Material Optimization of the Connecting Rod by using Finite Element Approach

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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 material optimization is done by replacing the existing model with aluminum based 6061 – T6 alloy material and SiC reinforced with Zirconium diboride. And it also describes the modeling and analysis of connecting rod. The 3D modeling of the part has been created by using CATIA V5 and FEA analysis was carried out by using ANSYS WORKBENCH. The parameter like von misses stress, von misses strain and deformations were obtained from ANSYS software considering two materials.**

Keywords: **material optimization, FEA analysis, Catia V5, Al 6061 – T6 alloy and SiC reinforced with Zirconium diboride**

1. INTRODUCTION

A connecting rod is a rigid member which connects a piston to a crank or crankshaft in a reciprocating engine. Together with the crank, it forms a simple mechanism that converts reciprocating motion into rotating motion. A connecting rod may also convert rotating motion into reciprocating motion, its original use. Earlier mechanisms, such as the chain, could only impart pulling motion. Being rigid, a connecting rod may transmit either push or pull, allowing the rod to rotate the crank through both halves of a revolution. In a few two-stroke engines the connecting rod is only required to push. Today, the connecting rod is best known through its use in internal combustion piston engines, such as automobile engines. These are of a distinctly different design from earlier forms of connecting rod used in steam engines and steam locomotives.

K. Sudershan kumar et al, 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 7.84%. Vivek. C. Pathade et al, he dealt with the stress analysis of connecting rod by finite element method using pro-ewild fire 4.0 and ansys work bench 11.0 software. And concluded that the stress induced in the all 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 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 crack able 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 et al, in his paper a dynamic simulation was conducted on a connecting rod made of aluminum 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 an FEA was conducted to find the stress at critical locations.

TABLE 1: MATERIAL PROPERTIES

s.no	properties	Al 6061 – T6	SiC reinforced ZrB2	units
1	density	2700	2060	Kg/m^3
2	Youngs modulus	68.9	486	GPa
3	Tensile strength	290	1070	MPa
4	Yield strength	276	930	MPa
5	Poisson ratio	0.33	.11	-
6	Coeff thermal expansion	$2.32*10^{-5}$	$5.9*10^{-6}$	/K
7	Bulk modulus	20	181	GPa
8	Shear modulus	26	179.8	GPa

II. DESIGN CALCULATIONS

2.1 Pressure calculation :

Consider a 150cc engine

Engine type air cooled 4-stroke

Bore × Stroke (mm) = 85.5 * 70

Displacement=$149.5cc^3$

Maximum Power = 13.8bhp at 8500rpm

Maximum torque= 13.4 Nm 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 in Pa.

V = Volume in m^3

m = Mass in kg.

$R_{specific}$= Specific gas constant

T = Temperature in K

But, mass = density * volume

m =737.22E-9*180E3

m = 0.1326 kg

Rspecific= R/M = 8.3143/0.1326 = 62.702

P = m.Rspecific.T/V = 0.1326*62.702*288.85/180E3

P = 13.34MPa ~ 13 MPa.

2.2. Design calculation of connecting rod:

From psg design data book pg. no: 7.123.,

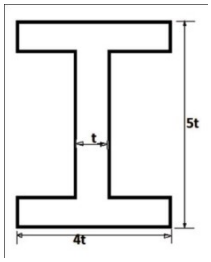


Fig.4.1: I Section for connecting rod

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 Ixx= 34.91t4
- Moment of inertia about y axis Iyy= 10.91t4
  Therefore Ixx/Iyy= 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 = 56 mm

Fp= ($\pi d^2/4$) * gas pressure

Fp= 38003.56 N

WB = FC × F. S.= 38003.06×1.78 = 95007.65 N

Here F.S factor of safety.

We know that radius of gyration of the section about X-axis,

Kxx= $\sqrt{(Ixx/A)} = \sqrt{(34.91t^4/11t2)}$ = 1.78 t

Radius of crank,

r = diameter of crank / 2 = 70/2 = 35mm.

Length of Connecting Rod = 2×stroke= 2×85.5=171.2 mm

Equivalent length of the connecting rod for both ends hinged, L= l = 171.2 mm

Total Force acting by the piston,F = Fp – Fi

Where Fp = force acting on piston Fi = force by inertia

Fp = (πd2/4) * gas pressure , Fp = 39473.1543 N

$$Fi = x = \frac{R\omega 2r}{g} * (cos\theta + \cos 2\theta/n)$$

R = weight of reciprocating parts R = 1.6 * 9.81 = 15.696 N

r = crank radius r = stroke of piston / 2 r = 70/2 = 29.3

= Crank angle from the dead center θ = 0 considering that connecting rod is at the TDC position

n = length of connecting rod / crank radius n1 = 171.2/35 = 4.89

g = acceleration due to gravity, 9.81

v = crank velocity m/s w = $2\pi n/60$ w = 2π8500/60 = 890.1179

v = rw = 35 e-3*890.1179 = 31.15 m/s

On substituting Fi = 9285.5481 Therefore F = 50029.86 – 9285.5481 F = 40744.31N

Now according to Rankine's formula, we know that buckling load (F),

$$F = \frac{fc * A}{1 + a(\sqrt{l/kxx)\hat{}2}}$$

Where, a = Rankine's constant.

$40744.31 = \frac{276*11\ \hat{}2}{1+.002(\sqrt{171.2/1.78t)\hat{}2}}$ = t = 3.02 mm

Thus, the dimensions of I-section of the connecting rod are:

Thickness of flange and web of the section = t =3.02 mm

Width of the section, B = 4 t = 4 × 3.02 =12.08mm

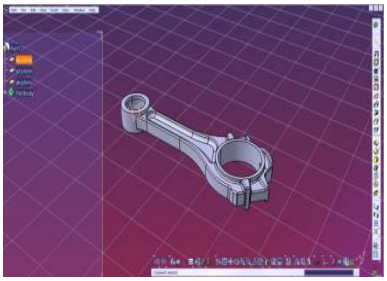
Height of the section, H = 5 t = 5 × 3.02= 15.10mm

Depth near the big end, H1 = 1.2H = 1.2 × 15.10= 18.12 mm

and depth near the small end, H2 = 0.85H = 0.85 × 15.10=12.835 mm

III. 3D MODELING

The 3d modeling from the given data has been drafted by using CATIA V5 software.



IV. FINITE ELEMENT ANALYSIS

4.1 Structural Analysis of the Connecting Rod:

Structural analysis is probably the most common application of the finite element method as it implies bridges and buildings, naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

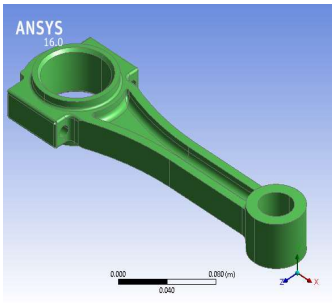


Fig 4.1 imported model from catia v5

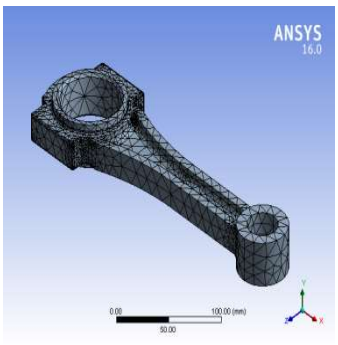


Fig 4.2 meshed part

4.2 Structural Analysis for Connecting Rod Using Aluminum 6061 – T6 Alloy:

The structural analysis process for the connecting rod has been carried out for the push and pulling action named as the tension and compression process. So, there are two types of the analysis process carried out for the pressure acting on the connecting rod.

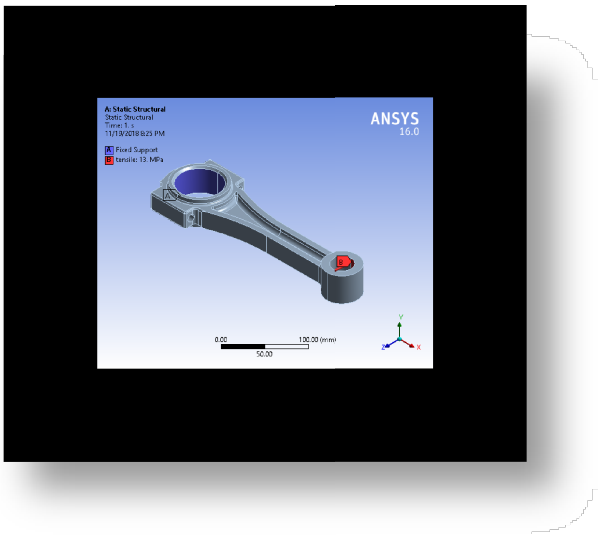


Fig 4.3 boundary conditions for the tensile stress

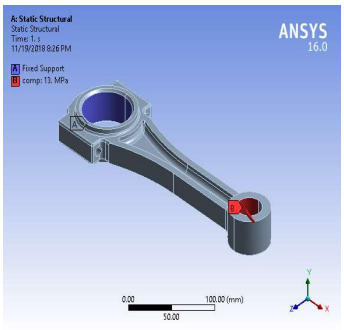


Fig 4.4 boundary conditions for the compressive stress.

Case 1: For the tensile stress:

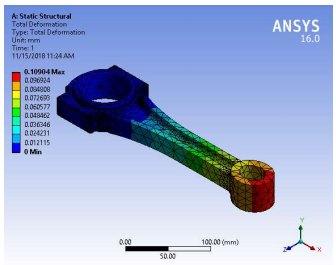


Fig 4.5 maximum deformation

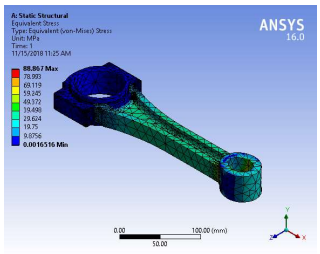


Fig 4.6 maximum von mises stress

Case 2: For the compressive stress:

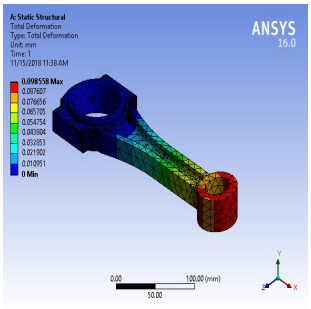


Fig 4.7 maximum deformation.

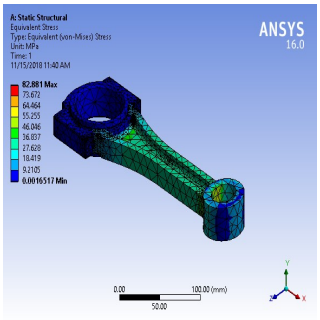


Fig 4.8 maximum von mises stress.

For Connecting Rod Using AL 6061-T6:

Case 1: For the tensile stress:

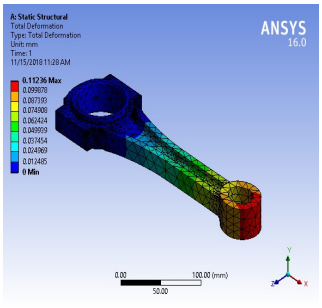


fig 4.9 maximum deformation

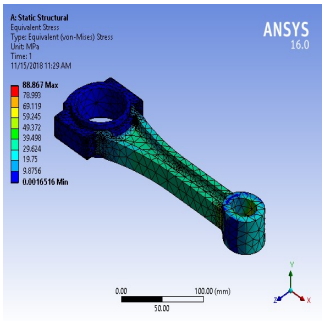


Fig 4.10 maximum von mises stress

Case 2: For the compressive stress:

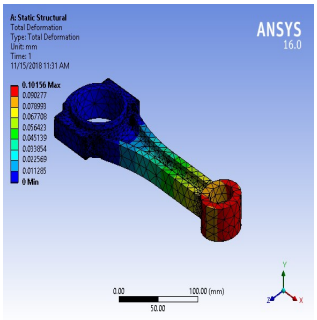


Fig 4.11 maximum deformation

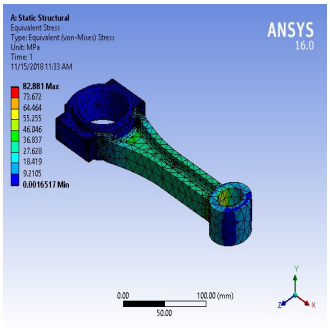


Fig 4.12 maximum von mises stress.

Structural Analysis For Connecting Rod Using Sic Reinforced Zrb2:

Case 1: For the tensile stress:

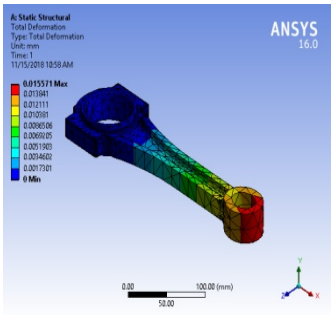


Fig 4.13 maximum deformation

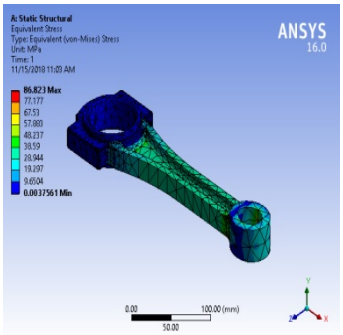


Fig 4.14 maximum von mises stress.

Case 2: For the compressive stress:

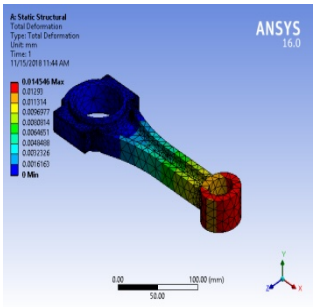


Fig 4.15 maximum deformation.

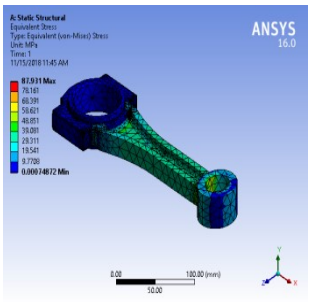


Fig 4.16 maximum von mises stress.

V. RESULTS

The following table represents the comparison between the theoretical and analytical values of the connecting rods like deformation and vonmises stress.

TABLE 5.1 RESULTS FOR THE TENSILE STRESS.

s.no	Material	Pressure (tensile)	Deformation (mm)	Von mises stress (MPa)
1	Aluminum alloy	13 MPa	0.10904	88.867
2	Al 6061-T6	13 MPa	0.11236	88.87
3	SiC reinforced ZrB2	13 MPa	0.015571	86.823

TABLE 5.2 RESULTS FOR THE COMPRESSIVE STRESS

s.no	Material	Pressure (compressive)	Deformation (mm)	Von mises stress (MPa)
1	Aluminum alloy	13 MPa	0.098558	82.881
	Al 6061-T6	13 MPa	0.11236	82.881
3	SiC reinforced ZrB2	13 MPa	0.014546	87.931

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VI. CONCLUSION

1. In this project we have designed a connecting rod used in a 150cc bike. We have modeled the connecting rod by using 3D parametric software CATIA V5.
2. To validate the strength of our design, we have done structural analysis and on the connecting rod. We have done analysis by varying aluminum alloy, aluminum 6061 – T6 and SiC reinforced ZrB2.
3. By analyzing the results getting by the ANSYS software, the SiC reinforced ZrB2 has the minimum deformation and the maximum stress. So the SiC reinforced ZrB2 is better than other two materials.
4. So we can conclude that as per our analysis using material SiC reinforced ZrB2 for connecting rod is best.

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