.D. of small end	17.75mm
5.	I.D. of small end	13.05mm

Table 2: Dimensions of Connecting Rod

A. *Pressure Calculation*

Consider an engine of Honda CBZ Unicorn having displacement of 150CC.

Engine Type	Air cooled 4 Stroke
Bore X Stroke (mm)	57 X 58.6
Displacement	150 CC
Maximum Power	13.85bhp @ 8500rpm
Maximum Torque	13.4 Nm @ 6000rpm

Table 3: Engine Specification

Density of petrol@ 288K= $737.25X10^{-9}$kg/mm^3
Molecular weight (M) = 114.228 g/mole
Ideal gas constant (R) = 8.3143 kJ/mole.K
From Ideal gas equation, we know that,
PV = m. $R_{specific}$ .T
m = Volume X Density
= $150X10^3$ X $737.25X10^{-9}$
= 0.1105 kg
$R_{specific}$ = R/ M
= 8.3143 X 10^3 / 114.228
= 72.753
So,
P = m. $R_{specific}$. T / V
= 0.1105 X 72.753 X 288/ 150X 10^3
= 0.01543 Kpa = 15.43 Mpa
P = 16 Mpa ……. (say)

B. *Design Calculation*

Generally, section of shank of connecting rod is taken as I section, as it will keep the inertia forces small and can withstand the high gas pressures also.

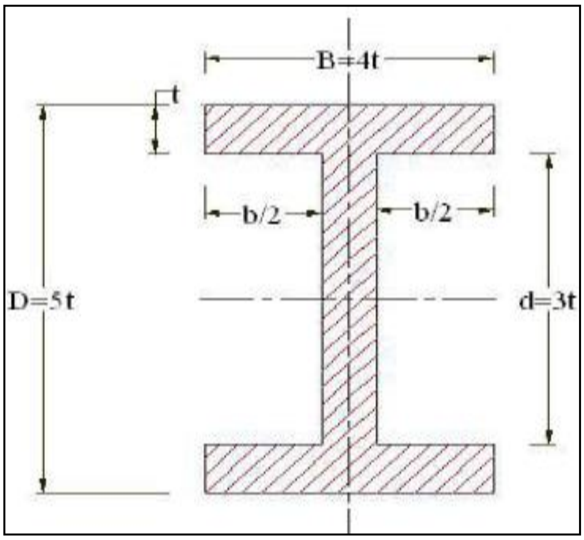

Fig. 2: Standard Dimensions of I Section

- Thickness of flange and web section = t
- Width of section B = 4t
- Height of section D = 5t
- Area of section A = 11 t^2
- Moment of inertia @ xx is.

I_{xx} = (419/12) t^4
Now,
K^2_{xx} = I_{xx} / A
= 3.17 t^2
So,
K_{xx} = 1.78 t
Similarly,
I_{yy} = 2 X MI of flange + MI of web
= (131/12) t^4
I_{xx} / I_{yy} = 419/131 = 3.2
Now, Maximum force acting on the connecting rod is given by,
P = $\frac{\pi}{4}$d. d x gas pressure
= (3.1415/4) X 57 X 57 X 15.43
= 39373.635N
P_{max} = 39373.635 N
Now, according to Rankings- Gordon equation, the buckling load is given by,
$P_{cr} = \sigma_c$ A/ 1+a $(L/K_{xx})^2$
Also,
P_{cr} =P_{max} X factor of safety
= 39373.635 X 6
= 236.2418 X 10^3 N
Therefore,
σ_c A/ 1+a $(L/K_{xx})^2$ = 236.2418 X 10^3
Where,
σ_c = crushing stress or yield stress in compression,
A = cross sectional area of section,
a= Rankine's constant = σ_c / $\pi\pi E$
= 1/1600 for cast iron
= 1/500 for composite material
L = length of connecting rod = 2 X Stroke
K_{xx} = Radius of gyration of the section @ XX .
For Cast iron:-
$$236.2418 \text{ X } 10^3 = \frac{550 \text{ X } 11t.t}{1+\frac{1}{1600}(117.2/1.78t)2}$$
On solving,

t = 6.44 mm

For Al6061-10%BC-15%fly ash:-

$$236.2418 \times 10^3 = \frac{360 \times 11t.t}{1+\frac{1}{500}(117.2/1.78t)^2}$$

On solving,

t = 7.72 mm

Width (B) = 4 t = 30.88 mm

Depth (H) = 5 t = 38.6 mm

Area of section (A) = 11 t^2 = 655.58 mm^2

III. FEA MODEL OF CONNECTING ROD

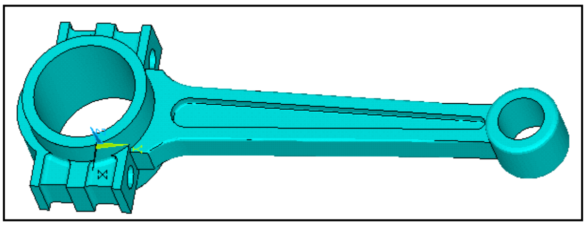

Fig. 3: Model of Connecting Rod

- Element Type: Solid 187
- Number of elements: 69613
- Number of nodes: 117439

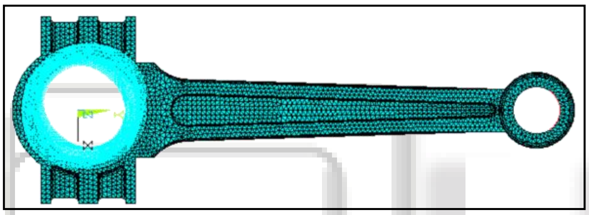

Fig. 4: All DOF Constrained at Crank End

IV. ANALYSIS OF CONNECTING ROD

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

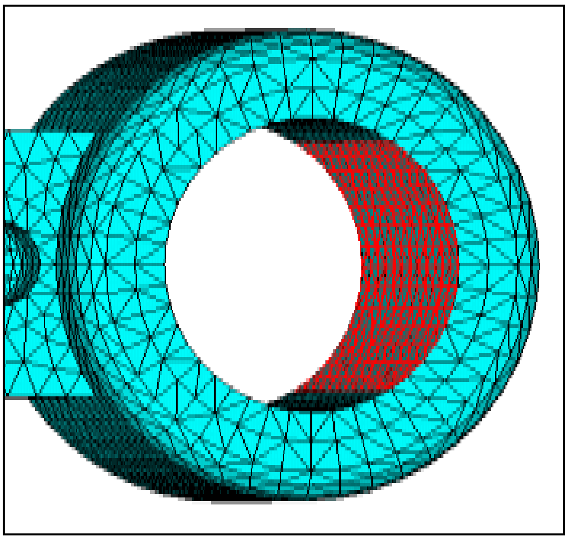

Fig. 5: Tensile Load Applied at Piston End

A. Von-Misses Stresses

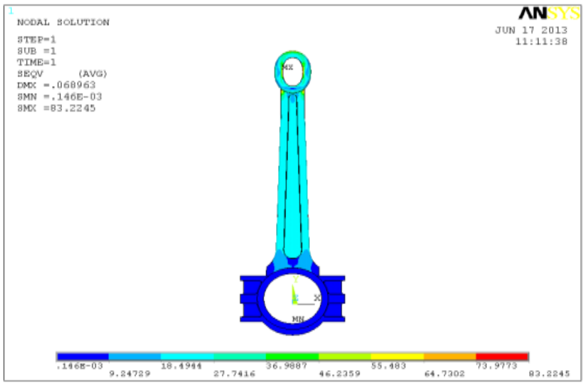

Fig. 6: Von- Misses Stress for Cast Iron

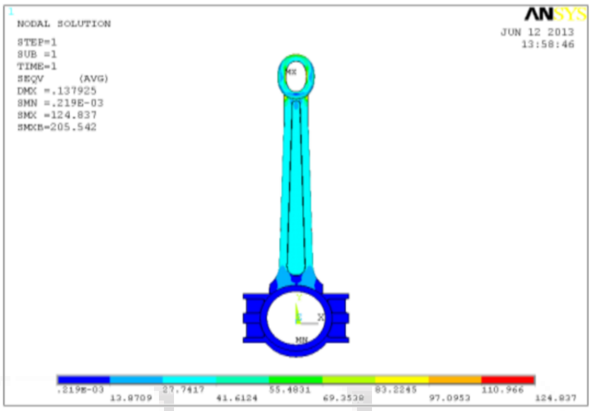

Fig. 7: Von-Misses Stress for Composite Material

B. Displacements

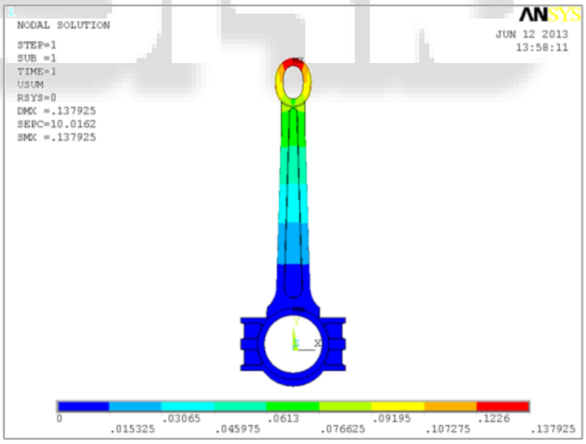

Fig.8 Displacement for cast iron

From fig. 6 the maximum stress occurs at the piston end of the connecting rod and is 83.225 Mpa and minimum stress is at crank end which is equal to 0.00014 Mpa.

From fig.7 the maximum stress that occurs at the piston is 124.84 Mpa and minimum value at the crank end is 0.00021 Mpa.

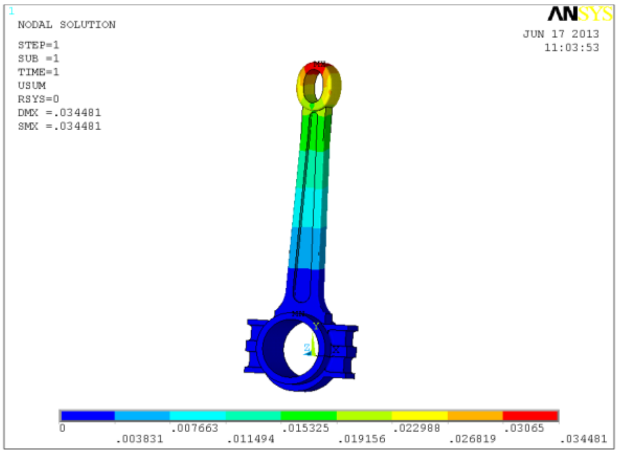

Fig. 9: Displacement for Composite Material

From fig. 8 the maximum displacement for the cast iron made connecting rod is 0.1381 mm.

From fig 9 the maximum displacement for the composite material connecting rod is 0.03448mm.

V. Result & Discussion

Material	Stresses	Displacement
Cast Iron	83.225 Mpa	0.1381mm
Composite material	124.837 Mpa	0.03448 mm
% difference	50	75

Table 4: Comparison of Result for Different Material

Weight of Cast iron composite connecting rod= 1500gm;
Weight of composite material connecting rod = 375 gm,
Therefore,
Weight Optimization = 1500-375/1500
= 0.75

So, there is net difference of 1125 gm in the new connecting rod for the same volume, i.e. near about 75% reduction in weight.

Stiffness of the connecting rod
For Cast iron:
Weight of the connecting rod = 1500gm
Deformation = 0.1381mm
Stiffness = weight / deformation
= 1500/ 0.1381
= 10861.7g/mm
For Composite material (Al6061-10%BC+flyash):-
Weight of the connecting rod = 375gm
Deformation = 0.03448 mm
Stiffness = 375 / 0.03448
= 10876 g/ mm

VI. Conclusion and Future Scope

1) The optimized connecting rod is much lighter than the cast iron connecting rod.
2) The optimized connecting rod if much stiffer than the old connecting rod, resulting 75% reduction in displacement.

From analysis it is observed that the minimum stresses occur at the crank end, so the material can be removed from these portions, thereby reducing material cost.

References

[1] Vivek.c.pathade, Bhumeshwar Patle, Ajay N. Ingale ”Stress Analysis of I.C. Engine Connecting Rod by FEM”, International Journal ofEngineering and Innovative Technology, Vol-1, Issue-3, pp-12-15, March2012.
[2] K. Sudershan Kumar, Dr. k. Tirupathi Reddy, Syed Altaf Hussan “Modeling and analysis of two Wheeler connecting rod”, International Journalof Modern Engineering Research, Vol -2, Issue- 5, pp-3367-3371, Sep-Oct-2012
[3] Anil Kumar, Kamaldeep Grover, Balvinder budina “optimization of connecting rod parameters using CAE tools”, International Journal of Latest Trends in Engineering and Technology, Vol- 1, Issue- 3 , Sep2012.
[4] Suraj Pal, Sunil Kumar, “Design Evaluation and Optimization of Connecting Rod Parameters Using FEM”, International Journal of Engineering and Management Research, Vol- 2, Issue- 6, Dec 2012.
[5] Design of Machine Element by R.S Khurmi, J.K. Gupta