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Stress Analysis of 220cc Engine Connecting Rod

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Abstract

The connecting rod is an intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to crank pin, thus converting the reciprocating motion of the piston in rotary motion of the crank. This thesis describe designing and analysis of connecting rod. Currently existing connecting rod is manufactured by using steel. In this drawing is drafted from the calculation. A parametric model of connecting rod is modeled using solidwork 2016software and to that model, analysis is carried out by using ANSYS 15.0 software. Finite element analysis of connecting rod is done by considering the materials, viz... forged steel. The best combination of parameters like Von misses stress and strain, Deformation, Factor of safety and weight reduction for two wheeler piston were done in ANSYS software. Forged steel has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material like carbon steel. With fatigue analysis we can determine the lifetime of connecting rod.
Keywords: Connecting Rod, Analysis of Connecting Rod, Four Stroke Engine Connecting Rod, Forged Steel Connecting Rod, Design and Analysis of Connecting Rod

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NOMENCLATURE

A = cross section area of the connecting rod.
L=length of connecting rod.
C =compressive yield stress.
Wcr =crippling or buckling load. crippling or buckling load.
Ixx = moment of inertia of section about x-axis.
Iyy =moment of inertia of section about y-axis.
Kxx = radius of gyration of section about x-axis.
Kyy = radius of gyration of the section about y-axis.
D = Diameter of piston.
r = Radius of crank.

I. INTRODUCTION

In a reciprocating piston engine, the connecting rod connect the piston to the crank or crankshaft. In modern automotive internal combustion engine, the connecting rod is are most usually made of steel for production engine, but can be made of aluminum or titanium for high performance engine or of cast iron for application such as motor scooters. The small end attaches to the piston pin, gudgeon pin or wrist pin, which is currently most often press fit into the con rod but can swivel in 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 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 car, frequently putting the broken rod through the side of the crankcase and there by 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 bolts where not recommended. Despite their frequent occurrence on televised competitive automobile events, such failure are quite rare on production cars during normal daily driving.

When building a high performance engine, great attention is paid to the connecting rod, eliminating stress risers by such techniques as grinding the edges of the rod to a smooth radius, shot peening to induce compressive surface stresses , balancing all connecting rod/piston assembliess 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 connecting rod bolts to exact value specified; often these bolts must be replaced rather than reused. The big end of the connecting rod is fabricated as a unit and cut or cracked in two to establish precision fit around the big end bearing shell.

II. SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyses of connecting rod made of forged steel. Steel materials are used to design the connecting rod. In this project the material of connecting rod replaced with forged steel. Connecting rod was created in solidwork 2016. Model is imported in ANSYS 15.0 for analysis. After analysis a comparison is made between existing steel connecting rod viz.. forged steel in terms of weight, factor of safety, stiffens, deformation and stress.

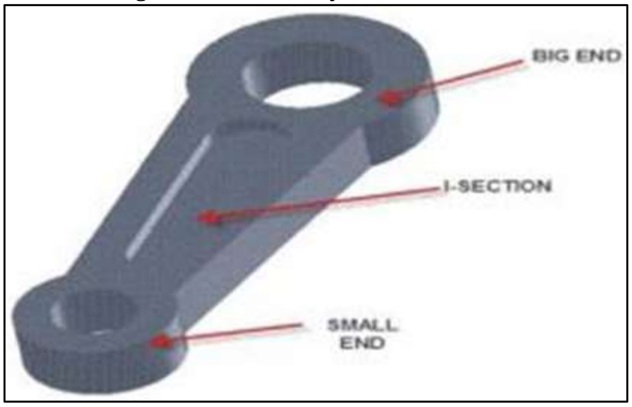

Fig. 2.1: Schematic Diagram of Connecting Rod

III. DESIGN OF 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 force, therefore the cross section of the connecting rod is designed as a strut and the rankine formula is used. A connecting rod subjected to an axial load W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod, y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both end fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis

According to rankine formulae

W_{cr} about x-axis

$$= \frac{[\sigma_c \times A]}{1+a[\frac{L}{K_{xx}}]^2} = \frac{[\sigma_c \times A]}{1+a[\frac{l}{K_{xx}}]^2}$$

$$[\therefore \textit{for both ends hinged } L = l]$$

W_{cr} about y-axis

$$= \frac{[\sigma_c \times A]}{1+a[\frac{L}{K_{yy}}]^2} = \frac{[\sigma_c \times A]}{1+a[\frac{l}{2K_{yy}}]^2} \quad [\therefore \textit{for both ends fixed } L = l/2]$$

In order to have a connecting rod equally strong in buckling about the axis, the buckling loads must be equal. i.e.

$$= \frac{[\sigma_c \times A]}{1+a[\frac{l}{K_{xx}}]^2} = \frac{[\sigma_c \times A]}{1+a[\frac{l}{2K_{yy}}]^2} \text{ [or]}$$

$K^2xx = 4K^2yy$ [or] Ixx=4Iyy

[$I=A \times K^2$]

This shows that the connecting rod is four times strong in buckling about y-axis than about-axis. If I xx > 4Iyy, Then buckling will occur about y-axis and if I xx < 4Iyy, then buckling will occur about x-axis .In Actual practice I xx is kept slightly less than 4Iyy. It is usually taken between 3 and 3.5 and the Connecting rod is designed for buckling about x-axis. The design will always be satisfactory for buckling about y-axis. The most suitable section for the connecting rod is I-section with the proportions shown mfg.

Area of the cross section = 2[4t x t] + 3t x t=$11t^2$

Moment of inertia about x-axis = 2[4txt]+3txt=$11t^2$

Moment of inertia about x-axis Ixx = $\frac{1}{12}[4t\{5t\}^3 - 3t\{3t\}^3] = \frac{419}{12}[t^4]$
And moment of inertia about y-axis
I yy = $\frac{2\times1}{12} \times t \times \{4t\}^3 + \frac{1}{12}\{3t\}t^3 = \frac{131}{12}[t]^4$
I$\frac{Ixx}{Iyy} = [\frac{419}{12}]x[\frac{12}{131}]$=3.2
Since the value of $\frac{Ixx}{Iyy}$ lies between 3 and 3.5 m therefore I-section chosen is quite satisfactory.

A. *Pressure Calculation for 220cc Engine:*

1) *Bajaj 220 cc Specifications:*

Motor compose air cooled 4-stroke
Bore x Stroke (mm) = 67×62.40
Dislodging = 220 CC
Maximun Power = 18.8 bhp @ 8400 rpm
Minimum Torque = 17.5 Nm @ 7000 rpm
Pressure Ratio = 9.5/1
Thickness of Petrol C8H18 = 737.22 kg/m3
= 737.22E-9 kg/mm3
Temperature = 288.855K
Mass = Density × Volume
= 737.22E-9 x220E^3 = 0.16kg
Sub-atomic Weight of Petrol = 114.228 g/mole
From Gas Equation,
PV = Mrt R
= Rx/Mw
= 8.3143/114228
= 72.76
P = $\frac{(0.16\times72.786\times288.85)}{220}$= 15.3 Mpa

B. *Design Calculations for Existing Connecting Rod:*

Thickness of flange & web of the section = t
Width of section B= 4t
The standard dimension of I - SECTION

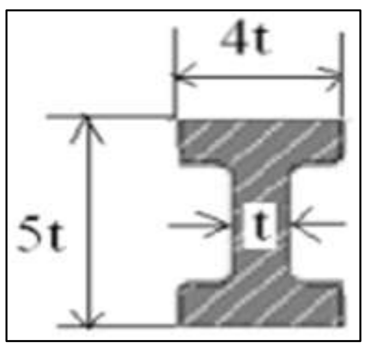

Fig. 3.1: Standard Dimension of I – Section

Height of section H = 5t
Area of section A= 2(4t×t) +3t×t
A = $11t^2$
M.O.I of section about x axis:
I xx = $\frac{1}{12}[4t\{5t\}^3 - 3\{3t\}^3]$
= $\frac{419}{12}[t^4]$
MI of section about y axis:
Iyy = 2×1
$\frac{2\times1}{12} \times t \times \{4t\}^3 + \frac{1}{12}\{3t\}t^3$
= $\frac{131}{12}[t^4]$

$\frac{Ixx}{Iyy} = 3.2$
Length of connecting rod (L) = 2 times the stroke
L = 124.80 mm
Buckling load WB = maximum gas force × F.O.S.

$$W_B = \frac{(\sigma_c \times A)}{(1+a\,(L/Kxx)2}$$

= 40663N
σc= compressive yield stress = 415MPa
K xx = $\frac{Ixx}{A}$
K xx = 1.78t
a = $\frac{\sigma c}{\pi 2_E}$
a = 0.0002
By substituting σc, A, a, L, Kxx on WB then
t^2 = 7.78
t = 2.78mm
Width of section B = 4t
= 11.15mm
Height of section H = 5t
= 14mm
Area A = $11t^2$
= $85.58mm^2$
Height at the big end (crank end) = H_2
= 1.1H to 1.25H
= 1.15×14
H_2 =16.0mm
Height at the small end (piston end) = 0.9H to 0.75H
= 0.9×14
H_1 =12.54mm
Stroke length (l) =124.8mm
Diameter of piston (D) =62.4mm
P=15.3N/mm2
Radius of crank(r) =stroke length/2
=62.4/2
=31.2
Maximum force on the piston due to pressure
$F_1 = \frac{\pi}{4} \times D^2 \times P$
=53913.13N
Maximum angular speed Wmax= $\frac{[2\pi Nmax]}{60}$
= [2π8400]/60
=879.2 rad/sec
Ratio of the length of connecting rod to the radius of crank
N= $\frac{L}{r}$ =124.8/ (33.5) = 3.72
Maximum Inertia force of reciprocating parts
F_{im} = Mr × $(Wmax)^2$ ×r (cosθ +$\frac{\cos 2\theta}{n}$)
= 0.16x $(879)^2$ x (0.0335) x (1+ (1/3.7))
F im = 5260.26N
Inner diameter of the small end d1 = $\frac{F_g}{P_{b1} \times l}$
$= \frac{8132}{12.5 \times 1.5 d_1}$ =d_1=20.80mm
Where,
Design bearing pressure for small end P_{b1}=12.5 to 15.4N/mm2
Length of the piston pin l_1 = (1.5to 2) d_1
Outer diameter of the small end = $d_1+2t_b+2t_m$ = 20.80 + [2×2] + [2×5] = 34.80mm
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 $d_2 = \frac{F_g}{P_{b2 \times l_2}}$ = 27.44mm

Where,
Design bearing pressure for big end P_{b2} = 10.8 to 12.6N/mm2
Length of the crank pin l_2 = (1.0 to 1.25) d_2

Root diameter of the bolt = $(\frac{2F_{im}}{\pi \times st}$)^1/2
=4.7mm

Outer diameter of the big end = $d_2 + 2t_b + 2d_b + 2t_m$
= 27.44+2×2+2×4.7+2×5
= 50.84mm

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× 4.7 = 5.64mm

C. Specifications of connecting rod:

s.no.	*Parameters (mm)*	
1.	*Thickness of the connecting rod (t)*	*= 3*
2.	*Width of the section (B = 4t)*	*= 12*
3.	*Height of the section(H = 5t)*	*= 14*
4.	*Height at the big end = (1.1 to 1.125)H*	*= 16*
5.	*Height at the small end = 0.9H to 0.75H*	*= 13*
6.	*Inner diameter of the small end*	*= 21*
7.	*Outer diameter of the small end*	*= 35*
8.	*Inner diameter of the big end*	*= 25*
9.	*Outer diameter of the big end*	*= 51*

IV. MODELING OF CONNECTING ROD

A. Making of Stem:

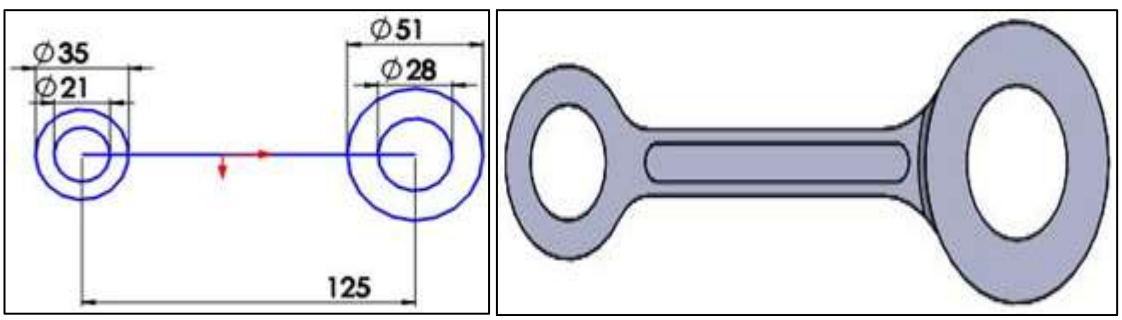

Fig. 4.1: Making of Stem

V. ANALYSIS OF THE CONNECTING ROD

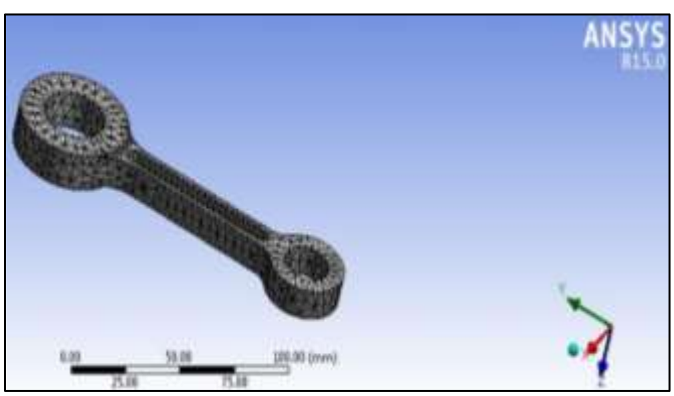

Fig. 5.1: Meshing of Connecting Rod in Tetrahedral

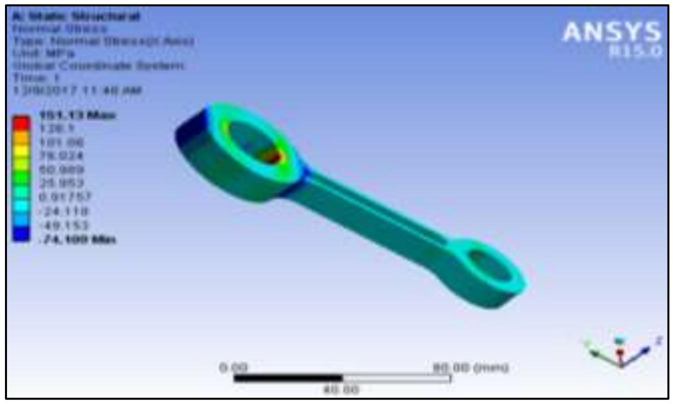

Fig. 5.2: Normal Stress (X-Axis)

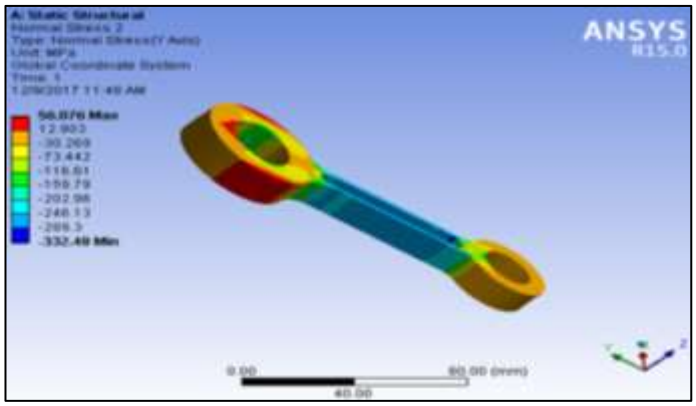

Fig. 5.3: Normal Stress (Y-Axis)

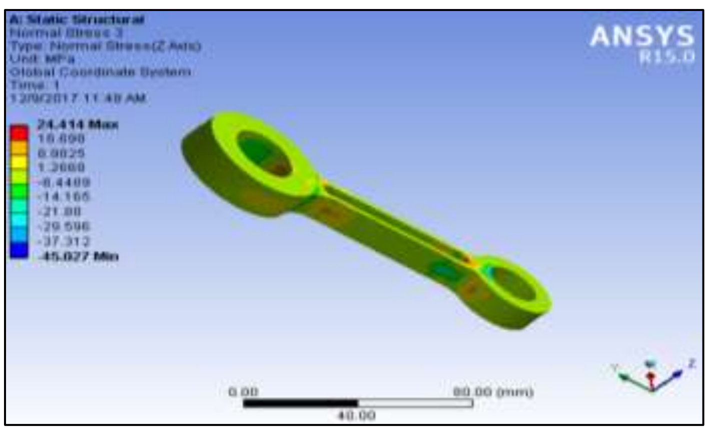

Fig. 5.4: Normal Stress (Z-Axis)

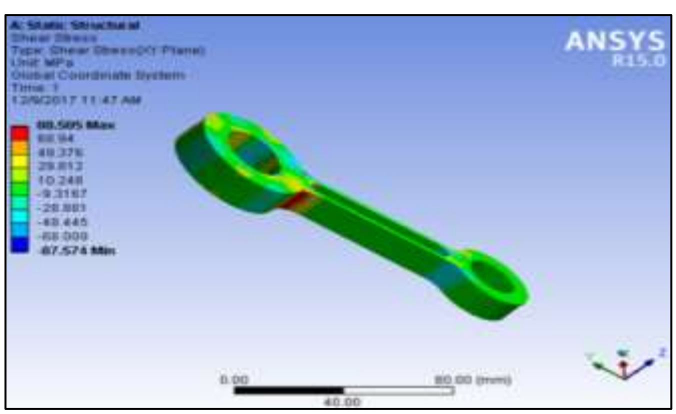

Fig. 5.5: Shear Stress (XY Plane)

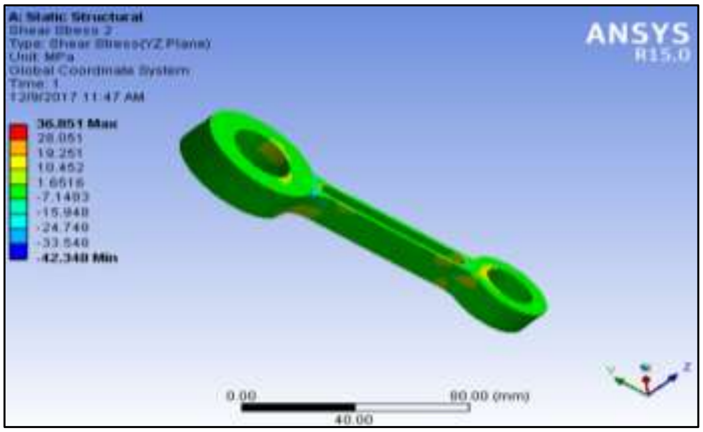

Fig. 5.6: Shear Stress (YZ Plane)

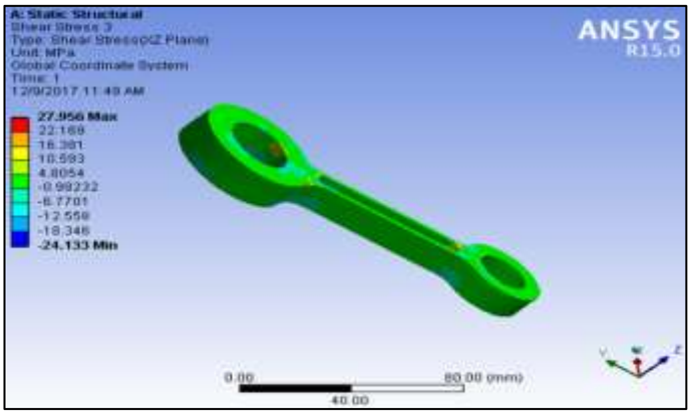

Fig. 5.7: Shear Stress (XZ Plane)

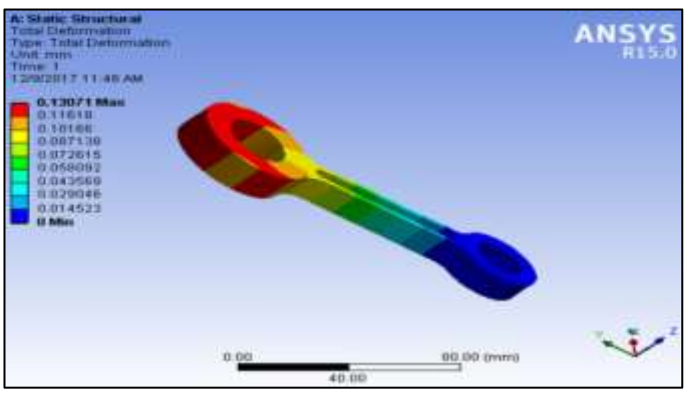

Fig. 5.8: Total Deformations

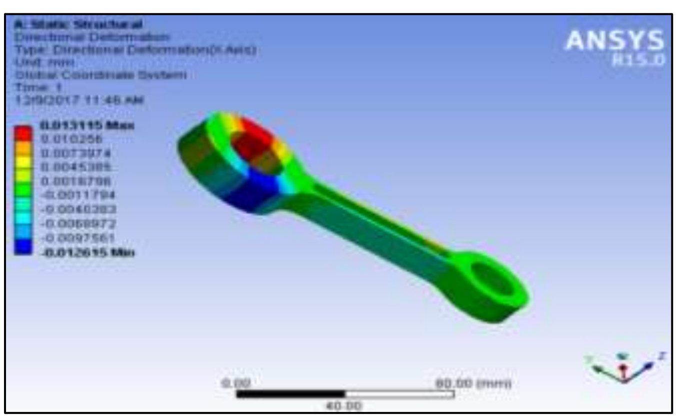

Fig. 5.9: Directional Deformations (X Axis)

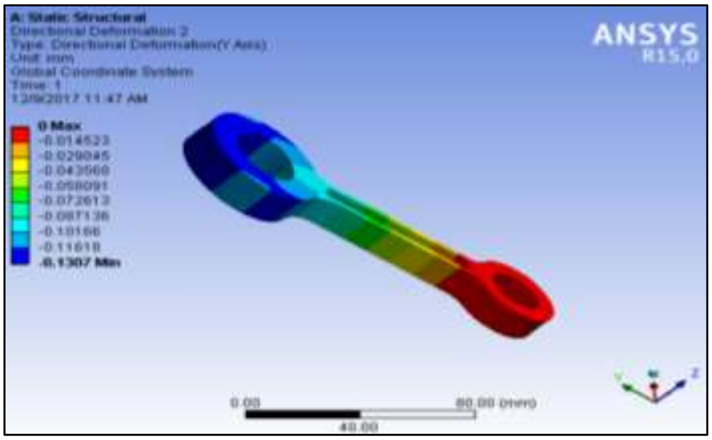

Fig. 5.10: Directional Deformations (Y Axis)

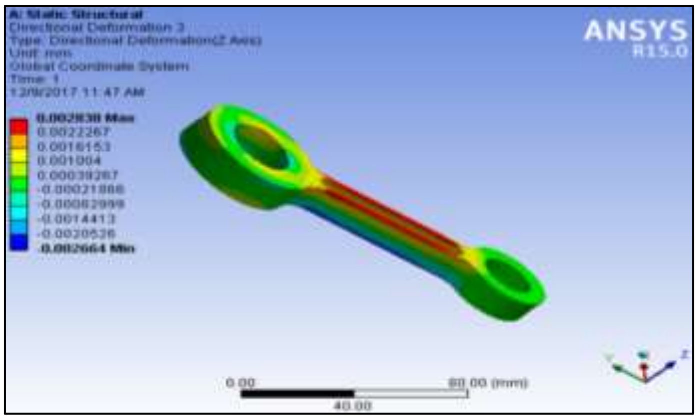

Fig. 5.11: Directional Deformations (Z Axis)

Table – 5.1
Stresses and Deformation of Forged Steel

S.NO.	Types	Max (Mpa)	Min (Mpa)
1	Normal stress(X-axis)	151.13	-74.189
2	Normal stress(y-axis)	56.076	-332.48
3	Normal stress(Z-axis)	24.414	-45.027
4	Shear stress(xy plane)	88.505	-87.574
5	Shear stress(YZ plane)	36.851	-42.348
6	Shear stress(XZplane)	27.956	-24.133
7	Total deformation	0.13071	0
8	Directional deformation (x-axis)	0.013115	-0.012615
9	Directional deformation (x-axis)	0	-0.1307
10	Directional deformation (x-axis)	0.002838	-0.002664

Table – 5.2
Mechanical properties for forged steel

s.no.	Mechanical Properties	Forged Steel
1	Density(g/cc)	7.7
2	Average hardness(HRB)	101
3	Modulus of elasticity,(Gpa)	221
4	Yield strength, YS,(Mpa)	625
5	Ultimate strength ,Su,(Mpa)	625
6	Percent reduction in area,%, RA	58
7	Poison ratio	0.29

VI. CHEMICAL COMPOSITION OF 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

VII. CALCULATION

A. *Calculation for factor of safety of connecting rod*

f.s = factor of safety
σ_m = mean stress
σ_y = yield stress
σ_v = variable stress
σ_e = endurance stress

$$\frac{1}{F.S.} = \frac{\sigma_m}{\sigma_y} + \frac{\sigma_v}{\sigma_e}$$

For Forged Steel
$\sigma_m = \frac{\sigma_{max}+\sigma_{min}}{2}$ = 19.149
σ_y= 625Mpa
$\sigma_v = \frac{\sigma_{max}-\sigma_{min}}{2}$ = 19.149
σ_e = 0.6× 625 = 375
$\frac{1}{F.S.}$= 0.081= 12.23
Factor of safety [F.S] = 12.23

VIII. CONCLUSION

By checking and comparing the results of materials in finalizing the results are shown in below.

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