iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** V **Month of publication:** May 2017

DOI:

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Design and Analysis of Connecting Rod for Different Material Using Ansys Workbench 16.2

Vikas Singh[1], Sumit Kr. Verma[2], Harish Chandra Ray[3], Vishal Kr. Bharti[4], Abhinesh Bhaskar[5]
Department of Mechanical, Rajkiya Engineering College, Banda, Uttar Pradesh, India-210001

Abstract: connecting rods are practically generally used in all varieties of automobile engines. Connecting rod acting as a converting intermediate link between the piston and the crankshaft of the engine, by the reciprocating motion of the piston to the rotary motion of crankshaft. Thus, this study aims to carry out for the load strain, stress, total deformation and analysis of factor of safety of pin end of the connecting rod of different materials. Generally connecting rods are manufactured using carbon steel and in recent days aluminium alloys are used for manufactured the connecting rods. In this work existing connecting rod material are replaced by beryllium alloy and magnesium alloy. Fea analysis was carried out by considering five material aluminium 360, forged steel, titanium alloy, ti-13v-11cr-3al, magnesium alloy, beryllium(alloy 25). In this study a solid 3d model of connecting rod was developed using solid works-2016 software and analysis was carried out by ansys 16.2 software and useful factors like stress, strain etc. Were obtained. Our main objective to determine best material for connecting rod after analysing at ansys workbench 16.2.

I. INTRODUCTION

Internal Combustion engine has many parts like cylinder, piston, connecting rod, crank and crank shaft. The connecting rod is very important part of an engine. Working of the connecting rod is to transmit power of piston to crank pin. Connecting rod has two ends one is pin end and other is crank end. Pin end is attached with piston. The big end (crank end) is attached to the crank pin by a crank shaft. The function of crank shaft is to transmit the reciprocating motion of piston into rotary motion. The connecting rod should be such that it can sustain the maximum load without any failure during high cycle fatigue. The connecting rod has generally three parts pin end, crank end, and long shank. Design of shank can be different type like rectangular, tubular, circular, I-section and H-section. Circular section is generally used for low speed engines. I-section is used for high speed engines.

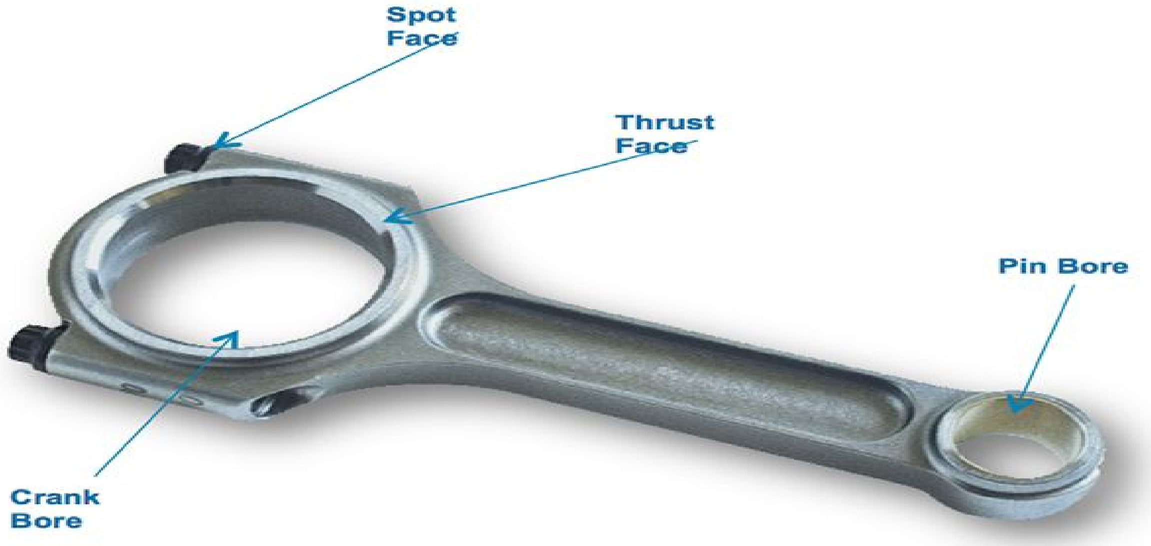


Fig-1 Schematic diagram of connecting rod

A. Kuldeep B “Analysis and optimization of connecting rod using ALFASiC composites”. Generally connecting rods are manufactured using carbon steel and in recent days aluminium alloys are finding its application in connecting rod. In this work connecting rod is replaced by aluminium based composite material reinforced with silicon carbide and fly ash. And it also

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

describes the modelling and analysis of connecting rod. FEA analysis was carried out by considering two materials. The parameter like von misses stress, von misses strain and displacements were obtained from ANSYS software. Compared to the former material the new material found to have less weight and better stiffness. It resulted in reduction of 43.48% of weight, with 75% reduction in displacement. [1]

B. Prof. N.p.doshi "analysis of connecting rod using analytical and finite element method". The most common types of materials used for connecting rods are steel and aluminium. Connecting rods are widely used in variety of engines such as, in-line engines, v-engine, opposed cylinder engines, radial engines and oppose-piston engines. For the project work we have selected connecting rod used in light commercial vehicle of tata motors had recently been launched in the market. We found out the stresses developed in connecting rod under static loading with different loading conditions of compression and tension at crank end and pin end of connecting rod. Design of connecting rod which is designed by machine design approach is compared with actual production drawing of connecting rod. We found that there is possibility of further reduction in mass of connecting rod. [2]

C. Webster et al. (1983) performed three dimensional finite element analysis of a high-speed diesel engine connecting rod. For this analysis they used the maximum compressive load which was measured experimentally, and the maximum tensile load which is essentially the inertia load of the piston assembly mass. The load distributions on the piston pin end and crank end were determined experimentally. They modelled the connecting rod cap separately, and also modelled the bolt pretension using beam elements and multi point constraint equations. [3]

D. Yoo et al. (1984) used vibrational equations of elasticity, material derivative idea of continuum mechanics and an ad joint variable technique to calculate shape design sensitivities of stress. The results were used in an iterative optimization algorithm, steepest descent algorithm, to numerically solve an optimal design problem. The focus was on shape design sensitivity analysis with application to the example of a connecting rod. The stress constraints were imposed on principal stresses of inertia and firing loads. But fatigue strength was not addressed. The other constraint was the one on thickness to bound it away from zero. They could obtain 20% weight reduction in the neck region of the connecting rod. [4]

E. Folgar et al. (1987) developed a fibre fp/metal matrix composite connecting rod with the aid of fea, and loads obtained from kinematic analysis. Fatigue was not addressed at the design stage. However, prototypes were fatigue tested. The investigators identified design loads in terms of maximum engine speed, and loads at the crank and piston pin ends. They performed static tests in which the crank end and the piston pin end failed at different loads. Clearly, the two ends were designed to withstand different loads. [5]

F. Serag et al. (1989) developed approximate mathematical formulae to define connecting rod weight and cost as objective functions and also the constraints. The optimization was achieved using a geometric programming technique. Constraints were imposed on the compression stress, the bearing pressure at the crank and the piston pin ends. [6]

G. Sarihan and song (1990), for the optimization of the wrist pin end, used a fatigue load cycle consisting of compressive gas load corresponding to maximum torque and tensile load corresponding to maximum inertia load. Evidently, they used the maximum loads in the whole operating range of the engine. To design for fatigue, modified goodman equation with alternating octahedral shear stress and mean octahedral shear stress was used. [7]

H. Balasubramaniam et al. (1991) reported computational strategy used in mercedes- benz using examples of engine components. In their opinion, 2d fe models can be used to obtain rapid trend statements, and 3d fe models for more accurate investigation. The various individual loads acting on the connecting rod were used for performing simulation and actual stress distribution was obtained by superposition. The loads included inertia load, firing load, the press fit of the bearing shell, and the bolt forces. No discussions on the optimization or fatigue, in particular, were presented. [8]

I. athavale and sajanpawar (1991) modelled the inertia load in their finite element model. An interface software was developed to apply the acceleration load to elements on the connecting rod depending upon their location, since acceleration varies in magnitude and direction with location on the connecting rod. They fixed the ends of the connecting rod, to determine the deflection and stresses. This, however, may not be representative of the pin joints that exist in the connecting rod. The results of the detailed analysis were not discussed, rather, only the modelling technique was discussed. The connecting rod was separately analysed for the tensile load due to the piston assembly mass (piston inertia), and for the compressive load due to the gas pressure. The effect of inertia load due to the connecting rod, mentioned above, was analysed separately. [9]

J. Hippoliti (1993) reported design methodology in use at piaggio for connecting rod design, which incorporates an optimization session. However, neither the details of optimization nor the load under which optimization was performed were discussed.

Two parametric FE procedures using 2D plane stress and 3D approach developed by the author were compared with experimental results and shown to have good agreements. [10]

K. sonsino and esper (1994) have discussed the fatigue design of sintered connecting rods. they did not perform optimization of the connecting rod. they designed a connecting rod with a load amplitude fa = 19.2 kn and with different regions being designed for different load ratios (r), such as, in the stem fm = -2.2 kn and r = -1.26, at the piston pin end fm = -5.5 kn and r = -1.82, at the crank end fm = 7.8 kn and r = -0.42. they performed preliminary fea followed by production of a prototype. fatigue tests and experimental stress analysis were performed on this prototype based on the results of which they proposed a final shape, shown in figure 1.4. in order to verify that the design was sufficient for fatigue, they computed the allowable stress amplitude at critical locations, taking the r-ratio, the stress concentration, and statistical safety factors into account, and ensured that maximum stress amplitudes were below the allowable stress amplitude. [11]

L. ishida et al. (1995) measured the stress variation at the column centre and column bottom of the connecting rod, as well as the bending stress at the column centre. the plots, shown in figures 1.5 and 1.6 indicate that at the higher engine speeds, the peak tensile stress does not occur at 360o crank angle or top dead centre. it was also observed that the r ratio varies with location, and at a given location it also varies with the engine speed. the maximum bending stress magnitude over the entire cycle (0° to 720° crank angle) at 12000 rev/min, at the column centre was found to be about 25% of the peak tensile stress over the same cycle. [12]

M. rabb (1996) performed a detailed fea of the connecting rod. he modelled the threads of the connecting rod, the threads of connecting rod screws, the prestress in the screws, the diametral interference between the bearing sleeve and the crank end of the connecting rod, the diametral clearance between the crank and the crank bearing, the inertia load acting on the connecting rod, and the combustion pressure. the analysis clearly indicated the failure location at the thread root of the connecting rod, caused by improper screw thread profile. the connecting rod failed at the location indicated by the fea. an axisymmetric model was initially used to obtain the stress concentration factors at the thread root. these were used to obtain nominal mean and alternating stresses in the screw. a detailed fea including all the factors mentioned above was performed by also including a plasticity model and strain hardening. based on the comparison of the mean stress and stress amplitude at the threads obtained from this analysis with the endurance limits obtained from specimen fatigue tests, the adequacy of a new design was checked. load cycling was also used in inelastic fea to obtain steady state situation. [13]

N. pai (1996) presented an approach to optimize shape of connecting rod subjected to a load cycle, consisting of the inertia load deducted from gas load as one extreme and peak inertia load exerted by the piston assembly mass as the other extreme, with fatigue life constraint. fatigue life defined as the sum of the crack initiation and crack growth lives, was obtained using fracture mechanics principles. the approach used finite element routine to first calculate the displacements and stresses in the rod; these were then used in a separate routine to calculate the total life. the stresses and the life were used in an optimization routine to evaluate the objective function and constraints. the new search direction was determined using finite difference approximation with design sensitivity analysis. the author was able to reduce the weight by 28%, when compared with the original component. [14]

as we seen in above references forged steel was use primarily but due to its heavy weight speed of engine reduced then after aluminium alloy was used so that speed of the engine increases but there large variation in stress and deformation in compared to other materials that were searched in that time like magnesium alloy, titanium alloy, as comparison with those materials beryllium 25 is the better among them because there is small variation in stress, strain, and total deformation.

the function of connecting rod is to transmit the thrust of the piston to the crankshaft. figure shows the role of connecting rod in the conversion of reciprocating motion into rotary motion. a four-stroke engine is the most common type. the four strokes are intake, compression, power, and exhaust. each stroke requires approximately 180 degrees of crankshaft rotation, so the complete cycle would take 720 degrees. each stroke plays a very important role in the combustion process. in the intake cycle, while the piston moves downward, one of the valves open. this creates a vacuum, and an air-fuel mixture is sucked into the chamber (figure 2 (a)). during the second stroke compression occurs. in compression both valves are closed, and the piston moves upward and thus creates a pressure on the piston, see (figure 2 (b)). the next stroke is power. during this process the compressed air-fuel mixture is ignited with a spark, causing a tremendous pressure as the fuel burns. the forces exerted by piston transmitted through the connecting rod moves the crankshaft; see (figure 2 (c)). Finally, the exhaust stroke occurs. In this stroke, the exhaust valve opens, as the piston moves back upwards, it forces all the air out of the chamber and thus which completes the cycle of crankshaft rotation Figure2(d).

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

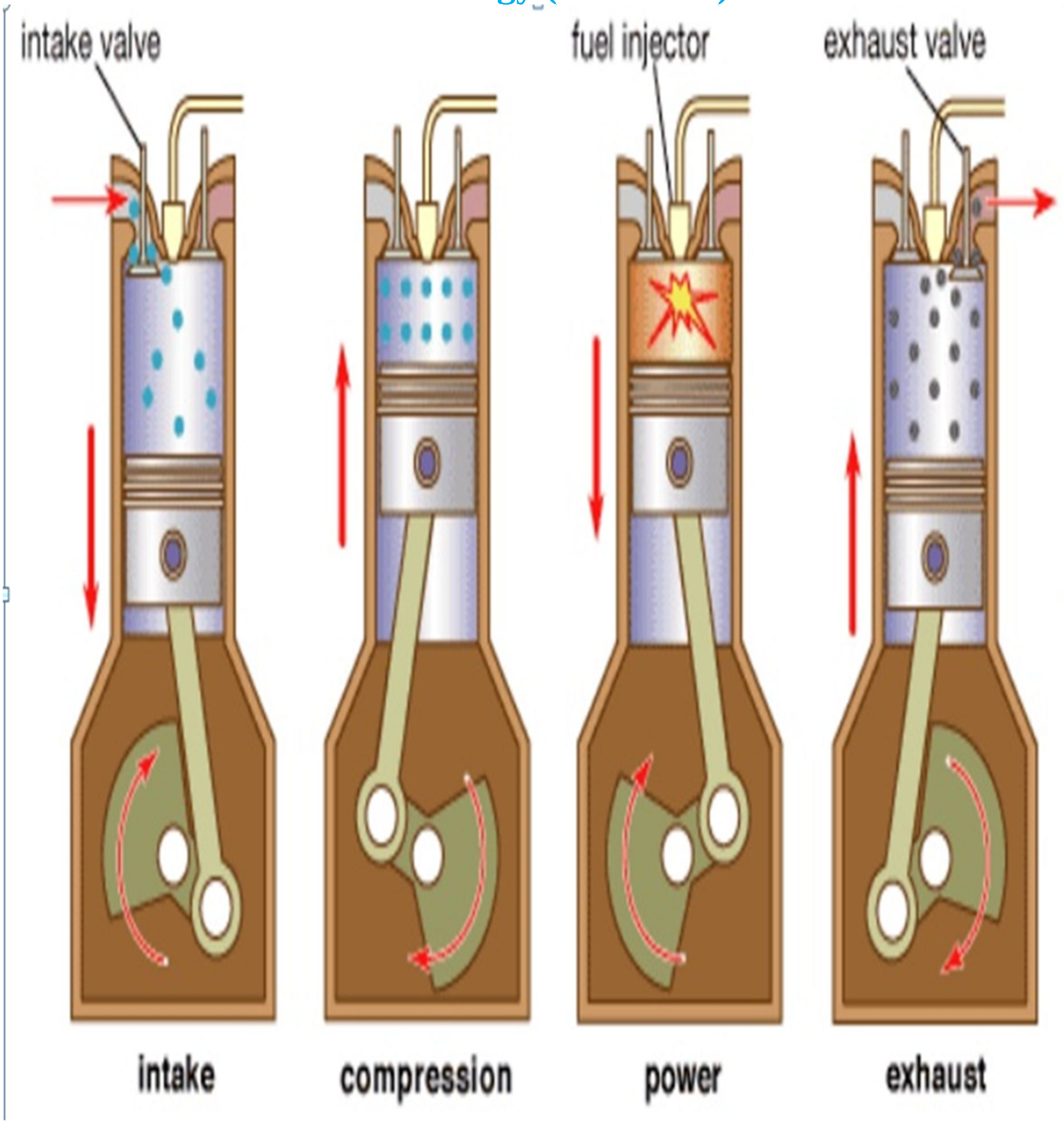
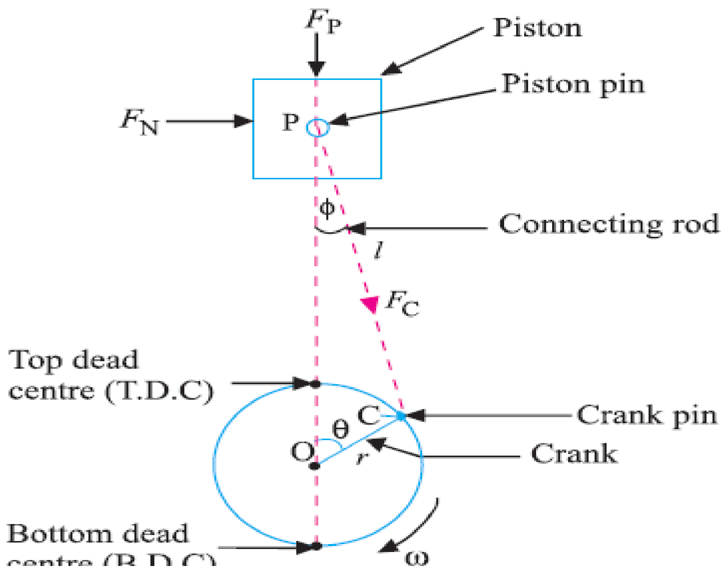


Fig-2(a) Fig-2(b) Fig-2(c) Fig-2(d)

O. Forces acting on the connecting rod

In I.C engine most stressed part is connecting rod. There are different types of stresses induced in connecting rod as shown in figure-3. One of them is axial stress which is induced by combustion of fuel in the cylinder so that a high compressive force is act on piston pin. And second one is the bending stress which is induced by centrifugal action. And third one is inertial force which is caused by reciprocating of piston. Connecting rod can be made of different type of materials. In modern era it is generally made of steel, but it can made of aluminium (reducing the weight and the ability of absorbing high impact) or titanium alloy (for high performance engines) or cast iron for two wheeler like scooters. In these study five materials Aluminium-360, High strength carbon fibre, Magnesium alloy, Titanium alloy and Beryllium alloy-25 are considered for Ansys.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)



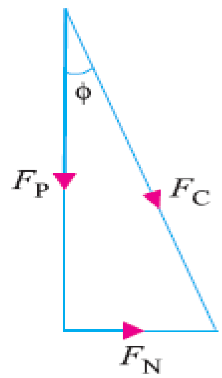


Fig-3 Vertical representation of connecting rod

P. Pressure Calculation for Connecting Rod

Engine type 4-stroke air cooled
Bore X Stroke = 57 × 58.6 mm
Displacement = 149.5 cc
Maximum Power = 13.8bhp@8500rpm
Compression Ratio = 9.35: 1
Density of petrol (C_8H_{18}) = 737.22kg/m3=737.22E-9 kg/mm3
Auto ignition temp. = 280°c (536°F) = 553°k
Mass= Density×Volume
= 737.22e-9x149.5e
= 0.110214kg
Molecular weight of petrol = 114.228g/mole
= 0.11423 kg/mole
Where, P = Pressure, MPa
V = Volume
m = Mass, kg
Rspecific = Specific gas constant
T = Temperature,°k
Rspecific = R/M
Rspecific = 8.3143/0.114228
Rspecific = 72.76 Nm/kg K
P = m.Rspecific.T/V
P = (0.110214 x 72.757 x 553) / 149.5 = 29.67 MPa
Calculation of analysis is done for maximum Pressure of 30 MPA and 15 MPA.

Q. Design Calculation For The Connecting Rod In general From standards,

1) Thickness of the flange & web of the section = t
2) Width of the section, B = 4t
3) Height of the section, H = 5t
4) Area of the section, A = $11t^2$\
5) Moment of inertia about x-axis, Ixx= 34.91t

6) Moment of inertia about y-axis Iyy= 10.91t
7) Therefore Ixx / Iyy = 3.2 (safe because it lies between 3 to 3.5)
8) Length of the connecting rod (L) = 2 times stroke L = 117.2 mm

Total Force acting $F = F_P - F_I$
Where F_p = force acting on the piston
F_I= force of inertia
$F_P = (\frac{\pi}{4}d^2)$ x gas pressure
F_P = 39473.1543 N
$F_I = mw^2r(\cos\theta \pm \frac{\cos 2\theta}{n})$
m = mass of the reciprocating parts
Weight = 1.6 * 9.81 = 15.696 N
r = crank radius
r = stroke of piston / 2
r = 58.6/2 = 29.3mm
Also, ɵ = Crank angle from dead centre
ɵ= 0 considering connecting rod is at TDC position
n = length of connecting rod / crank radius
g = acceleration due to gravity, 9.81m/s^2
v = crank velocity m/s
w = 2πn/60 w = 2π8500/60 = 890.1179
v = r w = 29.3e-3×890.1179 = 26.08 m/sec
On substituting these,
F_I = 9285.5481
Thus,
F = 39473.1543 – 9285.5481 F = 30187.6062 N
Now, According to Rankine's – Gordon formula,
$F = \frac{F_C A}{1+a(\frac{L}{K_{xx}})}$
Let,
A = Cross-section area of connecting rod,
L = Length of the connecting rod
F_C = Compressive yield stress,
F = Buckling load
I_{xx} & I_{yy} = Radius of gyration of section about the x
– x and y – y axis resp. K_{xx} & K_{yy} = Radius of gyration of section about x – x and y – y axis resp.
For Magnesium Alloy:
F_c=160Mpa
$30187.6 = \frac{160\times 11t}{1+.002(\frac{117.2}{1.78t})}$
t = 4.08mm
Width B = 4t = 4x4.08 =16.32mm
Height H = 5t = 20.40mm
At the small end (H_1) =.85H=.85x20.40=17.34mm
At the big end (H_2) = 1.2H=1.2x20.40=24.48mm

R. Design of small end

$$Load\ on\ piston\ pin\ (Fp) = projected\ area\ x\ bearing\ pressure = dp\ lp\ x\ P_{bp}$$

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

$$39473.154 = dp \; x \; 1.5dp \; x \; 10$$

$$d_p = 51.29mm$$

$$l_p = 76.5mm$$

$$Outer\ diameter\ of\ small\ end = d_p + 2t_b + 2t_m$$

$$= 51.29 + (2 \times 2) + (2 \times 5)$$

$$= 65.29mm$$

Design of big end:

$$F_p = d_c l_c \; x \; P_{bc} = d_c \; x \; 1.25 d_c \; x \; 7.5$$

$$39473.154 = 1.25 \; x \; 7.5 \; x \; d_c^2$$

$$d_c = 64.88 \; mm$$

II. ANALYSIS OF CONNECTING ROD

The connecting rods are most usually made of steel for production engines, but can be made of aluminium (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters.

A. Problem Formulation

The objective of the present study is to design and analysis of two wheeler connecting rod and to find the best alternative material of connecting rod. In the present study beryllium alloys and magnesium alloys have taken in place of currently using materials like aluminium 360 for CAE analysis and a meaningful comparison made among AL360, Beryllium alloy and Magnesium alloy for choosing the alternative of existing material using for manufacture the connecting rod of single cylinder 4 stroke combustion engines. In this work, an analysis is done for aluminium alloy, magnesium alloy and beryllium alloy. Beryllium alloys feature high fatigue strength and resistance to wear, corrosion, galling, and stress relaxation.

B. Properties of Materials

Aluminium 360

Table-2.1 Composition

Aluminium	Bal.
Copper	.6
Magnesium	0.4-0.6
Iron	13
Lead	---
Tin	0.15
Nickel	0.50
Zinc	0.50
Manganese	0.35
Silicon	9.0-10.0

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Table2.2 Physical Properties

Material	Alloy	Density	Melting Pt(C)	Thermal Conductivity(w/mK)	Coefficient of Thermal Expansion(µm/mK)	Electrical Conductivity
Aluminium	Al 360	2.63	577	113	21	29

Table 2.3Mechanical Properties

Material	Alloy	Tensile Strength	Yield Strength	Shear Strength	Hardness	Elongation
		Mpa	Mpa	Mpa	Brinell(HB)	%in 50 mm
Aluminium	Al 360	317	170	180	75	35

Magnesium Alloy

Table 2.4 Composition

Aluminium	8.3-9.7
Copper	0.03
Magnesium	Bal.
Iron	0.005
Nickel	0.002
Zinc	0.35-1.0
Manganese	0.15-0.5
Silicon	0.1
Other-Metallic	0.02

Table 2.5 Physical Properties

Material	Alloy	Density	Melting Point	Thermal Conductivity	Coefficient of thermal Expansion	Electrical Conductivity
		g/cm^3	C	W/mK	µm/mK	%IACS
Magnesium	AZ91D	1.81	533	72.3	25.2	12.2

Table 2.6 Mechanical Properties

Material	Alloy	Tensile Strength	Yield Strength	Impact Strength	Shear Strength	Hardness	Elongation
		Mpa	Mpa	J	Mpa	Brinell	% in 50 mm
Magnesium	AZ91D	230	160	3	140	63	3

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Beryllium 25

Table 2.7 Composition

Weight %	Min.	Max.
Be	1.80	2.00
Co+Ni	0.20	0.50
Fe		0.10
Cu		Balance

Table 2.8 Physical Properties

	Alloy 25 AT	Alloy 25 HT
Ultimate tensile strength, MPa	1130-1380	1200-1520
Elongation % in 4D	3-10	2-9
Hardness, HRC	36-41	37-45
Fatigue strength in 10^8, MPa	340-450	340-450
Elastic Modulus, GPa	131	131
Thermal conductivity, w/m·C	105	105
Thermal expansion, ppm/ ′C	17	17
Magnetic permeability	< 1.001	< 1.001
Density, g/cm^3	8.36	8.36

Table 2.9 Mechanical Properties

Ultimate Tensile Strength	1280-1480 Mpa
Yield Strength	965-120 Mpa
Young Modulus	125-130 Gpa
Poisson’s ratio	0.33
Modulus of rigidity	50 Gpa

Titanium Alloy (Ti-13V-11Cr-3Al)

Volume 5 Issue V, May 2017
ISSN: 2321-9653

Table 2.10 Composition

Vanadium	12.5-14.5
Chromium	10-12
Aluminium	2.5-3.5
Iron	0.35
Oxygen	0.17
Carbon	0.05
Nitrogen	0.05
Titanium	Remainder

Table 2.11 Physical Properties

Properties	Metric
Density	$4.84 g/cm^3$
Thermal Expansion	$9.4\times10^{-6}/C$

Table 2.12 Mechanical Properties

Properties	Metric
Tensile Strength	1276 Mpa
Yield Strength	1207 Mpa
Poisson Ratio	0.304
Elastic Modulus	101.4 Gpa
Elongation at Break	8%
Hardness	40

Forged Steel

Table 2.13 Chemical Properties

Carbon	0.612-0.68%
Sulpher	0.02-0.04%
Magnenes	0.50-1.20%
Phophorus	0.04%
Chromium	0.90-1.20%

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Table 2.14 Mechanical Properties

Density(g/cc)	7.7
Average Hardness(HRB)	101
Yield Strength(Mpa)	625
Ultimate Strength(Mpa)	625
Percent Reduction in Area	58
Modulus of Elasticity(Gpa)	221
Poission Ratio	0.21

C. Comparison of Materials

1) *Density Comparison:* The connecting rod has a tremendous field of research. In addition to this, vehicle construction led the invention and implementation of quite new materials which are light and meet design requirements. And the optimization of connecting rod had already started as early year 1983 by Webster and his team. There are many materials which can be used in connecting rod for optimization. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminium (for reducing the weight and the ability of absorbing high impact at the expense of durability) or titanium (for a high performance engines) or of cast iron for applications such as motor scooters. In this study materials compared are Forged Steel, Beryllium 25, Aluminium 360, Titanium alloy, Magnesium alloy. In this comparison we replace Beryllium alloy by Titanium alloy.

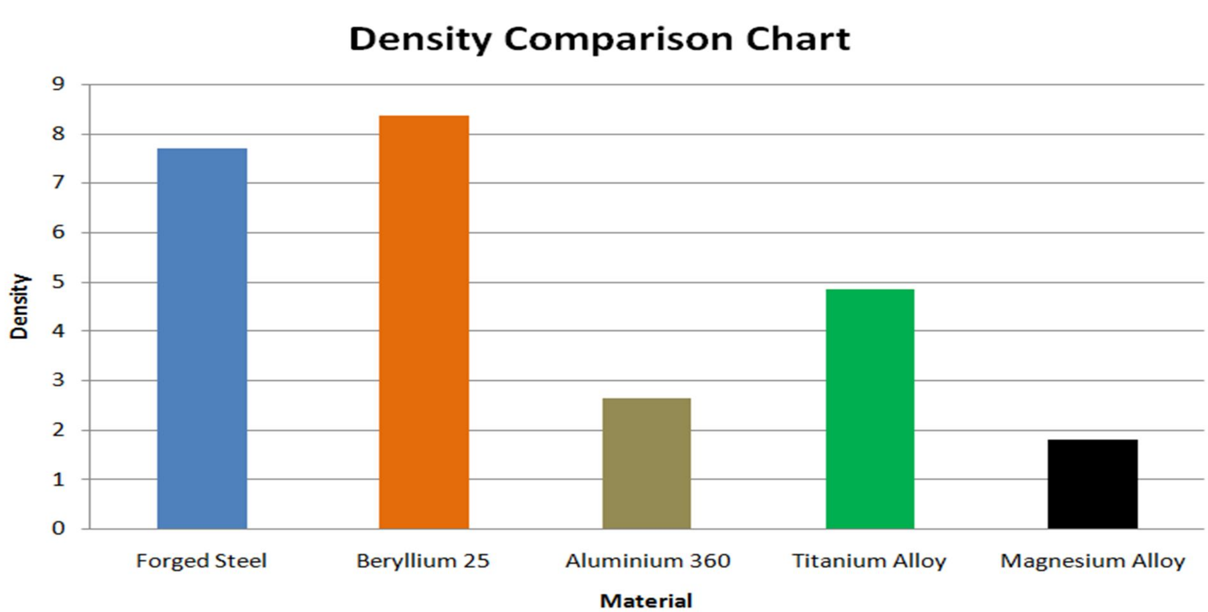


Fig-4 Density comparison chart

2) Weight Comparison**:** Compared five materials used for manufacturing of connecting rod these are Al360, Magnesium alloy, Beryllium 25, Forged Steel and Titanium alloy. The modelling and analysis of connecting rod was done. FEM analysis was carried out by considering three materials AL360, beryllium alloy and magnesium alloy. In his study he found out that out of above three material beryllium alloys is the best suitable material for connecting rod of two wheeler. Comparing the different

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

results obtained from the analysis, it is concluded that the stress induced in the beryllium alloy is less than the aluminium and magnesium alloy.

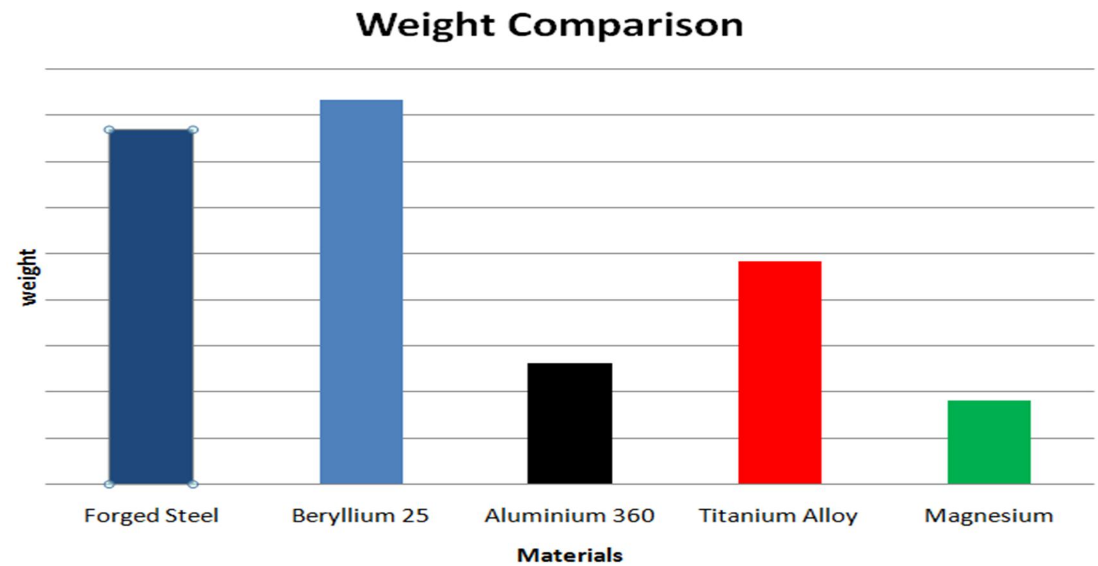


Fig-5 Weight comparison chart

3) Young Modulus

Here we compared Young's Modulus of five different materials. Materials are Aluminium 360, Forged Steel, Beryllium 25, Titanium Alloy and Magnesium Alloy.

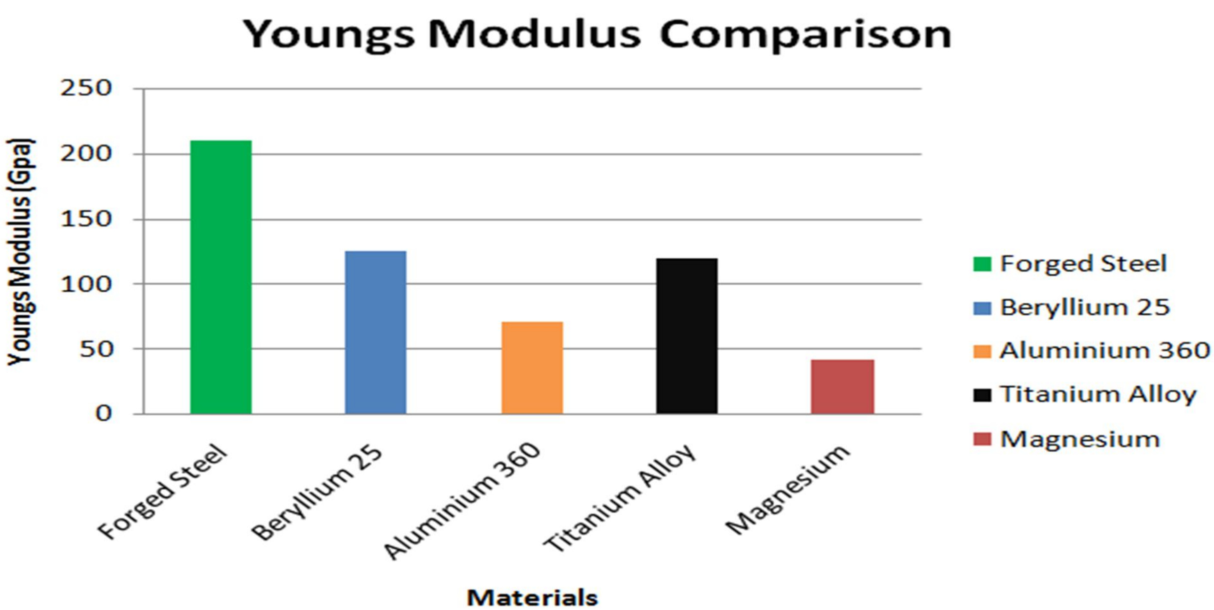


Fig-6 Young modulus chart

III. ANALYSIS ON ANSYS WORKBENCH 16.2

A. Introduction to Ansys

Ansys is analysis software. It is used to check design feasibility of the design almost in all aspect. Ansys as a software is made to be user-friendly and simplified as much as possible with lots of interface options to keep the user as much as possible from the hectic side of programming and debugging process. A glimpse of Ansys workbench is shown in figure-7 below

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

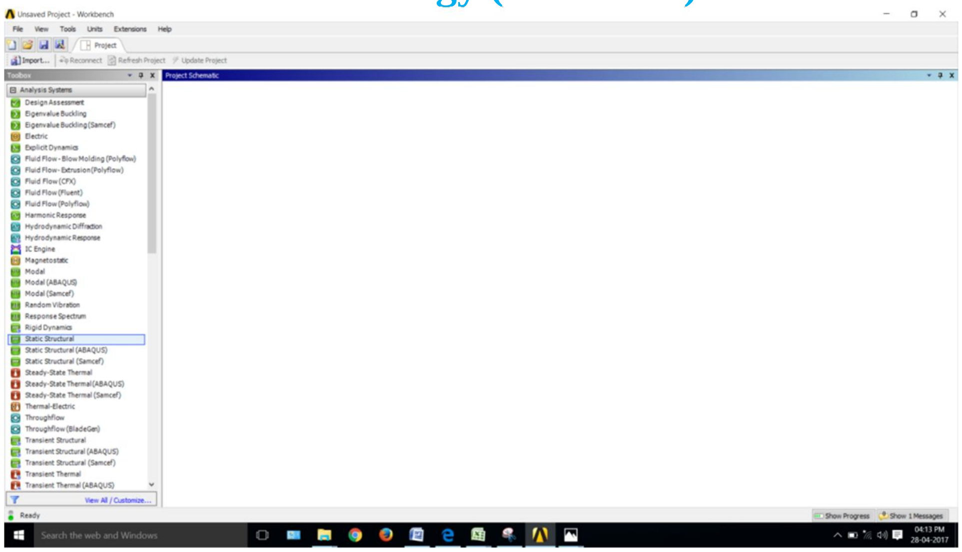


Fig-7 Static Structural Analysis System

1) *Create Analysis System*
a) Take one of the readymade stencil from the tool box according to the need of the project.
b) In this project we took static structural as analysis system for the analysis of connecting rod. To analysing connecting rod using different material at Ansys workbench 16.2 following step have been followed:-

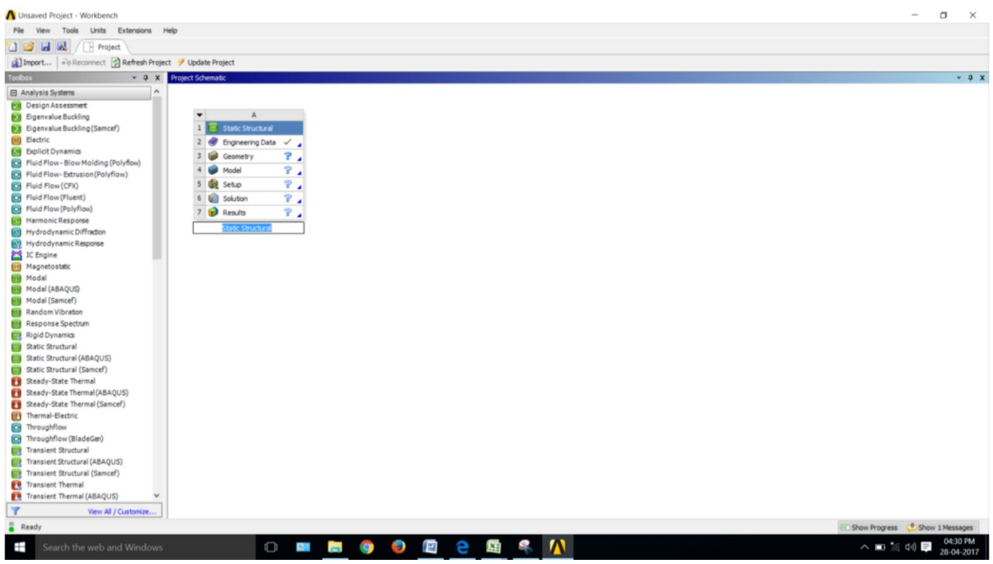


Fig-8 First view of static structure

2) *Define Engineering Data*
a) In this section material for the current project is assigned
b) In ansys by default structural steel is selected
c) To assign new material turn on the engineering data source
d) Generate new library for connecting rod
e) Make a tick mark on the new generated library named connecting rod to convert it into edit mode.
f) Add different four material which is kept under study as shown in figure-9 below
g) After giving all required properties for connecting rod save them into the Library
h) In the same way save the information about all consideration

Volume 5 Issue V, May 2017
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

i) Add all the four materials in the content by clicking on the plus sign as shown below-

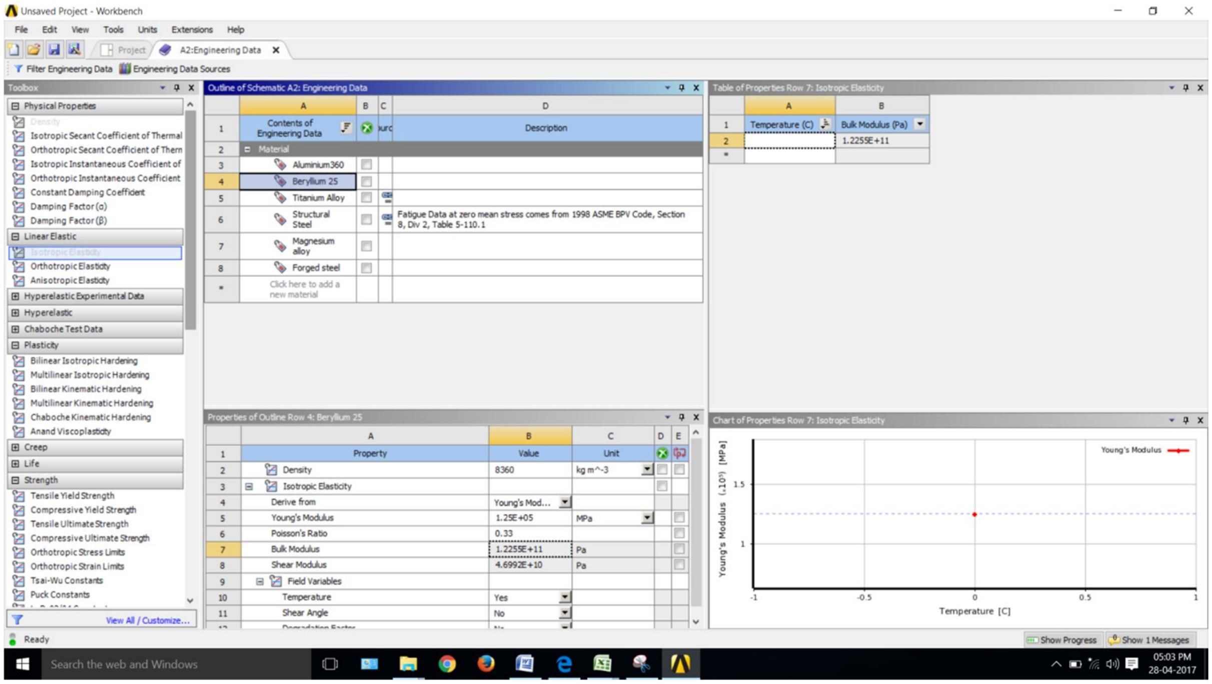


Fig-9 Adding new material

3) *Importing External Geometry:* As design of connecting rod is done on SOLID WORKS is imported as shown below:-

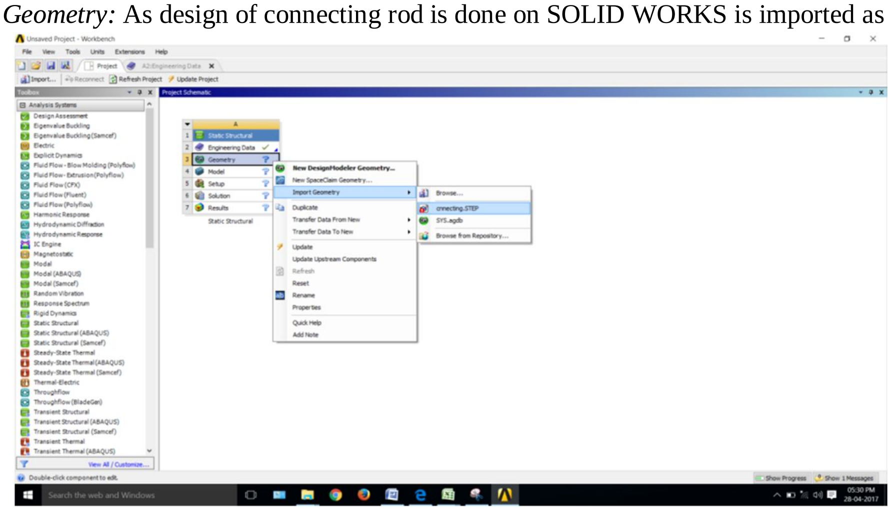


Fig-10 Importing external geometry

4) *Meshing* After importing the external geometry further function is meshing. Meshing is done for better accuracy in result. It is many types-

a) Triangular meshing

b) Rectangular meshing

c) Tetrahedron meshing ....etc.

Volume 5 Issue V, May 2017
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

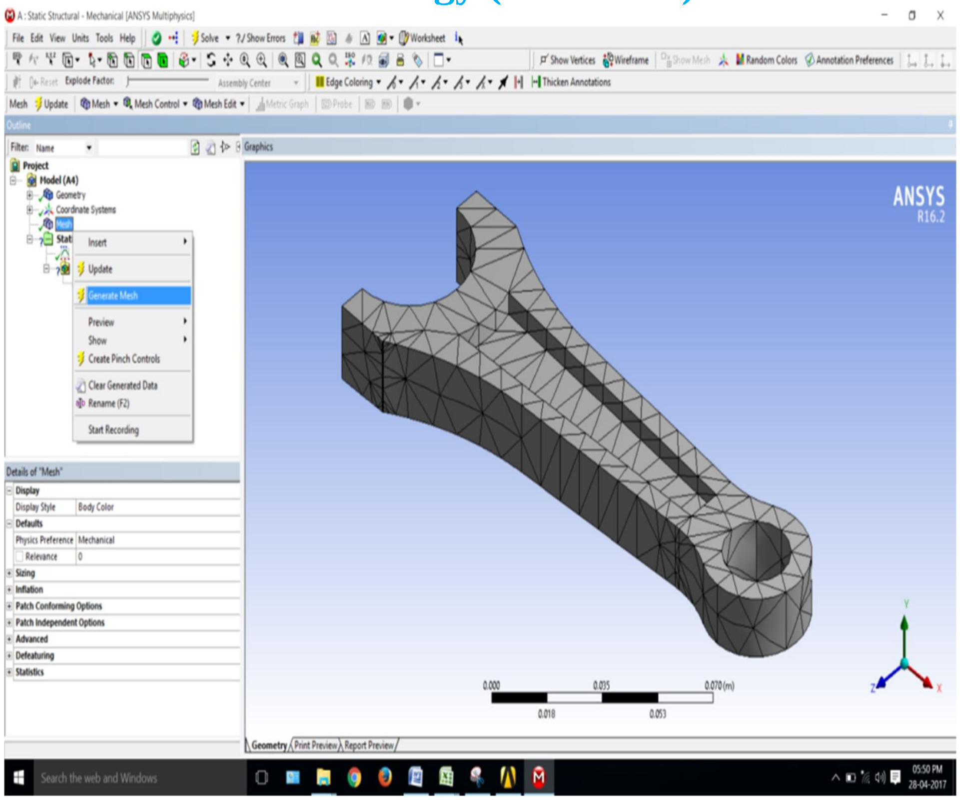


Fig-11 Generate meshing

5) *Working on Model*

a) After meshing we go to SET UP we click on CONNECTING and see like this-

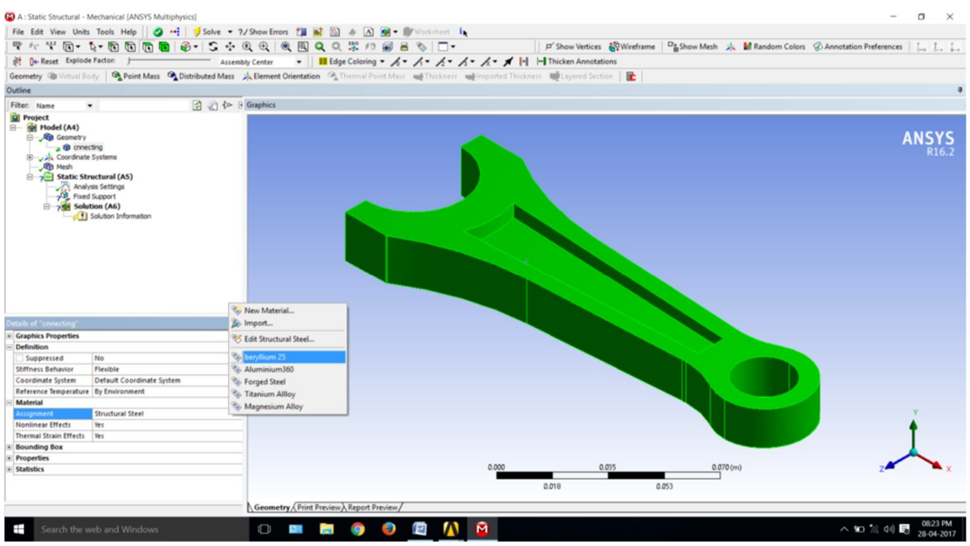


Fig-12 Giving new material to connecting rod

b) In Details of CONNECTING click on assignment we see there are importing materials.

c) Then we selecting one of them for further implementation.

6) *Static Structural Setting:* In static structure Analysis we have to fixed one part then right click on static structure then go to insert and further click on fixed support and apply on one part of the connecting rod.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

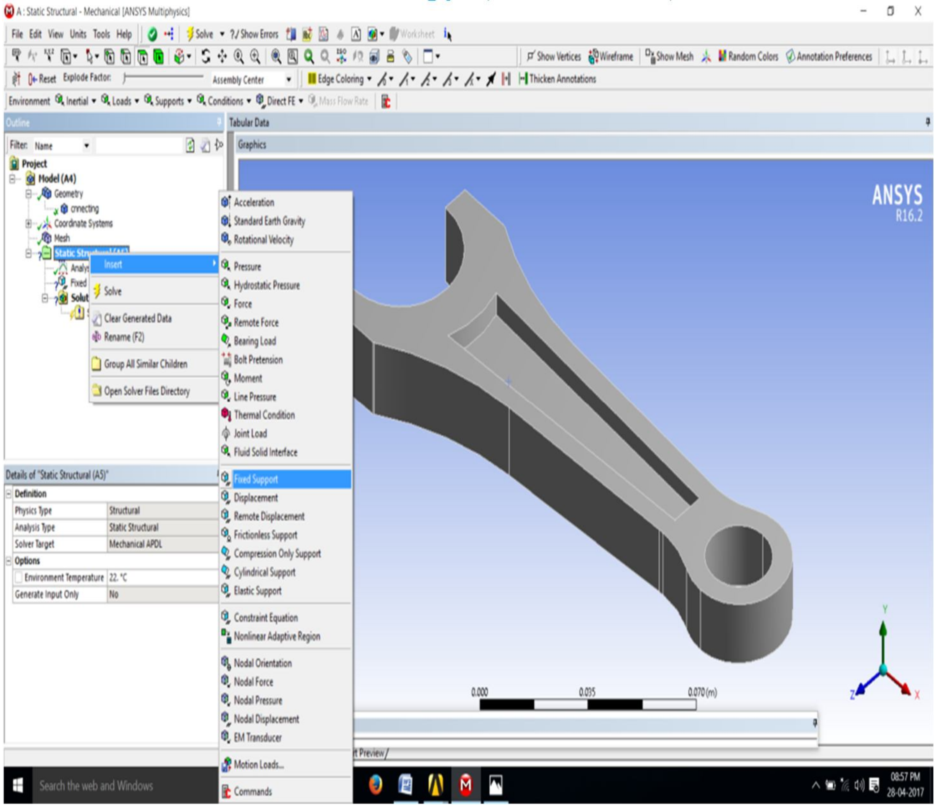


Fig-13 Giving fixed support

7) *Definition of Stress:* To define stress various theories have been already assigned in the ansys like Von-Mises, Maximum principal etc. In this project Von- Mises used as stress theory.

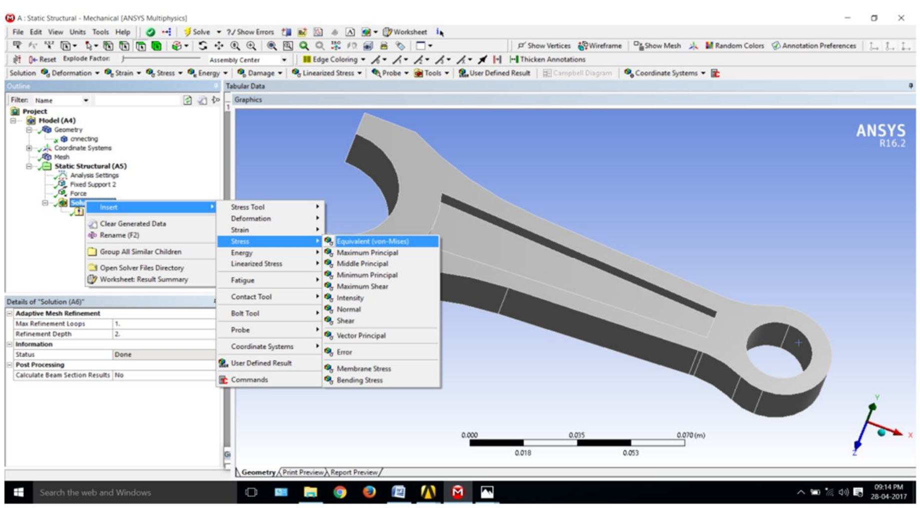


Fig-14 Applied stress in model

8) *Deformation:* Two type of deformation is given in ansys-

a) Total Deformation It is the volumetric deformation in geometry.

b) Directional Deformation: In directional deformation, deformation is in a particular direction i.e. in x, y and z-direction.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

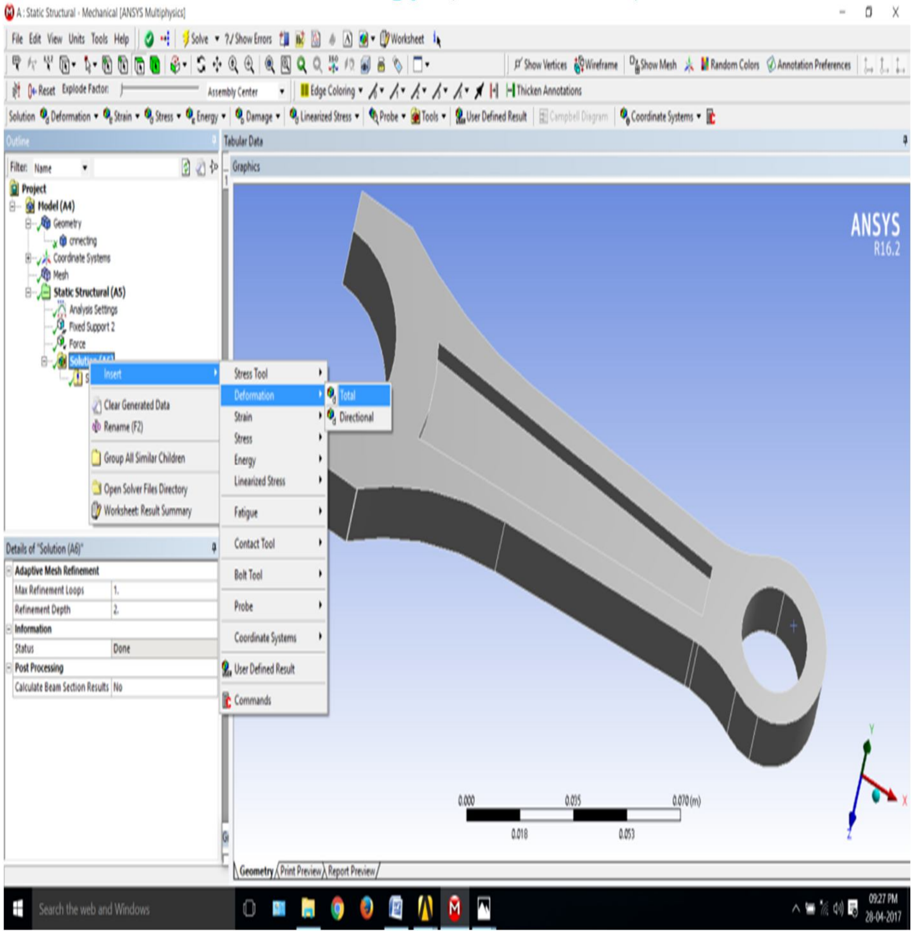


Fig-15 Total deformation in connecting rod

9) *Strain:* There are many type of strain in ansys as von-mises, maximum principle strain, maximum shear strain. In this project we discuss only von-mises strain.

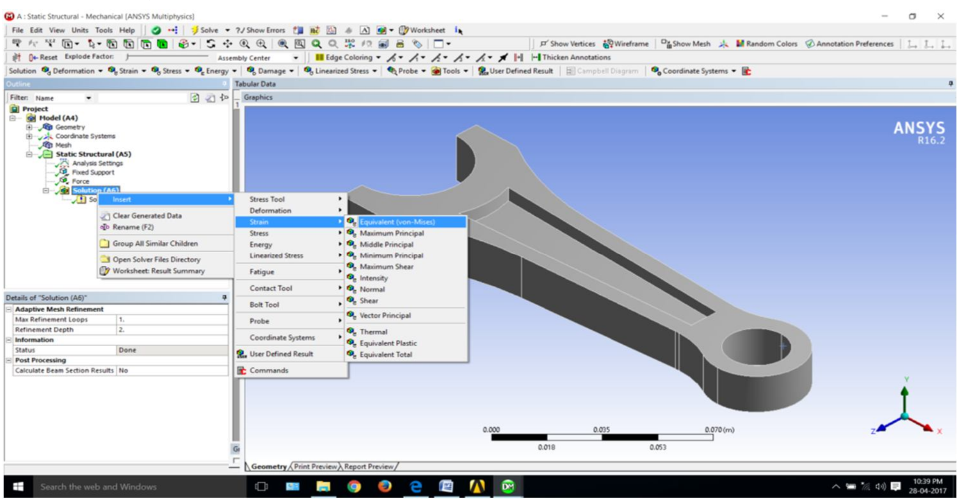


Fig-16 Strain in model

B. Comparison of Different Materials

1) Stress Comparison

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

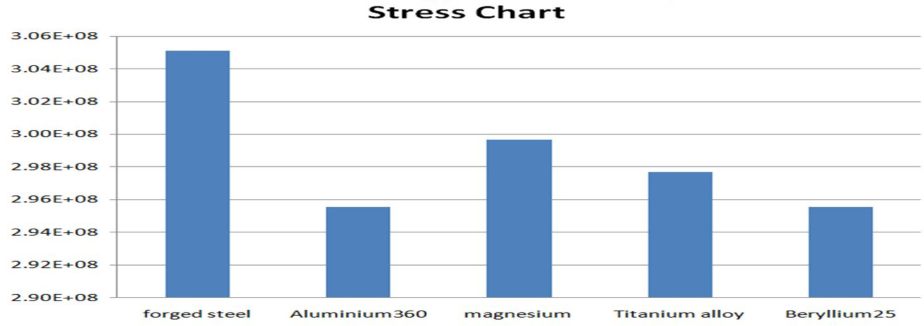


Fig-17 Stress comparison chart

2) Strain Comparison

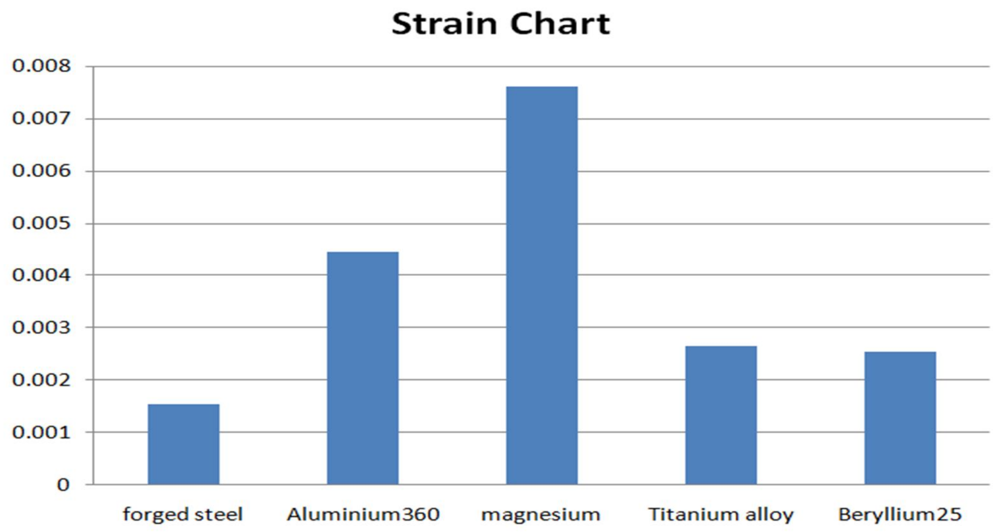


Fig-18 Strain comparison chart

3) Deformation Comparison

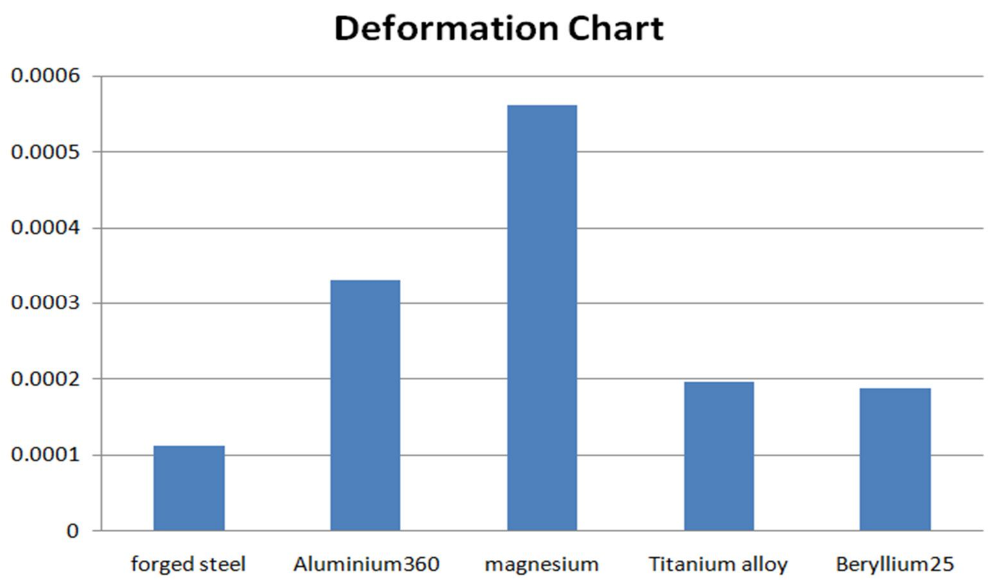


Fig-19 Deformation comparison chart

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

IV. RESULTS AND DISCUSSION

A. Analysis of Connecting Rod of Forged Steel

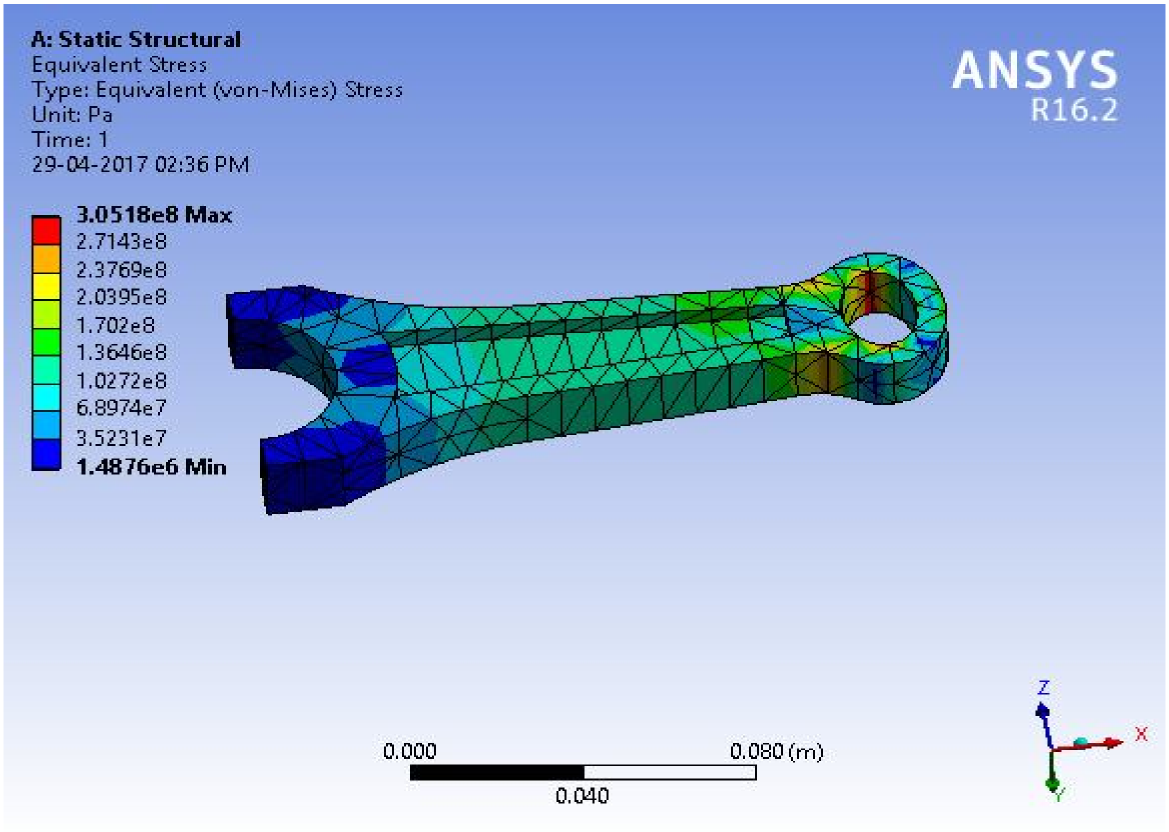


Fig-20 Equivalent Stress Analysis

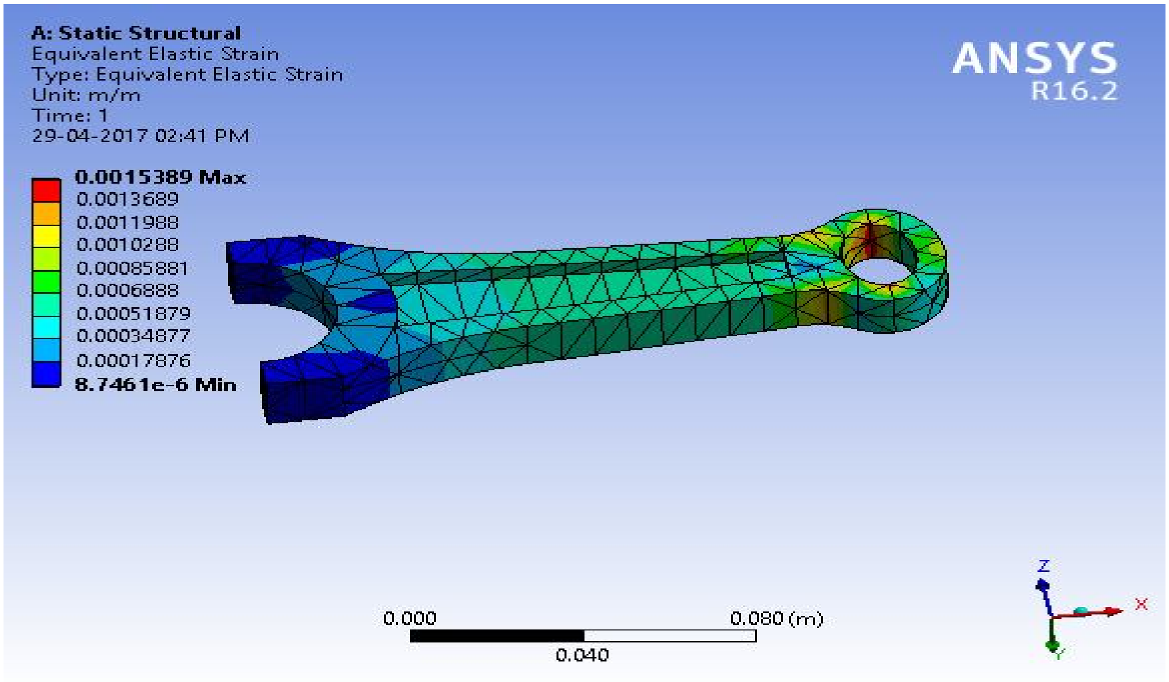


Fig-21 Equivalent Strain Analysis

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

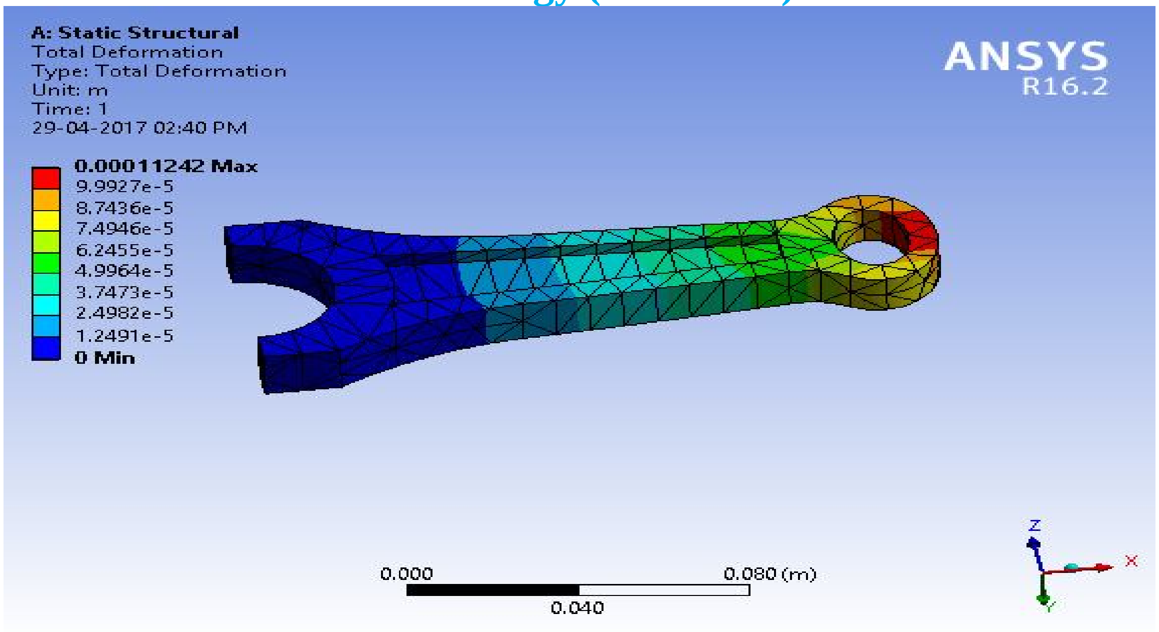


Fig-22 Equivalent Deformation Analysis

Table-4.1 Result and Analysis

	Minimum	Maximum
Stress	$1.4876x10^6$	$3.0518x10^8$
Strain	$8.7461x10^{-6}$	0 .0015389
Deformation	0.0	0.00011242

B. Analysis of Connecting Rod of Aluminium 360-

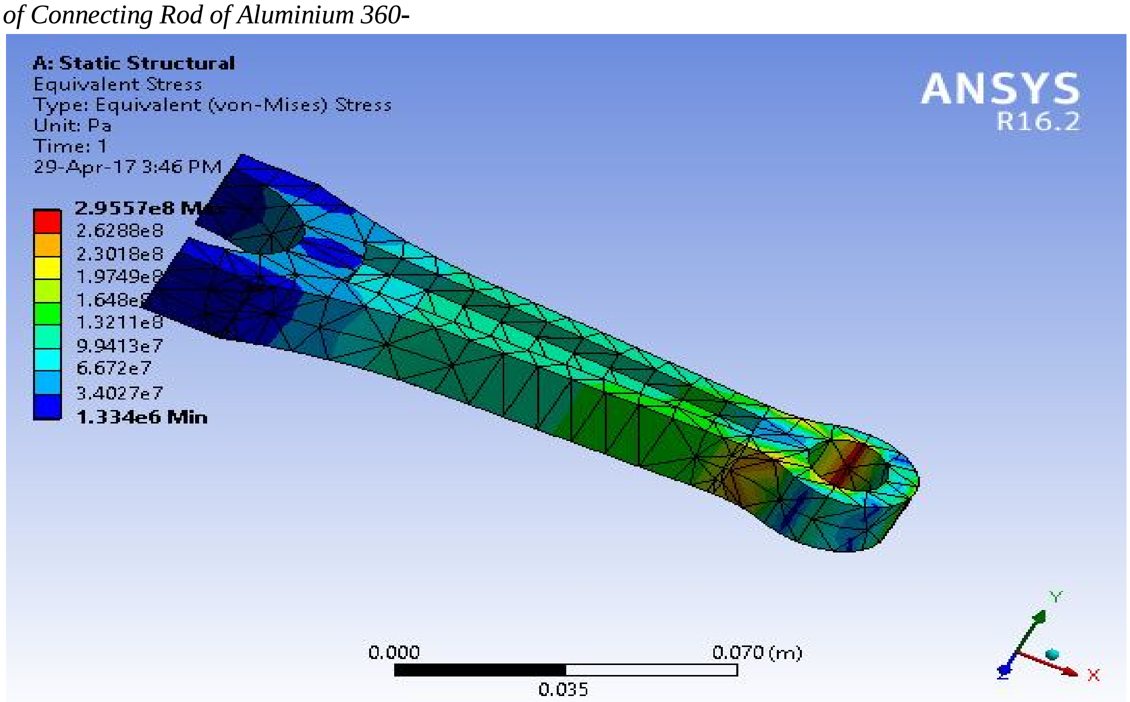


Fig-23 Equivalent Stress Analysis

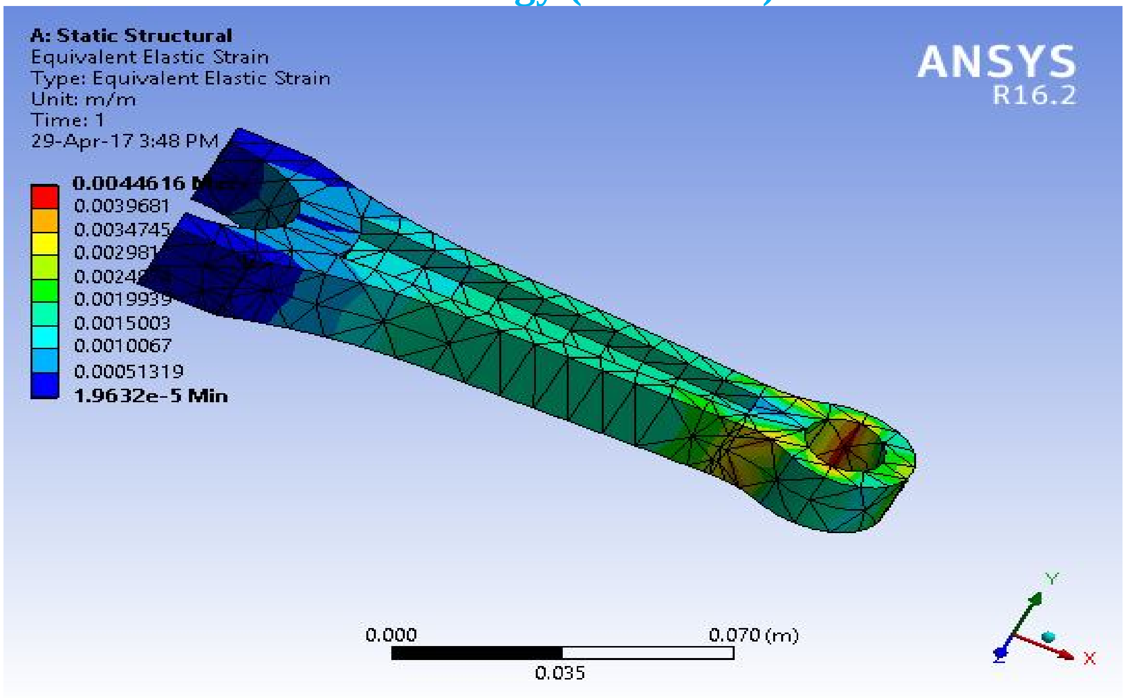


Fig-24 Equivalent Strain Analysis

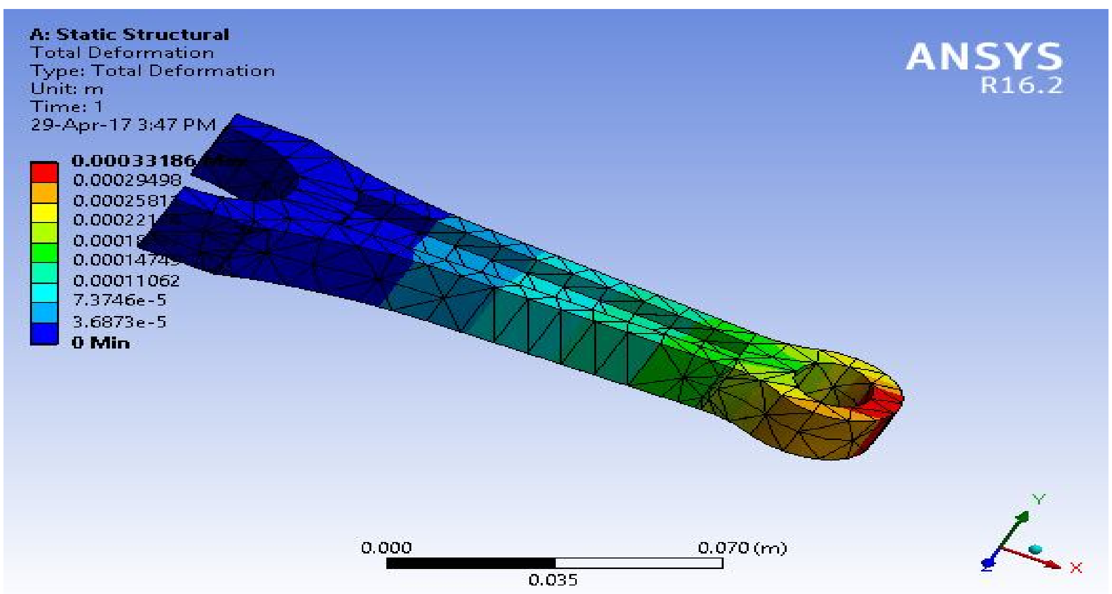


Fig-25 Equivalent Deformation Analysis

Table-4.2 Result and Analysis

	Minimum	Maximum
Stress	1.334×10^{6}	2.9557×10^{8}
Strain	1.9632×10^{-5}	0 .0044616
Deformation	0.0	0.00033186

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

C. Analysis of Connecting Rod of Magnesium Alloy

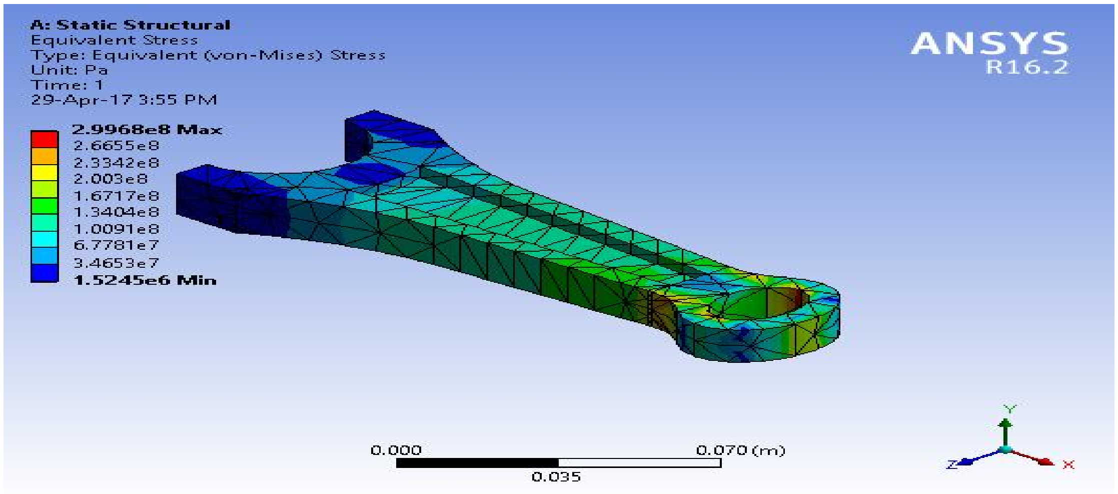


Fig-26 Equivalent Stress Analysis

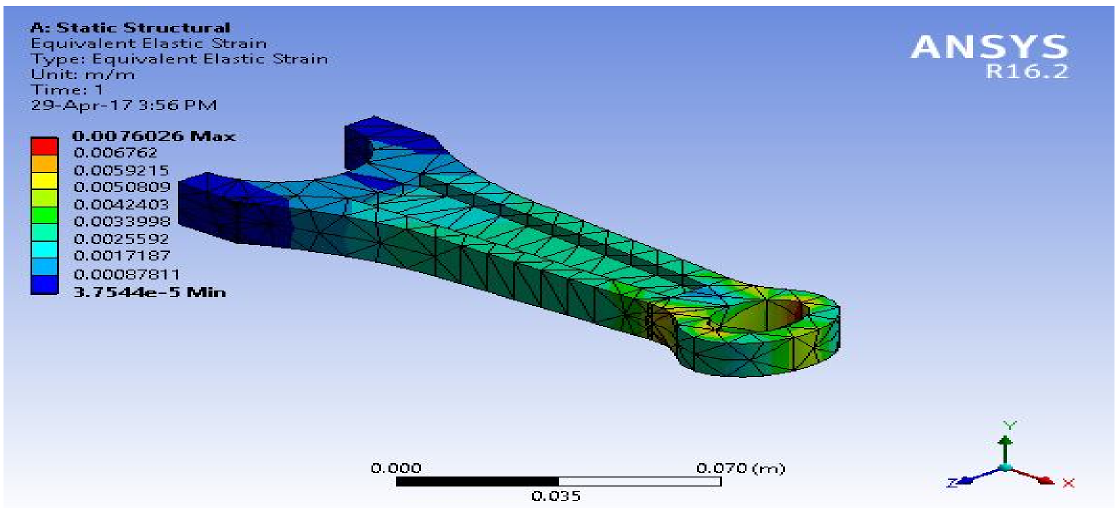


Fig-27 Equivalent Strain Analysis

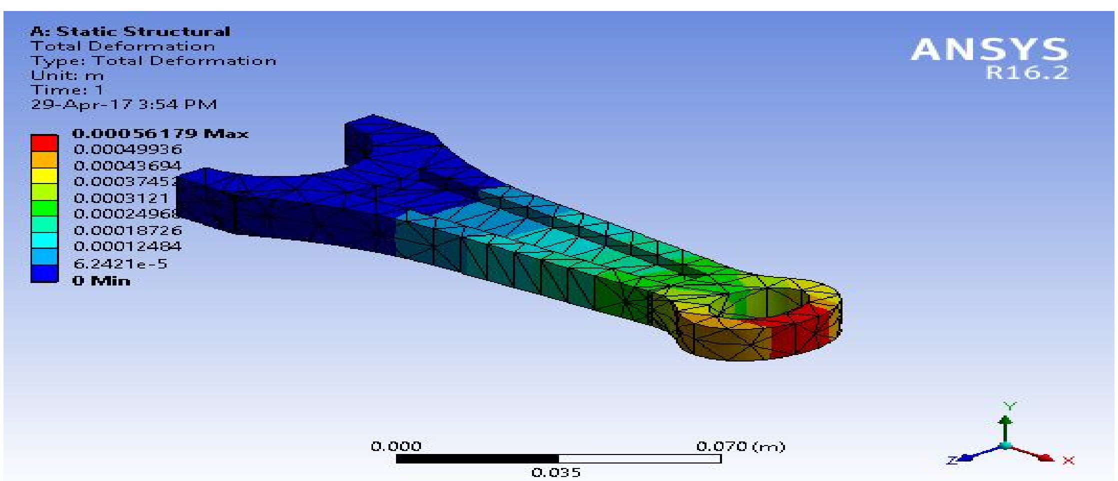


Fig-28 Equivalent Deformation Analysis

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Table-4.3 Result and Analysis

	Minimum	Maximum
Stress	$1.5246x10^{6}$	$2.9968x10^{8}$
Strain	$3.7544x10^{-5}$	0 .0076026
Deformation	0.0	0.00056179

D. Analysis of Connecting Rod of Beryllium 25-

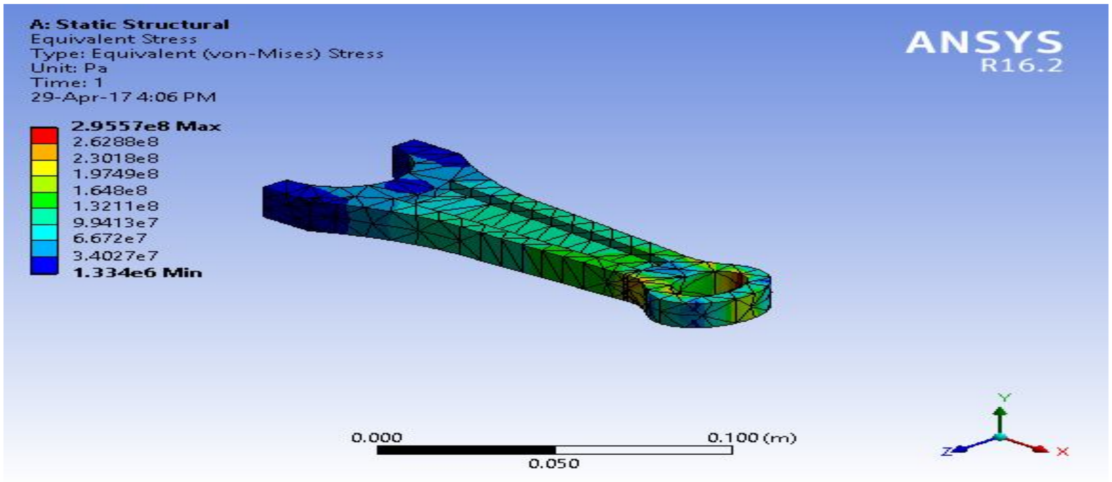


Fig-29 Equivalent Stress Analysis

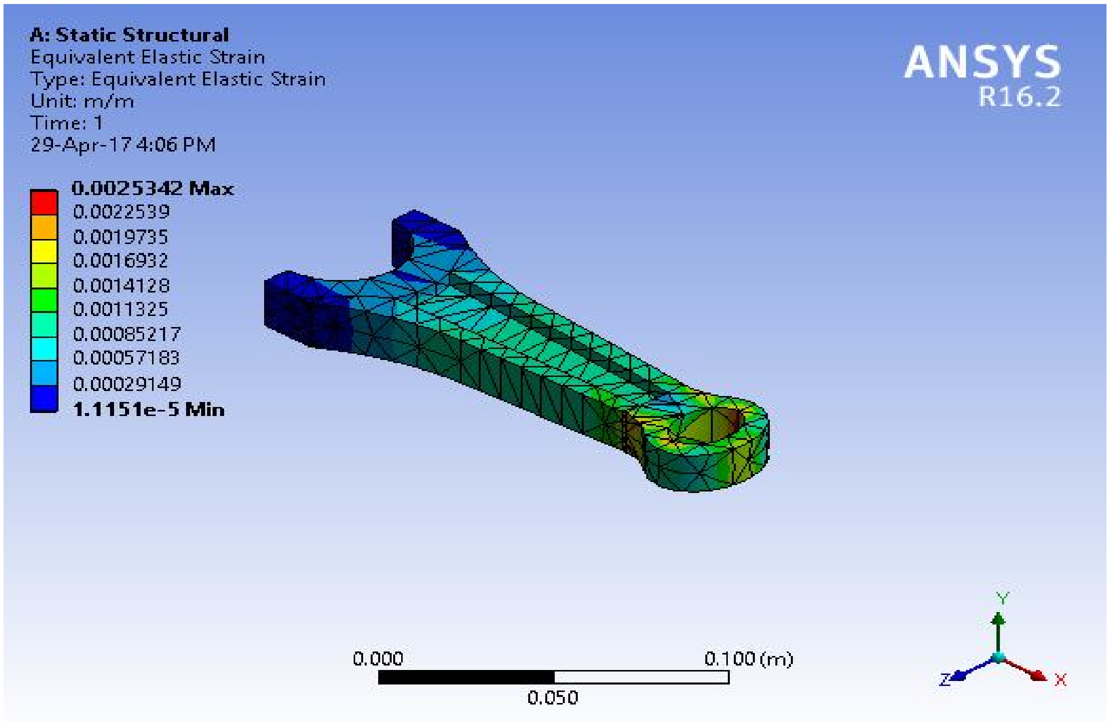


Fig-30 Equivalent Strain Analysis

Volume 5 Issue V, May 2017
ISSN: 2321-9653

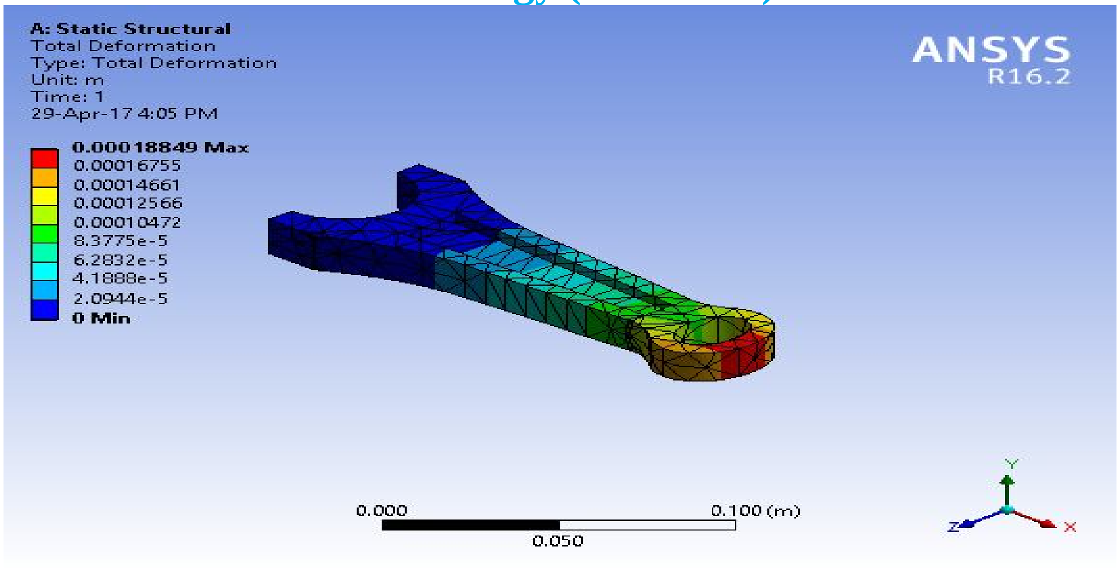


Fig-31 Equivalent Deformation Analysis

Table-4.4 Result and Analysis

	Minimum	Maximum
Stress	$1.334x10^{6}$	$2.95578x10^{8}$
Strain	$1.1151x10^{-5}$	0.0025342
Deformation	0.0	0.00018849

E. Analysis of Connecting Rod of Ti-13V-11Cr-3Al.

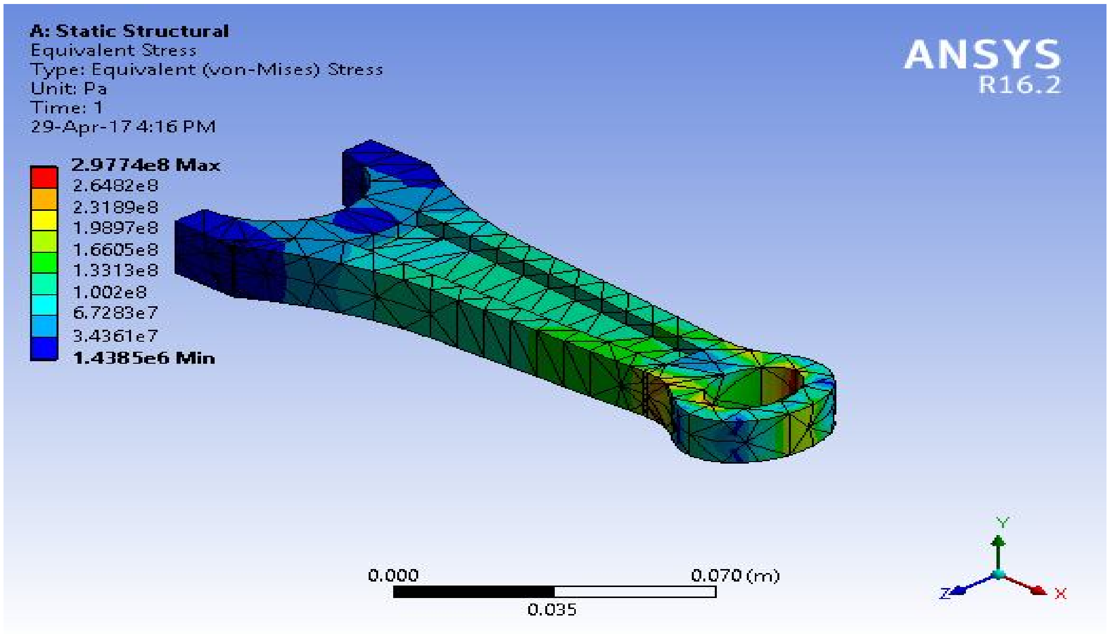


Fig-32 Equivalent Stress Analysis

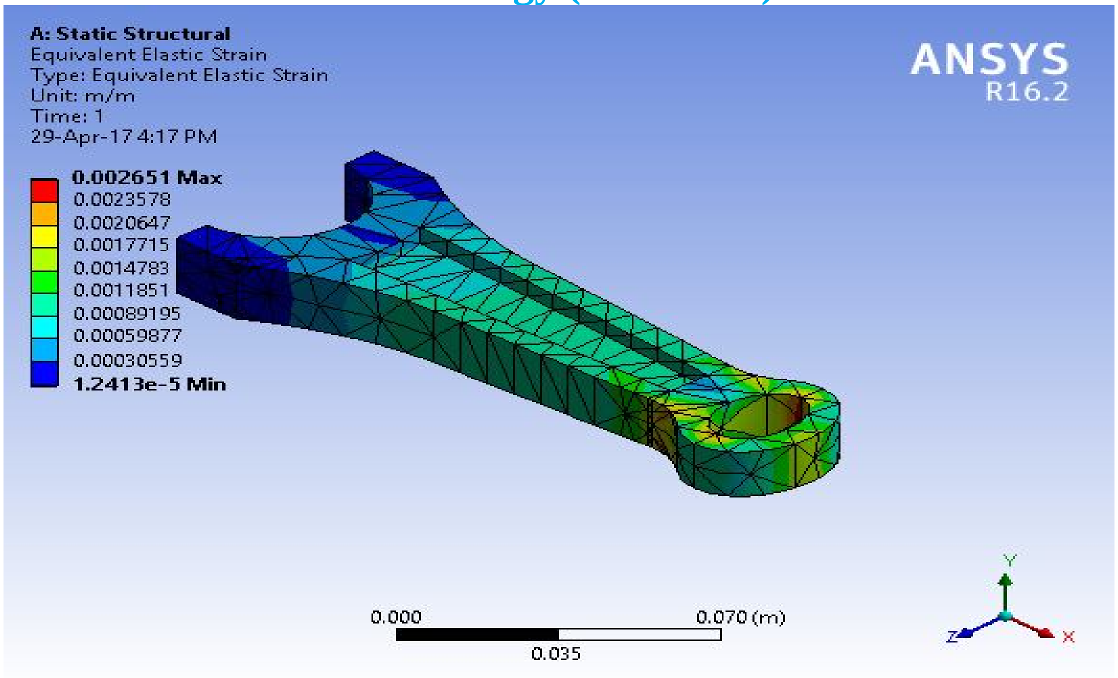


Fig-33 Equivalent Strain Analysis

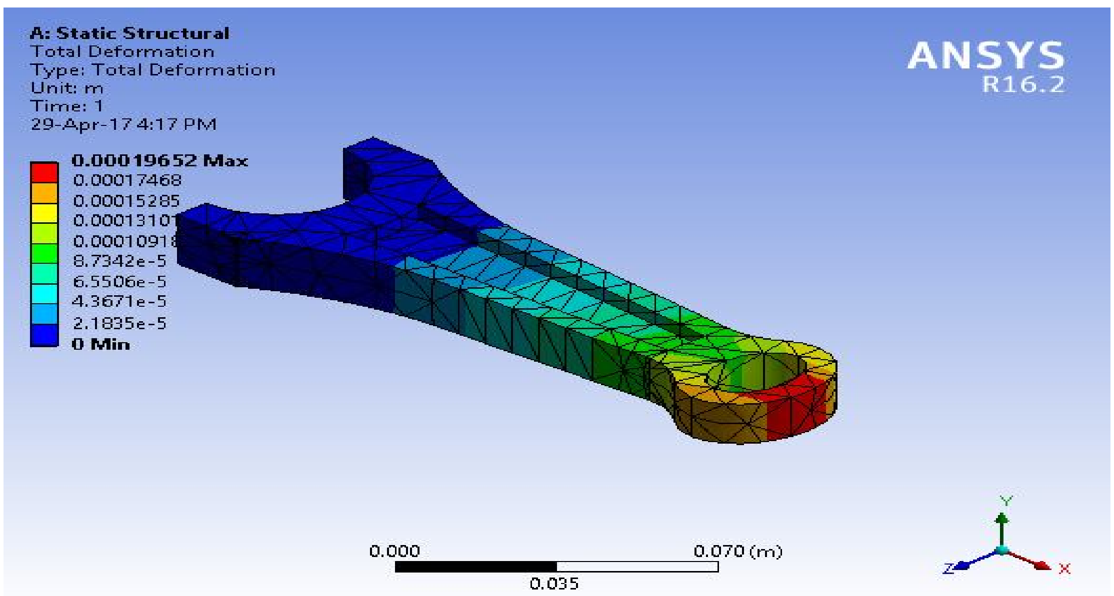


Fig-34 Equivalent Deformation Analysis

Table-4.5 Result and Analysis

	Minimum	Maximum
Stress	1.4385×10^{6}	2.9774×10^{8}
Strain	1.2413×10^{-5}	0.002651
Deformation	0.0	0.00019652

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

V. CONCLUSION

A. Solid modelling of connecting rod was made in fusion 360 according to production drawing specification and analysis under the effect of tensile and compressive loads in terms of pressure is done in ANSYS Workbench.
B. From analysis it is observed that the minimum stresses among all loading conditions, were found at crank end cap as well as at piston end. So the material can be reduced from those portions, thereby reducing material cost. For further optimization of material dynamic analysis of connecting rod is needed. After considering dynamic load conditions once again finite element analysis will have to be performed. It will give more accurate results than existing.
C. It is the conclusion of this study that the connecting rod can be designed and optimized under a load range comprising compressive load as one extreme load and tensile load. Furthermore, the existing connecting rod can be replaced by optimization with a new connecting rod made of lighter in weight (approx. 15%).
D. From the above analysis we can conclude that stresses of all the materials are almost comparable and also in safe limit, i.e., well below the yield stress.
E. The section modulus of the connecting rod should be high enough to prevent high bending stresses due to inertia forces.
F. Weight of connecting rod is reduced, Thereby reduces the inertia force by comparing the results of three different materials used for connecting rod analysis it is found that equivalent von mises stress for all the materials is approximately same.
G. From the static analysis the stress is found maximum at the small end of the connecting rod.
H. Carbon steel as a connecting rod material is less stiff and having more weight than forged steel and other material taking in consideration.
I. Forged steel connecting rod is having more weight than Aluminium, magnesium and beryllium alloys connecting rod.
J. Aluminium alloy connecting rod is having more weight and displacement than magnesium and beryllium alloys. So, aluminium connecting rod show more shaky behaviour.
K. Maximum von mises stress, Maximum von mises strain and Maximum displacement are minimum in connecting rod of Beryllium alloy.
L. Comparing the different data it is observed that stress, strain and displacement is minimum in beryllium alloy connecting rod. So, beryllium alloy can be used for production of connecting rod for longer life.

VI. FUTURE SCOPE

A. Vibrational analysis can be done at ansys for minimizing the premature failure.
B. Dynamic analysis of connecting rod can also be performed on ansys to get the better analysis.
C. Thermal analysis can be done of connecting rod to minimize the thermal stress effect on connecting rod.
D. Torsional analysis can be done due to presence of small amount of torsional moment at the end points.
E. Design modification can be done to minimize the weight of connecting rod and the inertia force.
F. Work on the internal coating of hard material inside the both ends can be done to minimize the wear failure in connecting rod.

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