EFIICIENT DESIGN AND ANALYSIS OF CONNECTING ROD USING CATIA AND ANSYS

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Abstract: Connecting rod is the main component of an internal combustion engines. The main function of a connecting rod is to convert linear motion of piston to rotary motion of crank. During the operation the connecting rod is subjected to compressive and tensile loads. There are lots of research is going on connecting rods in terms of its geometry, type of materials and manufacturing techniques. For the better performance, connecting rod is manufactured by steel, cast iron, aluminium alloys. In this present work a connecting rod is designed using CATIA software and complete design is imported into ANSYS 19.0 software for analysis. In this paper aluminium alloys have been selected for structural analysis of connecting rod. Results are shown and comparison is made to get better performance of connecting rod.

Key Words: Connecting Rod, Design, Structural Analysis, Materials.

Nomenclature

A = Cross sectional area of the Connecting Rod.

L = Length of the Connecting Rod.

C = Compressive Yield Stress.

W_B = Crippling or Buckling Load.

Ixx = Moment of Inertia of the section about X-Axis

Iyy = Moment of Inertia of the section about Y-Axis respectively.

Kxx = Radius of Gyration of the section about X-Axis

Kyy = Radius of Gyration of the section about Y- Axis respectively.

D = Diameter of Piston

R = Radius of Crank

t= Thickness of connecting rod (t)

σ_c= compressive yield stress

I. INTRODUCTION

In engine the connecting rod is the major part. The weight reduction and structural analysis of connecting rod can have a certain role in weight reduction of the engine and it is highly desirable goal if it can be achieved without increasing cost and decrease in quality and reliability. It is possible to achieve a design of connecting rod with less weight and material selection to increase in the strength, decreasing stresses which can be done by a design and material optimization of connecting rod. A connecting rod can be of two types H-beam or I-beam or a combination of both. They are used respectively depending on their field of application or use. An I-beam is both light weight and strong but the type of material used limits it's capacity to handle load. Whereas a H-beam can handle much more stress without bending. So they are used in high power engines.

1.1 Connecting Rod Design

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 Rankin 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,{or} y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both ends fixed for buckling about y axis. A connecting rod should be equally strong in The connecting rod is four times strong in buckling about y-axis than about-axis. If Ixx> 4Iyy, Then buckling will occur about y-axis and if Ixx< 4Iyy, then buckling will occur about x-axis .In Actual practice Ixx 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

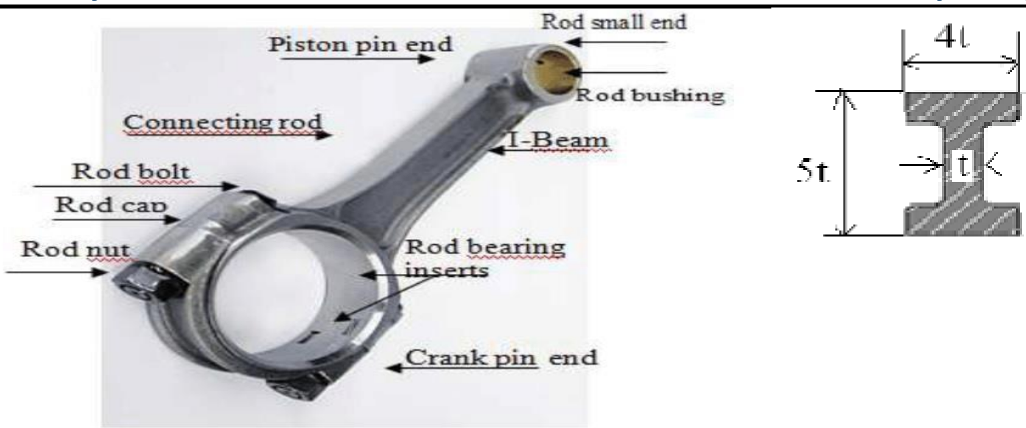

Fig1: Connecting rod and its cross section

Thickness of connecting rod (t)

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:

$I_{xx} = 1/12[4t\ \{5t\}^3 - 3t\ \{3t\}^3] = 419/12\ [t^4]$

M.O.I of section about y axis:

Iyy = 2×1 /12 × t × {4t} 3 + 1 /12 {3t}t3 = 131 /12 [t4]

Ixx/ Iyy=[(419/12)]×[(12/131)]= 3.2

Since Ixx< 4Iyy design is safe.

Length of connecting rod (L) = 2 times the stroke =2*58.6=117.2 mm

Buckling load W_B = Maximum gas force × F.O.S

$W_B = (\sigma c \times A)/\ (1+a\ (L/K_{xx})^2 = 37663N$

σ_c= compressive yield stress = 415MPa (consider)

K xx = I xx/ A ie K xx = 1.78t

a = $\sigma_c/\pi 2E$ where a = 0.0002

By substituting σ_c, A, a, L, Kxx on W_B then

$4565t^4-37663t^2-81639.46 = 0$

t = 3.2mm

Width of the section (B)

Width of section B = 4t = 4×3.2

= 12.8mm

Height of the section (H)

Height of section H = 5t = 5×3.2

= 16mm

Inner diameter of small end (d_1)

Area A = $11t^2$ =11×3.2×3.2

= $112.64mm^2$

Diameter of piston (D) =57mm

Pressure inside the piston =15.5N/mm2

Radius of crank(r) =stroke length/2

=58.6/2

Maximum force on the piston due to pressure $Fl = \pi/\ 4 \times D^2 \times p$

$=\pi/4\times\ (57)^2\times 15.469$

=39473.16N

Maximum angular speed Wmax=768 rad/sec

Ratio of the length of connecting rod to the radius of crank

$$N= l/ r =112/ (29.3) = 3.8$$

Maximum Inertia force of reciprocating parts

$F_{im} = Mr (W_{max})^2 r (\cos\theta + COS2\theta/n)$ (Or)

$F_{im} = Mr (W_{max})^2 r (1+1/n)$

$= 0.11x (768)^2 \times (0.0293) \times (1+ (1/3.8))$

$F_{im} = 2376.26N$

Inner diameter of the small end d_1 = $\mathbf{F_g/Pb_1 \times l_1}$

$= 6277.167/ 12.5\times1.5d_1$

$= 17.94mm$

Outer diameter of smaller end (D_1)

Design bearing pressure for small end pb_1=12.5 to 15.4N/mm2

Length of the piston pin l_1= (1.5to 2) d1

Outer diameter of the small end = $d_1+2t_b+2t_m$

$= 17.94 + [2\times2] + [2\times5]$

$= 31.94mm$

Inner diameter of the big end (d_2)

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= Fg/ $Pb_2 \times l_2$

$= 6277.167/ 10.8\times1.0d_1$

$=23.88mm$

Outer diameter of big end (D_2)

Design bearing pressure for big end pb_2= 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 = $((2F_{im})/ (\pi\times St))1/2$

$= (2\times6277.167/\pi\times56.667)1/2$

= 4 .mm

Outer diameter of the big end $= d2 + 2t_b + 2d_b + 2t_m$

$= 23.88+2\times2+2\times4+2\times5$

$= 47.72mm$

Specifications of connecting rod:

- Thickness of the connecting rod (t) = 3.2 mm
- Width of the section (B = 4t) = 12.8 mm
- Height of the section(H = 5t) = 16 mm
- Height at the big end = (1.1 to 1.125)H = 17.6 mm
- Height at the small end = 0.9H to 0.75H= 14.4 mm
- Inner diameter of the small end = 17.94 mm
- Outer diameter of the small end = 31.94 mm
- Inner diameter of the big end = 23.88 9 mm
- Outer diameter of the big end = 47.72 mm

II. MODELLING OF CONNECTING ROD

Computer aided three dimensional interactive applications(CATIA) is used to model a connecting rod depends on above specifications

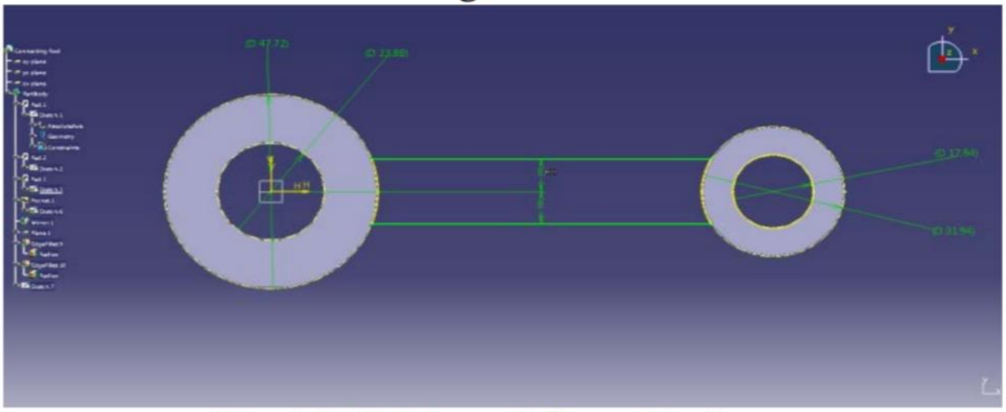

Fig.2.1 Making of stem pad

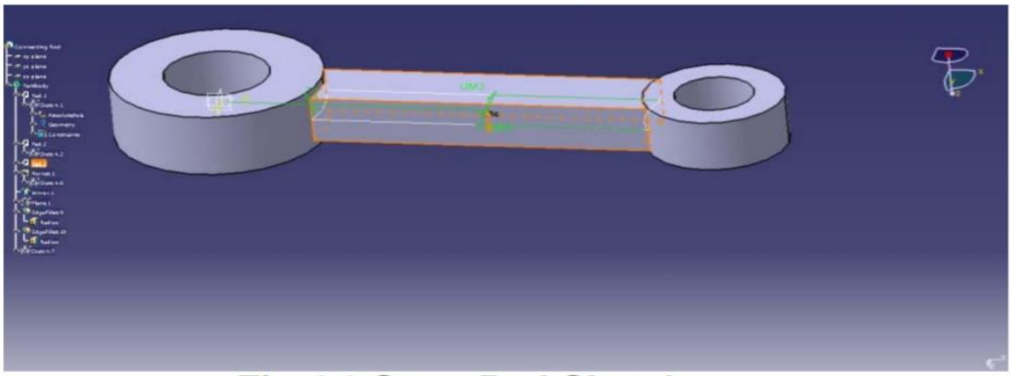

Fig.2.2 Stem pad sketch

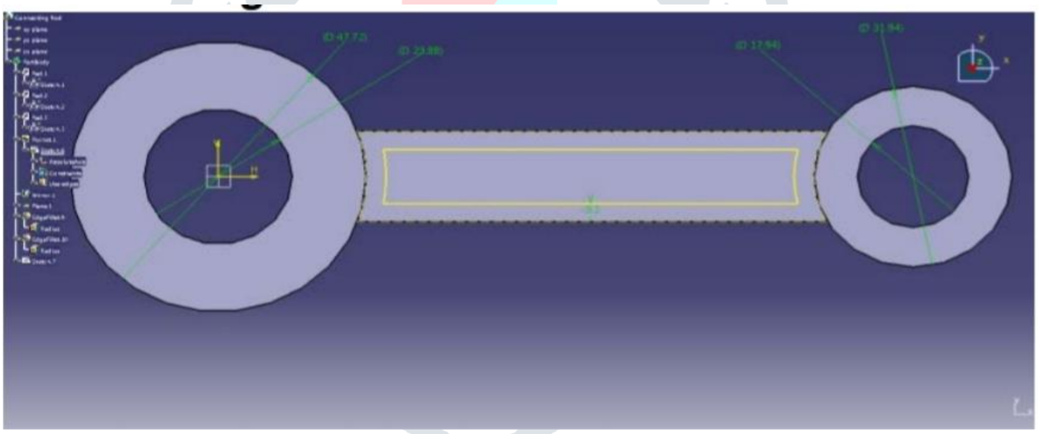

Fig.2.3 Weight reduction in stem sketch

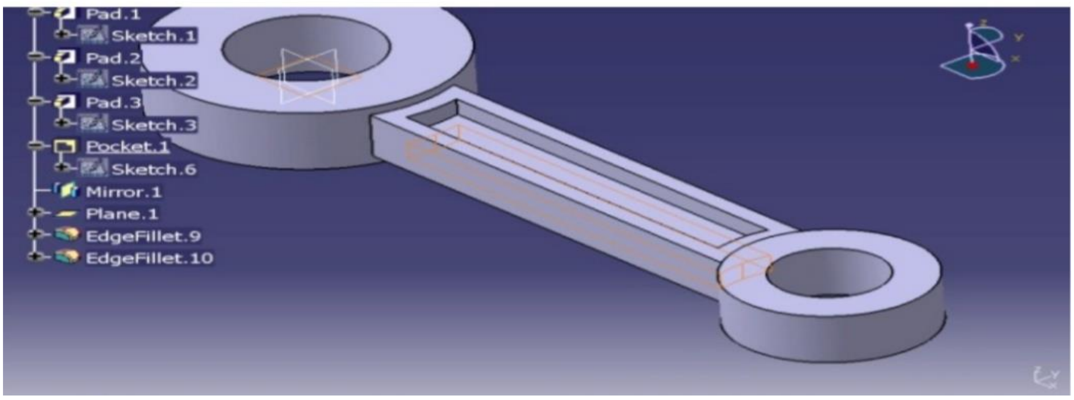

Fig.2.4 Pocket sketch

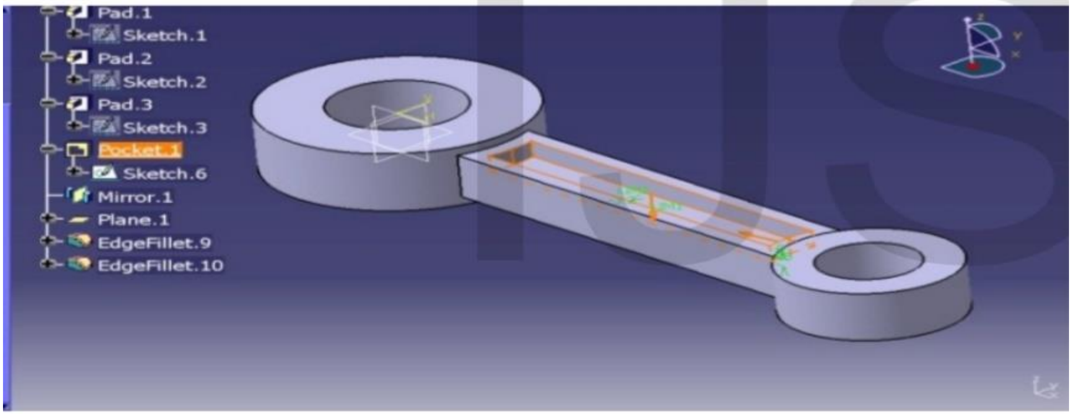

Fig.2.5 Edge fillet sketch

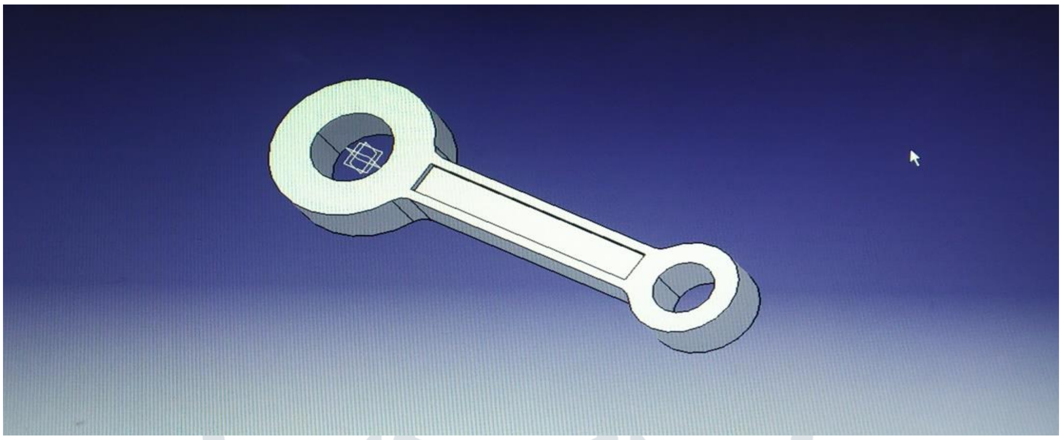

Fig.2.6 Connecting rod sketch

3. STRUCTURAL ANALYSIS OF CONNECTING ROD

3.1 Properties of Materials

Si.no	Mechanical properties	AlSic-12 material	Aluminium alloy 7068,T6,T6511	Aluminium silicon
1.	Density(g/cc)	2.89	2.85	2.93
2.	Average hardness(HRB)	47.6	174	45
3.	Modulus of elasticity,(Mpa)	210	731	210
4.	Yield strength, YS,(Mpa)	257	683	214
5.	Ultimate strength ,Su,(Mpa)	488	710	488
6.	Fatigue strength,(Mpa)	167	159	130
7.	Poison ratio	0.21	0.33	0.21

Table 3.1 Mechanical Properties of Materials

3.2 Analysis with AlSic-12 material:

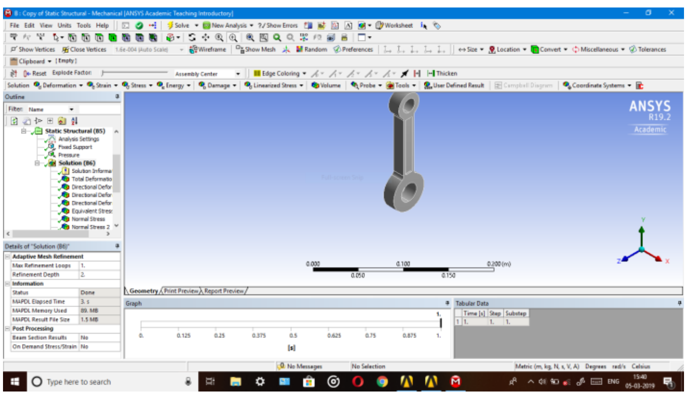

Fig:3.2.1 Model of a connecting rod in ANSYS

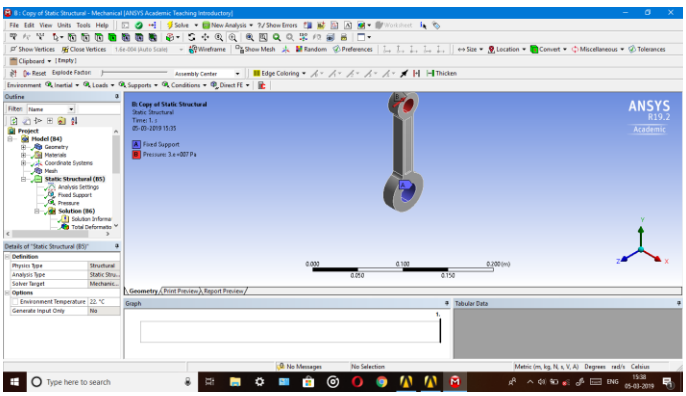

Fig: 3.2.2 Applications of loads at the ends of connecting rod

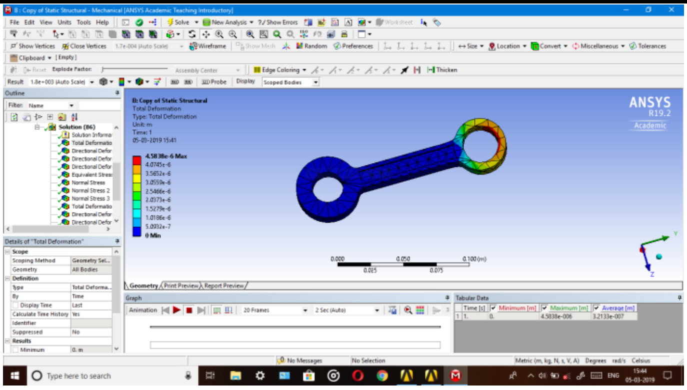

Fig: 3.2.3 Solution for total deformation

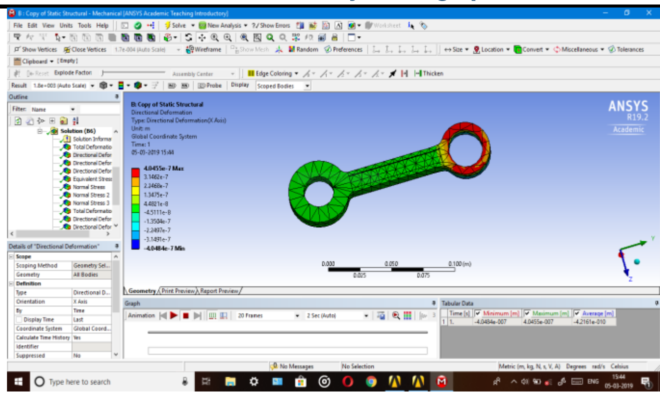

Fig: 3.2.4 Solution for directional deformation (x-axis)

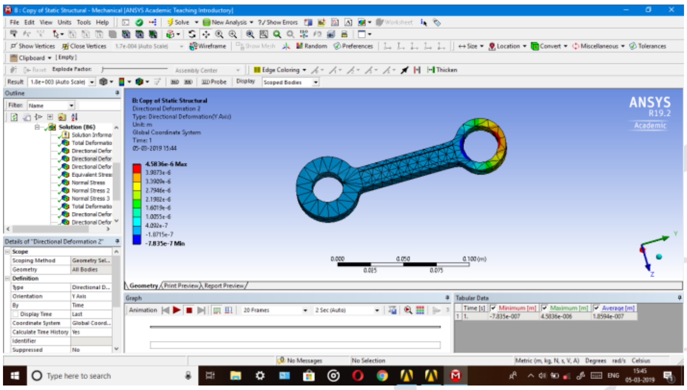

Fig: 3.2.5 Solution for directional deformation(y-axis)

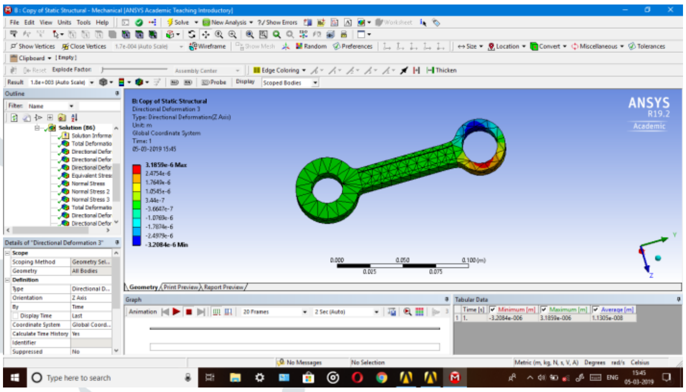

Fig: 3.2.6 Solution for directional deformation(z-axis)

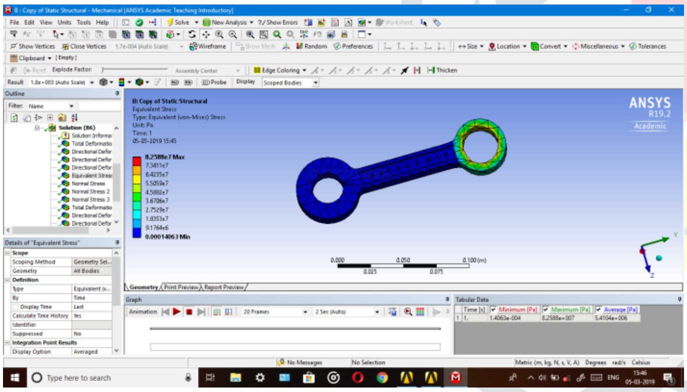

Fig: 3.2.7 Solution for Equivalent(von-mises)stress

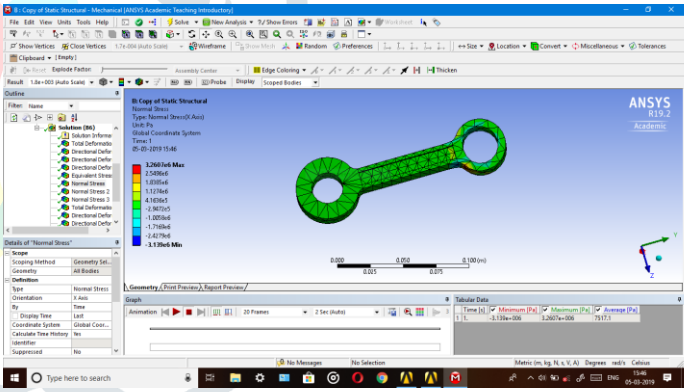

Fig: 3.2.8 Solution for normal stress (x-axis)

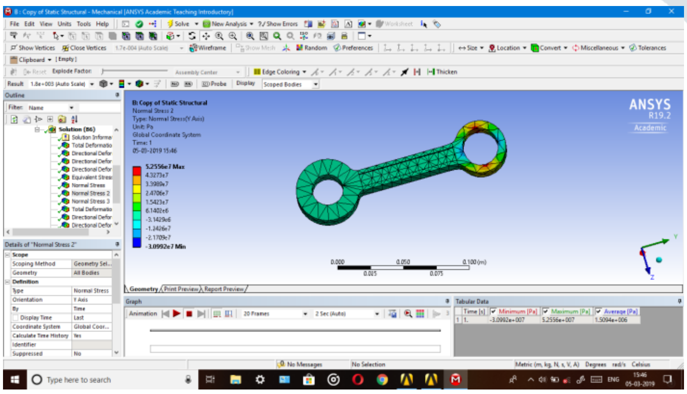

Fig: 3.2.9 Solution for normal stress (y-axis)

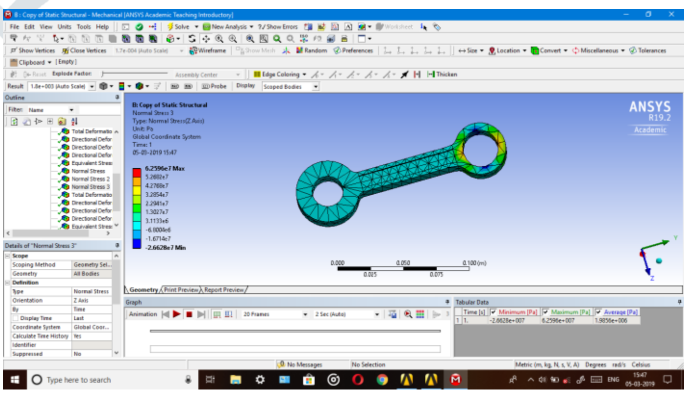

Fig: 3.2.10 Solution for normal stress (z-axis)

3.3 Analysis with Aluminium alloy 7068, T6,T6511 Material:

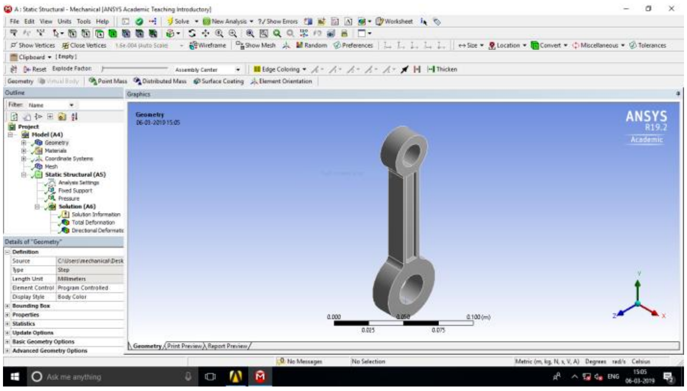

Fig:3.3.1 Model of a connecting rod in ANSYS

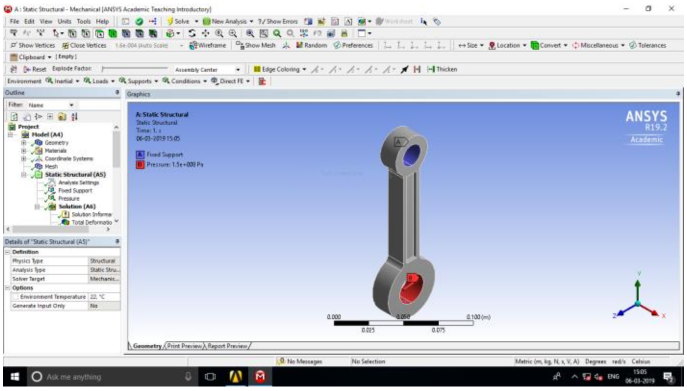

Fig: 3.3.2 Applications of loads at the ends of connecting rod

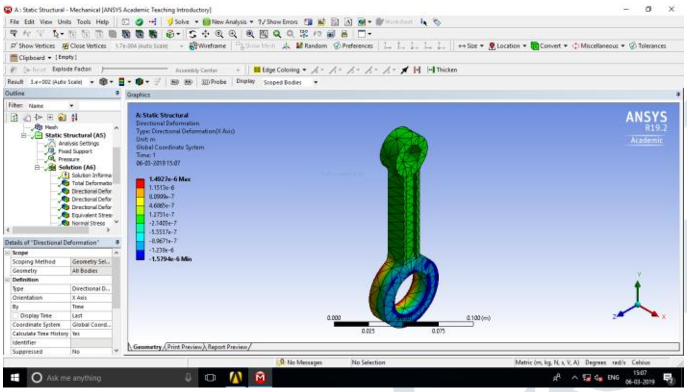

Fig: 3.3.3 Solution of directional deformation (x-axis)

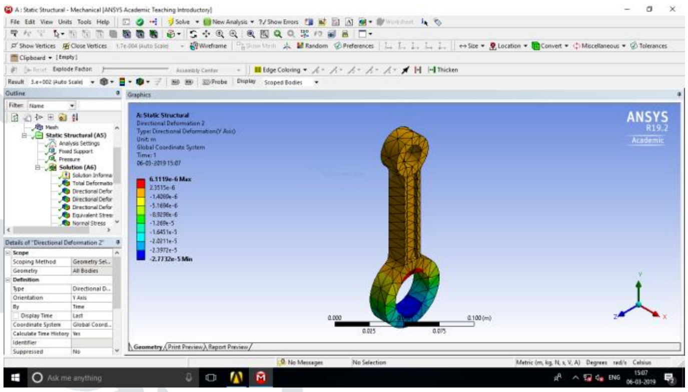

Fig: 3.3.4 Solution of directional deformation (y-axis)

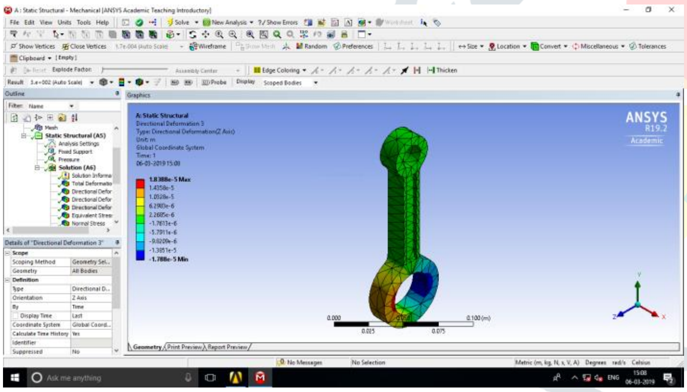

Fig: 3.3.5 Solution of directional deformation (z-axis)

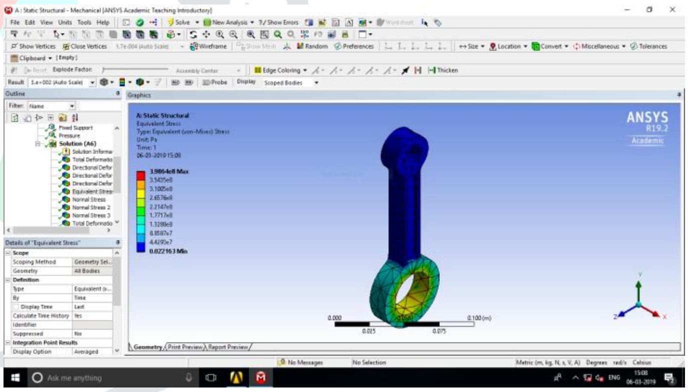

Fig: 3.3.6 Solution for total equivalent (von-mices) stress

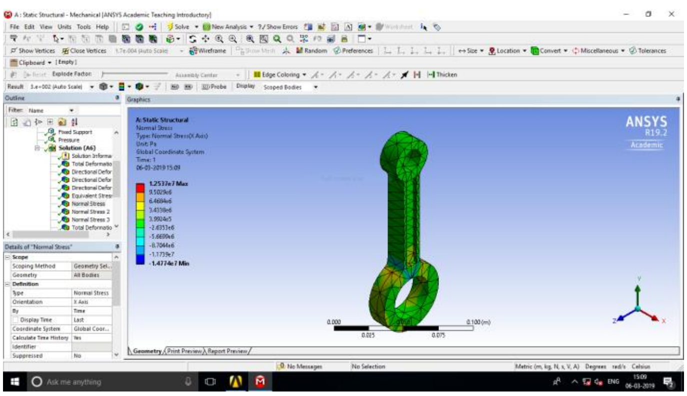

Fig: 3.3.7 Solution of normal stress (x-axis)

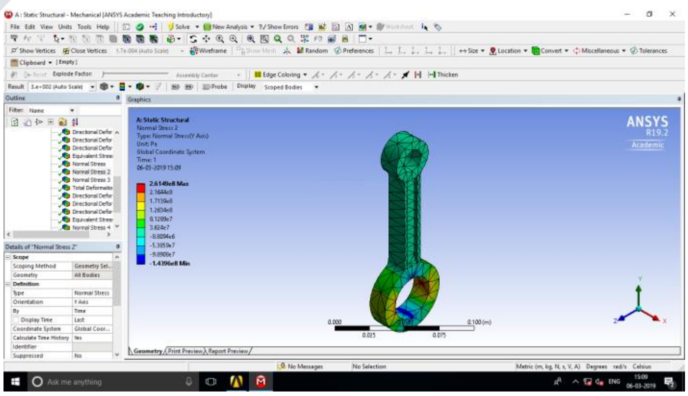

Fig: 3.3.8 Solution of normal stress(y-axis)

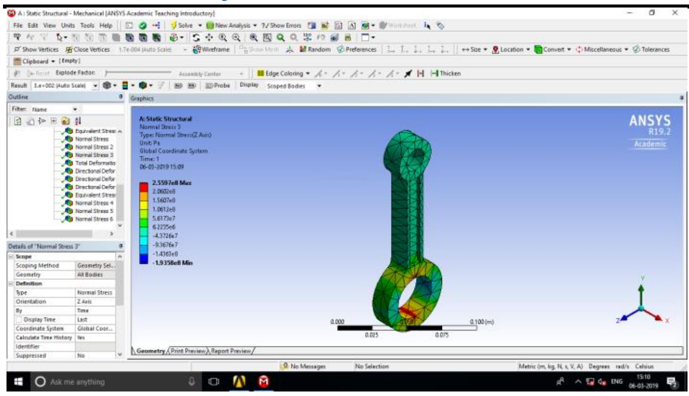

Fig: 3.3.9 Solution of normal stress (z-axis)

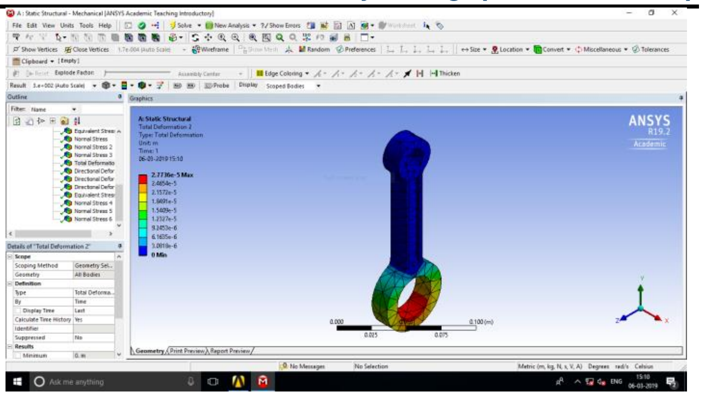

Fig: 3.3.10 Solution for total deformation

3.4 Analysis with AlSi Material:

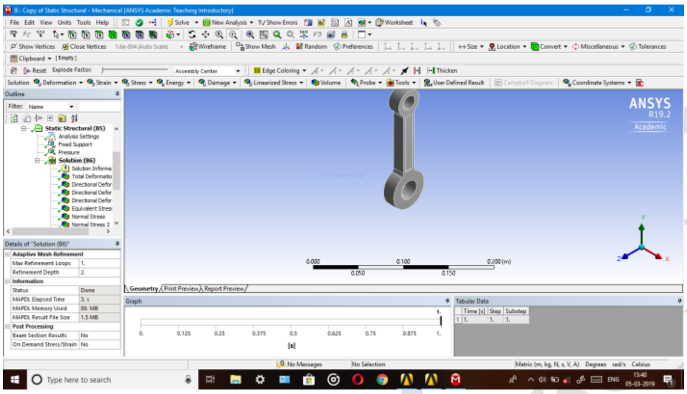

Fig:3.4.1 Model of a connecting rod in ANSYS

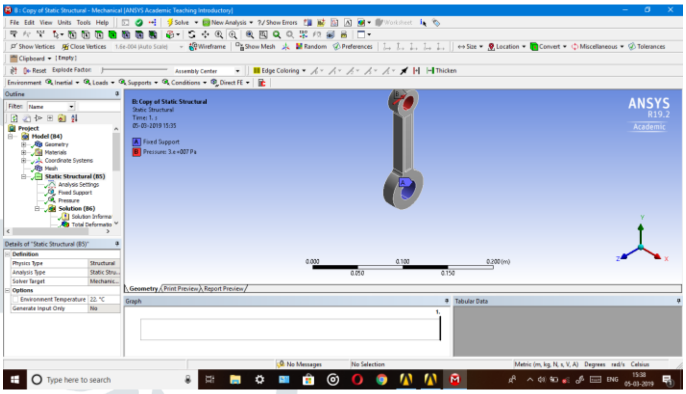

Fig: 3.4.2 Applications of loads at the ends of connecting rod

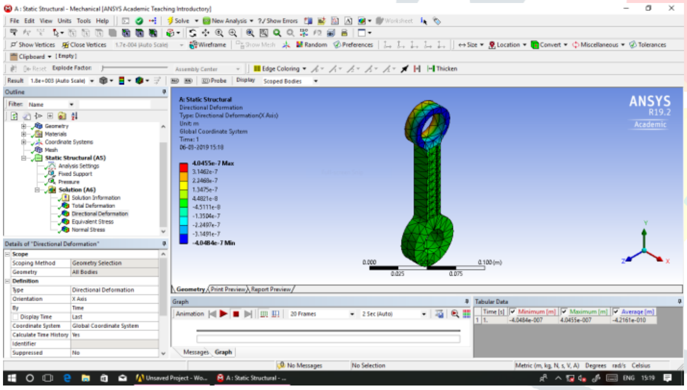

Fig: 3.4.3 Solution for directional deformation (x-axis)

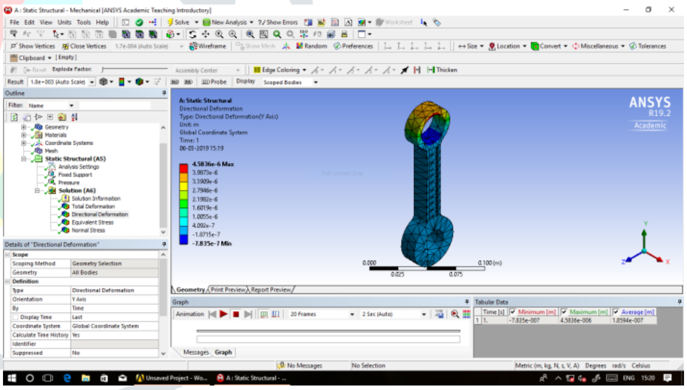

Fig: 3.4.4 Solution for directional deformation (y-axis)

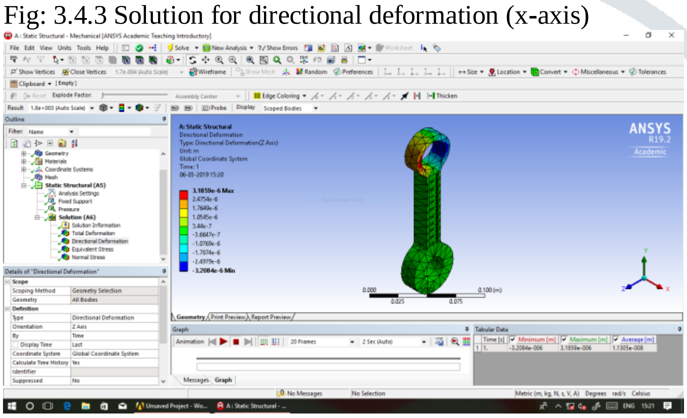

Fig: 3.4.5 Solution for directional deformation (z-axis)

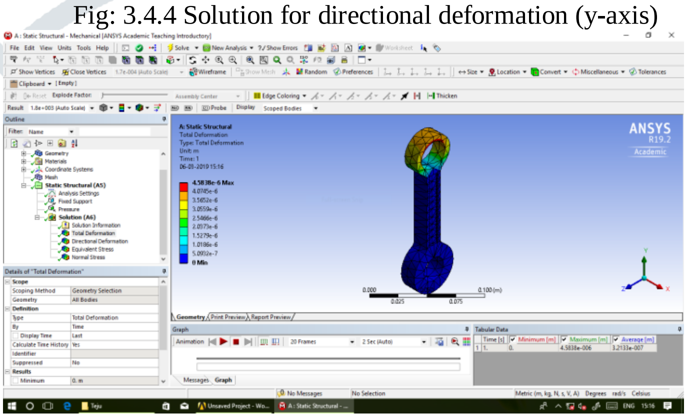

Fig: 3.4.6 Solution for Total deformation

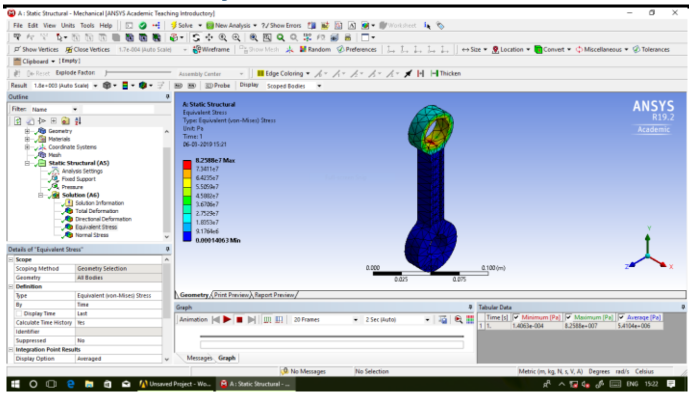

Fig: 3.4.7 Equivalent (von-mises) stress

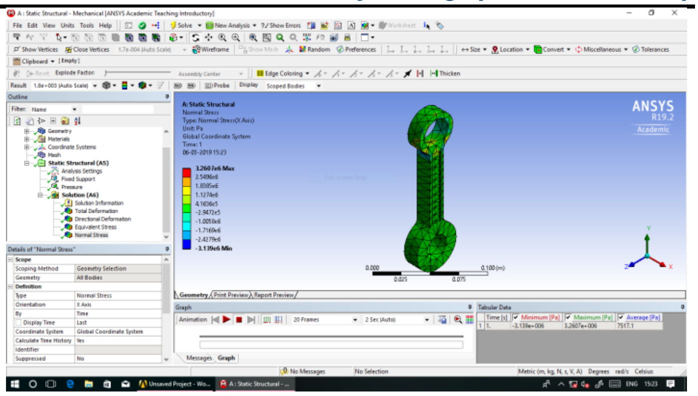

Fig: 3.4.8 Solution for normal stress (x-axis)

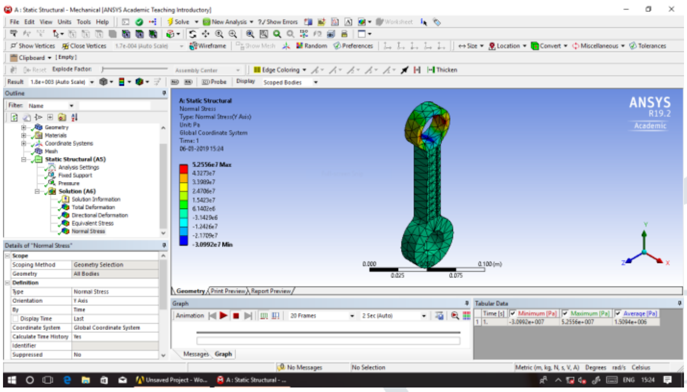

Fig: 3.4.9 Solution for normal stress (y-axis)

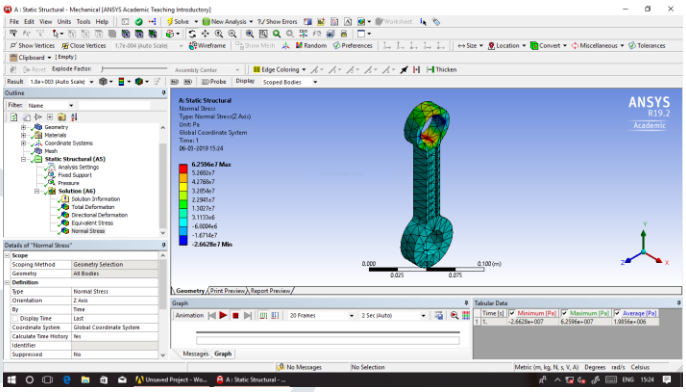

Fig: 3.4.10 Solution for normal stress (z-axis)

4.Results

S.no	Types	AlSic-12 Material		Aluminium alloy Material		AlSi Material	
		Max(Mpa)	Min(Mpa)	Max(Mpa)	Min(Mpa)	Max(Mpa)	Min(Mpa)
2	Equivalent stress	7.5922e-7	0.010229	8.2588e7	0.00014063	4.5573e-6	0
3	Normal stress (x-axis)	3.1385e-6	-3.5751e6	3.2609e6	-3.139e6	3.8229e-7	-4.0268e-7
4	Normal stress (y-axis)	5.3227e7	-2.6893e7	5.2556e7	-3.0992e7	4.5566e-6	-7.9509e-9
5	Normal stress (z-axis)	5.8698e7	-2.8509e7	6.2596e7	-2.6628e7	3.1794e-6	-3.1946e-6
6	Total deformation	4.5573e-6	0	4.5838e-6	0	7.5922e7	0.010229
7	Directional deformation (x axis)	3.8229e-7	-4.0268e-7	4.0455e-7	-4.0484e-7	3.1385e6	-3.5751e6
8	Directional deformation (y axis)	4.5566e-6	-7.9509e-7	4.5836e-6	-4.835e-7	5.3227e7	-2.6893e-7
9	Directional deformation (z axis)	3.1794e-6	-3.1946e-6	3.1859e-6	-3.2084e-6	5.8698e7	-2.85e-709

Table 4.1 Results

5. CONCLUSIONS

- From the analysis results of different material on connecting rod is observed that the total deformation and equivalent stress of in AlSic12, AiSi, aluminium alloy.
- Results comparison between AlSic12 and aluminium alloy also comparison between AlSi and AlSic12 materials.
- A connecting rod made of composite material (aluminium silicon carbide12) is designed and analysed successfully. Composite connecting rod made of metal matrix offers high strength retention on ageing even at severe environments.
- Compared to AlSic12, AlSi the AlSic12 is found to have lesser deformation lesser stress and good load distribution.
- Some the limitation faced by aluminium alloy connecting rod are overcome by the aluminium silicon carbide connecting rod. From this project we get clear knowledge about the composite material AlSic12 and its features.

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