IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 3, Issue 4, Aug-Sept, 2015
ISSN: 2320 – 8791 (Impact Factor: 2.317)
www.ijreat.org

Design And Finite Element Analysis Of Connecting Rod Using Solidworks And ANSYS Workbench

Debayan Das [1], Saurav Rajgadia[2], Anush Karki[3], Ankit Basnet[4], Pawan Jaiswal[5], Rakesh Jaiswal[6], Anupam Raj Jha[7], Rabindra Nath Barman[8]

[8]Assistant Professor, Mechanical Engineering Department, National Institute of Technology Durgapur.
[1,2,3,4,5,6,7]B.Tech Students, Mechanical Engineering, National Institute of Technology Durgapur,
Durgapur-713209, West Bengal, India,

Abstract

Connecting rod is a crucial moving component of a reciprocating internal combustion (I.C.) engine. It is the intermediate linkage between piston and crankshaft. And its primary function is to transmit the push or pull force from piston to crank shaft, hence converting the reciprocating motion of piston to rotary motion of crankshaft. Being a critical element of an Internal Combustion engine, it should be light in weight and have high rigidity. This paper presents design and analysis of connecting rod. Here connecting rod is modeled using Solidworks 12.0 and analyzed in ANSYS 14.5, using Aged Maraging steel v 250. The objective of this work is to determine Von misses stress-strain and deformation of the connecting rod using Finite Element Analysis in ANSYS. The value of stresses and deformation were larger at the big end with respect to small end.

Keyword: *Connecting Rod, Solidworks, ANSYS, Finite Element Analysis (FEA).*

1. Introduction

Connecting rod is a mechanical link which connects piston and crankshaft. It is also known as Conrod. The basic function connecting rod is to transmit thrust of piston, due to gas pressure, to the crankshaft converting the reciprocating motion of piston to rotary motion of crankshaft. It also provides splash or jet of oil to piston assembly by transferring lubricating oil from crank pin to piston pin.

The connecting rod consists of an eye at the small end to accommodate the piston pin, a big end opening split into two parts for accommodation of the crankpin and a long shank between the two ends.

As small end of connecting rod is attached to piston pin, it experiences pure reciprocating motion where as big end attached to crank pin experiences pure rotary motion and only the shank of connecting rod experiences both motions. So mass of reciprocating component is considered to be one third of total mass of connecting rod.

i.e. reciprocating mass = 33% of mass of conrod.

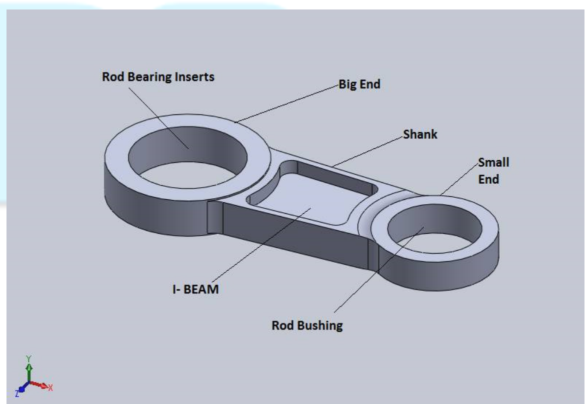

Fig 1: 3-D Model of Connecting rod

The connecting rod is a heavily stressed part of I.C. engine subjected to complex loading. It is subjected to axial and bending stresses when engine is under operation. There are various forces and factors causing these stresses i.e. force on piston due to gas pressure, force due to inertia of reciprocating parts, force due to friction between piston rings and piston and piston pin bearing and crank pin bearing, centrifugal force and also due to eccentricities.[1]

'Throwing a rod', failure of connecting rod, is mostly responsible for ruinous engine failure. It makes the engine irreparable by pushing the broken rod through the side of crankcase. It can result from the fatigue near physical defect in rod, lubrication failure in bearing due to faulty maintenance or from the failure of bolts from a defect, Improper tightening, or re-use of already used bolts.[2]

1.1 Material and its properties

The connecting rod is usually manufactured by drop forging, casting or powdered metallurgy. The commonly used materials for the connecting rod are carbon steels, alloy steel, cast iron, aluminum alloy (T6-2024, T651-7075) and titanium alloy. Connecting rod made from aluminum is light and can absorb high impact at expense of durability while the connecting rod made using titanium is used for combination of light and strength at expense of affordability.

Aged Grade 250 Maraging steel has ultra-high strength, good toughness and superb transverse properties and is widely used in motorsport industry. It derives its strength not from carbon, but from precipitation of intermetallic compound. Secondary alloying elements such as Cobalt (Co), Manganese (Mn) and Titanium (Ti) are added to Nickel to produce intermetallic precipitates. The addition of chromium produces stainless grades resistant to corrosion.[3]

Due to low carbon content maraging steels have good machinability prior to aging. It may also be cold rolled up to 90% without cracking. Ti offers good weldeability. High alloy content maraging steels have a high hardenability.

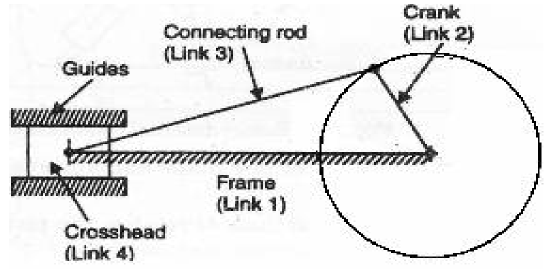

Fig 2: Slider crank mechanism
*Source: retrieve from internet [11]

Fig 3: Throwing of Rod
*Source: retrieve from internet [12]

2. Objective

The objective of problem is to design connecting rod made of **Aged Grade 250 Maraging Steel** using Solidworks 12.0, and to carry out the Finite Element Analysis (FEA) on the prepared model in ANSYS 14.5, and determine the values of Von Misses equivalent stress and strain values.

3. Design of connecting rod

If a connecting rod is designed in such a way that it equally resistant buckling in either plane then,

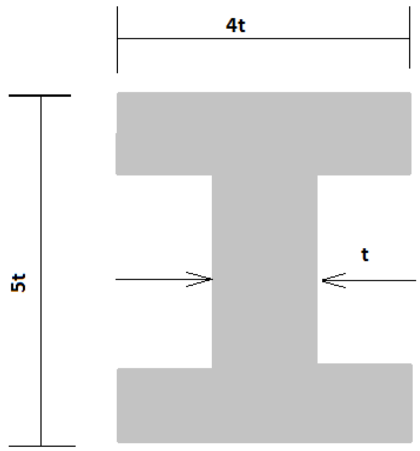

Fig 4: Typical cross-section of connecting rod

4 $4I_{yy} = I_{xx}$ (1)

Where,

$I = moment\ of\ inertia\ of\ cross - section\ (mm^4)$

Substituting ($I = Ak^2$),

$4k_{yy}^2 = k_{xx}^2$

$k_{yy}^2 = \frac{1}{4} k_{xx}^2$

Where,

$k = radius\ of\ gyration\ of\ cross - section\ (mm)$

Figure 4.shows the typical proportions for the cross-section of the connecting rod for I.C. engine. For this cross-section,

$$A = 2(4t \times r) + (5t - 2t) \times t$$
$$= 8t^2 + 3t^2$$
$$= 11t^2 \quad (2)$$

Where,

$A = area\ of\ cross - section\ (mm^2)$

$$I_{xx} = \frac{1}{12}(4t)(5t)^3 - \frac{1}{12}(4t - t)(5t - 2t)^3$$
$$= \frac{1}{12}(500t^4 - 81t^4)$$
$$= \left(\frac{419}{12}\right)t^4 \quad (3)$$

Also,

$$k_{xx}^2 = \frac{I_{xx}}{A} = \left(\frac{419t^4}{12}\right)\left(\frac{1}{11t^2}\right) = 3.17t^2$$
$$k_{xx}^2 = 3.17t^2$$
$$k_{xx} = 1.78t$$

Again,

$$I_{yy} = 2\left[\frac{1}{12}(t)(4t)^3\right] + \frac{1}{12}(5t - 2t)(t)^3$$
$$= \frac{1}{12}[128t^4 + 3t^4]$$
$$= \left(\frac{131}{12}\right)t^4 \quad (4)$$

$$k_{yy}^2 = \frac{I_{yy}}{A} = \left(\frac{131t^4}{12}\right)\left(\frac{1}{11t^2}\right) = 0.992t^2$$
$$k_{yy}^2 = 0.992t^2$$
$$k_{yy} = 0.996t$$

Therefore from equations (3) and (4), we get:

$$\frac{I_{xx}}{I_{yy}} = \frac{\left(\frac{419}{12}\right)t^4}{\left(\frac{131}{12}\right)t^4} = \frac{419}{131} = 3.2$$
$$3.2I_{yy} = I_{xx} \quad (5)$$

[Note: $I_{xx} > 4I_{yy}$, buckling occurs about Y- axis
$I_{xx} < 4I_{yy}$, buckling occurs about X- axis.
In practice I_{xx} is kept less than $4I_{yy}$. Usually taken as 3 to 3.5]

It is observed from equation (5) that the above that the proportions of I- sections of the connecting rod is satisfactory.

3.1 Pressure Calculation

Specifications for Yamaha R15 150cc
Engine type: Liquid cooled 4-stroke
Bore X Stroke (mm) = 57 x 58.7
Displacement = 149.8 CC
Maximum Power = 16.8 bhp @ 8500rpm
Maximum Torque = 15 Nm @ 7500rpm
Compression Ratio = 10.4/1
Density of Petrol (C8H18) = 737.22 kg/m^3
=737.33E^{-9} kg/mm^3
Temperature (T) = 60° F = 288.855 ° K
Mass of petrol per Injection (M) = Density X Volume
=737.33E^{-9} X 149.8E^3
=0.11 kg
Molecular Weight of Petrol (M_w) = 114.228 g/mole
From Gas Equation,
P_{gas}*V =M*T* R_{petrol}
$R_{petrol} = \frac{R}{M_w}$
= 8.3143/ (114.228*10^{-3})
=72.78

$P_{gas} = \frac{(0.11\times72.786\times288.85)}{149.8E^3}$ = 15.5MPa,
Where, P_{gas}= Gas petrol

3.2 Design Calculations

Thickness of flange & web of the section = t
Width of section B = 4t
The standard dimension of I-section
Height of section, H = 5t
Area of section A = $11t^2$
Length of connecting rod (L) = 2 times the stroke
L = 117.4mm
Maximum Gas Force = $\frac{\pi}{4}\times57^2\times15.5$
=39552.56 N (6)
Buckling load W_B = maximum gas force × F.O.S

$$W_B = \frac{(\sigma_c\times A)}{1+(\frac{L}{K_{xx}})^2} = 158209.04 \text{ N} \quad (7)$$

Where,
σ_c= compressive yield stress = 1660 MPa
$K_{xx} = \frac{I_{xx}}{A}$ = 1.78t
$a = \frac{\sigma_c}{\pi^2 E}$ = 0.0002
By substituting the values of σ_c, K_{xx}, A, a, L, in equation (7), we get
$18260t^4-158209.04t^2-137644 = 0$
t^2 = 9.46 mm
t = 3.0798mm ≈ 3.1mm
Width of the section, B = 4t
= 4×3.1 = 12.4mm
Height of the section, H = 5t
= 5×3.1 = 15.5mm
Cross-section Area, A = $11t^2$
= 11×3.1×3.1
=105.71mm²
Height at the big end (crank end),
H_2 = (1.1 to 1.25) H
H_2 = 17.05mm
Height at the small end (piston end),
H_1= (0.75 to 0.9) H
H_1 = 11.625mm
Stroke length (l) = 117.4mm
Diameter of piston (D) = 57mm
P_{gas} = 15.5N/mm²
Radius of crank (r) = stroke length/2
= 58.7/2 =29.35mm

Maximum force on the piston due to pressure

$F_1 = \frac{\pi}{4}\times D^2\times p$
$= \frac{\pi}{4}\times(57)^2\times15.5$
=39552.26N
Maximum angular speed,
$W_{max} = \frac{[2\pi N_{max}]}{60}$
$=\frac{[2\pi\times8500]}{60}$
=890.11rad/sec
Ratio of the length of connecting rod to the radius of crank
$N=\frac{l}{r}$= 117.4/29.35= 3.8
Maximum Inertia force of reciprocating parts
$F_{im} = Mr\,(W_{max})^2\, r\,(\cos\theta + \frac{\cos 2\theta}{n})$ OR
$F_{im} = M_r\,(Wmax)^2\, r\,(1+\frac{1}{n})$
$=0.11\times(890.11)^2\times(0.0293)\times(1+(1/4))$
F_{im} =3191.96N

Inner diameter of small end $d_1=\frac{Fg}{Pb1\times L1}$
$=\frac{39552.26}{12.5\times2d1}$
=39.77 mm
Where,
Design bearing pressure for small end P_{b1}=12.5 to 15.4 N/mm²
Length of the piston pin L_1= (1.5to 2) d_1
Outer diameter of the small end = $d_1+2t_b+2t_m$

=39.77+ (2×2) + (2×5)
=53.77 mm
Where,
Thickness of the bush (t_b) =2 to 5 mm
Marginal thickness (t_m) =5 to 15 mm
Inner diameter of big end $d_2=\frac{F}{Pb2\times L2}$
$=\frac{39552.26}{12.6\times1.25d1}$
=50.11 mm
Where,
Design bearing pressure for big end
$p_{b2} = 10.8\ to\ 12.6N/mm^2$
Length of the crank pin $l_2 = (1.0\ to\ 1.25)d_2$

Root diameter of the bolt $= \left(\frac{(2F_{im})}{(\pi\times St)}\right)^{1/2}$
$= \left(\frac{2\times3191.96}{\pi\times58.7}\right)^{1/2}$
$= 5.98mm$
Outer diameter of the big end

$$= d_2 + 2t_b + 2d_b + 2t_m$$
$$= 50.11 + 2 \times 2 + 2 \times 5.98 + 2 \times 5$$
$$= 76.07mm$$

Where,
Thickness of the bush $[t_b] = 2\ to\ 5\ mm$
Marginal thickness$[t_m] = 5\ to\ 15\ mm$
Nominal diameter of bolt

$$[d_b] = 1.2 \times root\ diameter\ of the\ bolt$$
$$= 1.2 \times 5.98 = 8.97\ mm$$

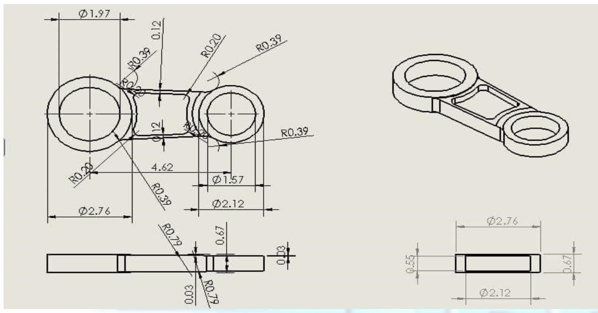

Fig 5: Sketch of connecting rod (scale 1:2)

3.3 Specifications of Connecting Rod

Table 3.3.1

S.no.	Parameters (mm)
1	Thickness of the connecting rod $(t) = 3.1$
2	Width of the section $(B = 4t) = 12.4$
3	Height of the section $(H = 5t) = 15.5$
4	Height at the big end $= (1.1\ to\ 1.125)H$ $= 17.05$
5	Height at the small end $= 0.9H\ to\ 0.75H$ $= 11.625$
6	Inner diameter of the small end $= 39.77$
7	Outer diameter of the small end $= 53.77$
8	Inner diameter of the big end $= 50.11$
9	Outer diameter of the big end $= 69.$

4. Methodology

For the analysis of the connecting rod we have designed our model in Solidworks 12.0 and then save it as IGES format for exporting the part into ANSYS 14.5 Workbench environment.

4.1 Meshing

Solidworks and ANSYS workbench software are used for the Finite Element Analysis of the connecting rod. At first the connecting rod is designed in the Solidworks software and then the file is saved as IGES format and imported in the ANSYS workbench software. The next step was to mesh the model as shown in the fig 7, the 10 node tetrahedral element are used as shown in the fig 6.The finite element was generated using the tetrahedral element of size 1mm.We have divided the part into 50833 element. The reason for choosing this huge number of element was to make our part very complex which enable us to gain more authentic results based on the high technique of fatigue life calculation.[8]

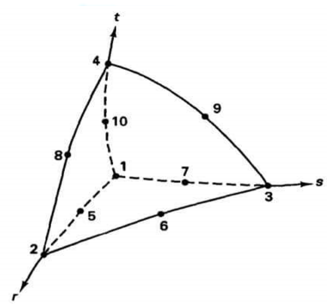

Fig 6: Meshing type: tetrahedral

Fig 7: Mesh model of connecting rod

IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 3, Issue 4, Aug-Sept, 2015
ISSN: 2320 – 8791 (Impact Factor: 2.317)
www.ijreat.org

4.2 Loading conditions and constrains.

We are considering that the loading condition is static. Here one case is analyzed where the force is acting on the big end and the other end i.e. small end remains fixed. For all practical purpose, the force acting on the connecting rod is taken to be equal to the maximum force which is acting on the piston due to the pressure exerted by the gas and it is shown below in fig 8. [9]
The maximum gas force which is acting on the piston is calculated as:
$F_{max} = 39552.25$ N

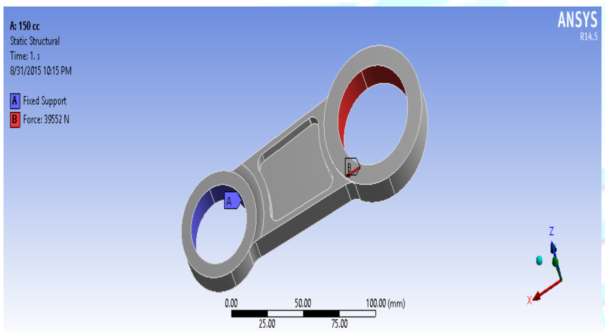

Fig 8: Loading Condition in connecting rod

4.3 Finite Element Method (FEM)

The Finite element method (FEM) is a numerical technique for finding the approximate solutions to boundary value problems for partial differential equations. It uses subdivision of a whole problem domain into simpler part, called finite elements and solve the problem by minimizing an associated error function. The subdivision of the whole domain has several advantages:
I. Accurate representation of the complex geometry.
II. Inclusion of dissimilar material property.
III. Easy representation of the solution.
IV. Capture of the local effects.
It divides the domain into a group of subdomain; every subdomain is represented by a set of element equations of the original domain.

4.4 Procedure

4.4.1 Design procedure in Solidworks

I. Top plane is selected.
II. Sketch (1) is drawn.
III. Sketch is extruded up to desired height.
IV. Sketch (2) is drawn.
V. Extrusion is cut up to the desired depth
VI. A plane is sketched between the two surface ends
VII. Cut extrude is mirrored with newly sketched plane as reference
VIII. Now, the piston side circle is sketched.
IX. Cut extrude is performed on the sketch
X. It is mirrored.
XI. Fillets are made on desired edges.
XII. Middle I-Section Slot is sketched.

4.4.2 FEA procedure in ANSYS

Any analysis which is performed by using the Finite element analysis can be divided into the following steps:
I. Discretization
II. Selection of the displacement model.
III. Deriving element stiffness matrices.
IV. Assembly of overall equations/ matrices.
V. Solution for unknown displacement
VI. Computations for the strains/stresses.

5. Analysis of connecting rod

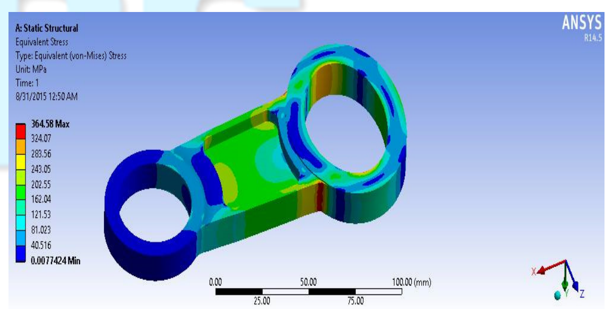

Fig 9: Equivalent Stress on connecting rod

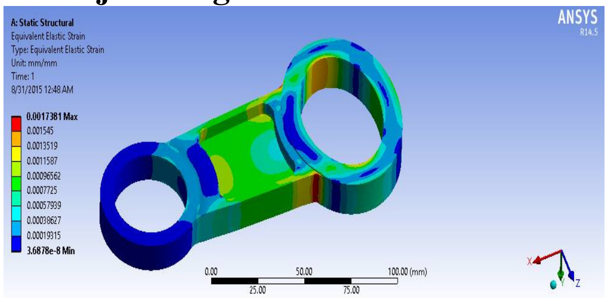

Fig 10: Equivalent Strain of connecting rod

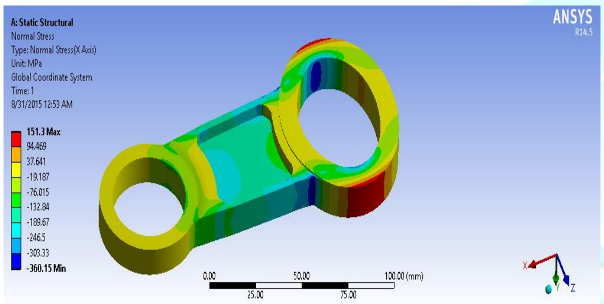

Fig 11: Normal stress (X- axis) on connecting rod

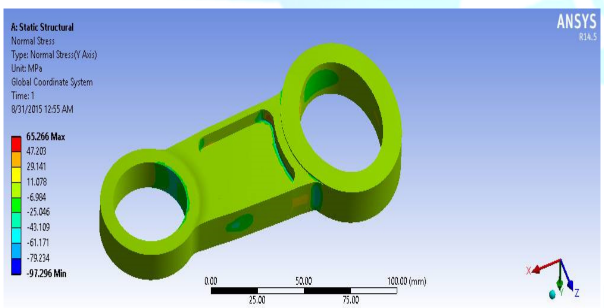

Fig 12: Normal Stress (Y-axis) on connecting rod

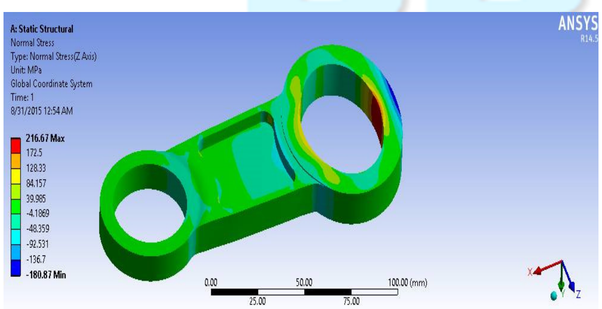

Fig 13: Normal Stress (Z-axis) on connecting rod

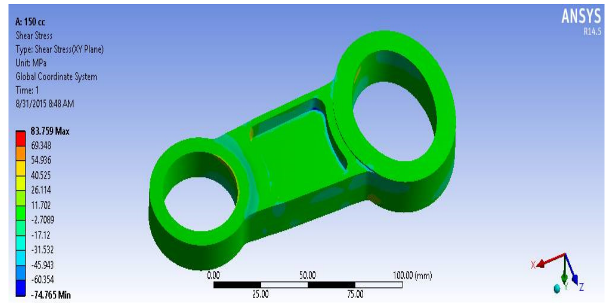

Fig 14: Shear stress (XY Plane) on connecting rod

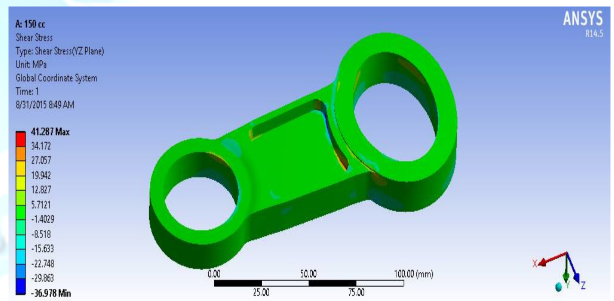

Fig 15: Shear stress (YZ Plane) on connecting rod

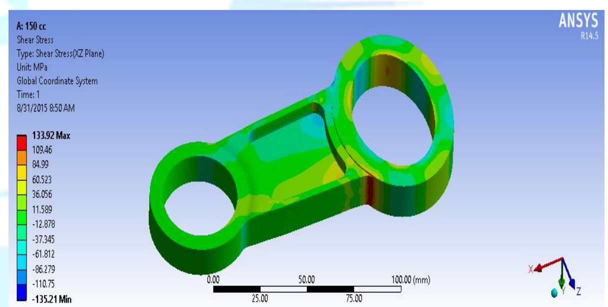

Fig16: Shear stress (ZX Plane) on connecting rod

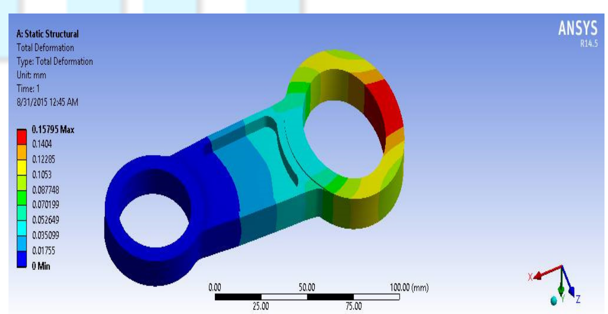

Fig 17: Total Deformation of connecting rod

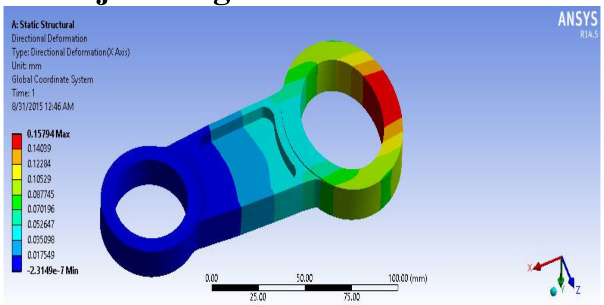

Fig 18: Directional Deformation (X Axis) of connecting rod

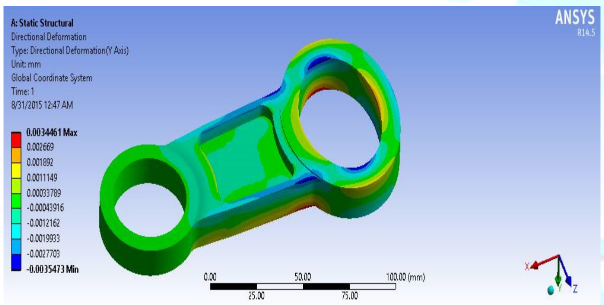

Fig 19: Directional Deformation (Y Axis) of connecting rod

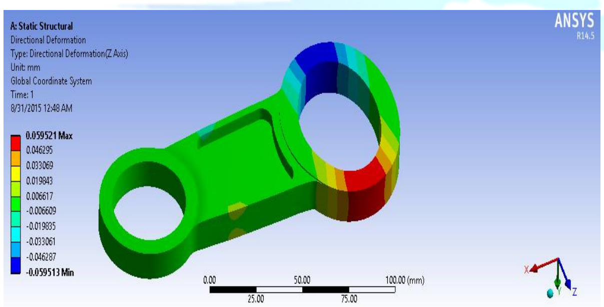

Fig 20: Directional Deformation (Z Axis) of connecting rod

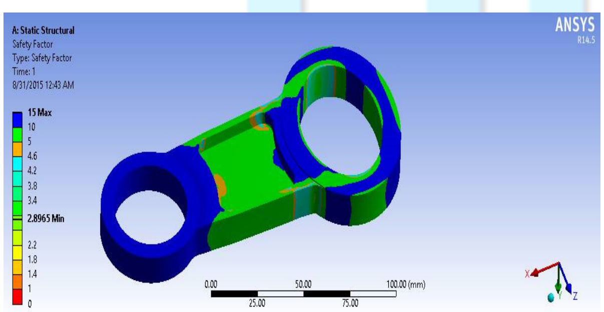

Fig 21: Safety Factor of connecting rod

5.1 Results

Table: 5.1.1

Parameter	Max	Min
Equivalent Stress(MPa)	364.58	0.0077424
Equivalent Strain(mm)	0.0017381	3.6878e-8
Normal Stress (X Axis) (MPa)	151.3	-360.15
Normal Stress (Y Axis) (MPa)	65.266	-97.296
Normal Stress (Z Axis) (MPa)	216.67	-180.87
Shear stress (XY Plane) (MPa)	83.759	-74.765
Shear stress (YZ Plane) (MPa)	41.287	-36.978
Shear stress (ZX Plane) (MPa)	133.92	-135.21
Total Deformation (mm)	0.15795	0
Directional Deformation (X Axis)(mm)	0.15794	-2.3149e-7
Directional Deformation (Y Axis) (mm)	0.0034461	-0.003547
Directional Deformation (Z Axis) (mm)	0.059521	-0.059513
Safety Factor	50	0

6. Conclusion

This paper, not only deals with the design of connecting rod of Yamaha R15 150cc engine but also the stress-strain effect applied to the connecting rod. The connecting rod chosen is of 4-stroke single cylinder in which failure results in replacement of the whole connecting rod assembly. In design, the connecting rod is taken to have maximum weight possible with ability to withstand high pressure and inertia forces. In calculation, the length of the connecting rod has been taken twice the stroke i.e.117.4mm. For connecting rod design, I-section has been considered with reference to buckling load evaluation. The stresses were found to be high at the big end but they were relatively uniformly distributed. The maximum stress and strain values were found to be 364.58 MPa and 0.0017381 mm.

7. References

[1] A. Mirehei, M. Hedayati Zadeh , A. Jafari and M. Omid "Fatigue analysis of connecting rod of universal tractor through finite element method (ANSYS)". JAT 2008, V.4(2): 21-27

[2] Swapnil B. Ikhar and Saifullah Khan "modeling and analysis of connecting rod of two wheeler". Discovery, volume 24, Number 83, October 4, 2014.

[3] Leela Krishna Vegi and Venu Gopal Vegi "Design and analysis of connecting rod using forged steel" (IJSER) Volume 4, Issue 6, June-2013

[4] Maraging Steel, Wikipedia

[5] K. Sudershan Kumar, Dr. K. Tirupathi Reddy and Syed Altaf Hussain "Modeling and Analysis of Two Wheeler Connecting Rod". (IJMER) Vol.2. Issue.5, sep-oct 2012 pp-3367-3371, ISSN: 2249-6645

[6] Cho Mar Aye and Chit Oo Maung "Design and stress Analysis of Connecting Rod for Light Truck Engine". (IJSETR), Vol.03, Issue 11, june-2014, Pages: 2542-2547

[7] Sasi Kiran Prabhala and K. Sunil Ratna Kumar "Design and Weight Optimization OF IC Engine". IJAERS, E-ISSN2249-8974 Research paper.

[8] Pravardhan S. Shenoy, "Dynamic load analysis and optimization of connecting rod". 2004, Master's thesis, University of Toledo.

[9] Mr. Pranav G Charkha and DR. Santosh B Jaju "Analysis and optimization of connecting rod". (ICETET-09)

[10] V.B. Bhandari, Design of Machine Elements,
ISBN: 0-07-0681791-1, Design of IC Engine Component, Page no. 867-870.

[11]https://www.google.co.in/search?q=reciprocating+mechanism&espv=2&biw=1366&bih=667&source=lnms&tbm=isch&sa=X&ved=0CAYQ_AUoAWoVChMI-vzT99DVxwIVxgqOCh1gtQBq#tbm=isch&q=reciprocating+motion&imgdii=_v4bqLQKY_wzoM%3A%3B_v4bqLQKY_wzoM%3A%3BaUH3qjtno0IHzM%3A&imgrc=_v4bqLQKY_wzoM%3A

[12]https://www.google.co.in/search?q=failure+of+the+connecting+rod&espv=2&biw=1366&bih=623&source=lnms&tbm=isch&sa=X&ved=0CAYQ_AUoAWoVChMIi7jS4tHVxwIVRwiOCh1e-AFy#imgrc=TzfgnyyF5vdk2M%3A