Design and Optimization of Connecting Rod for Different Material Using Ansys Workbench 16.0

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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 Aluminum alloys are used for manufactured the connecting rods. In this work existing connecting rod material are replaced by Mild Steel and Magnesium Alloy. FEA analysis was carried out by considering five materialsAluminum 360, Forged Steel, Titanium Alloy, Mild Steel, and Magnesium Alloy. In this study a solid 3d model of connecting rod was developed using NX 10.0 software and analysis was carried out by ansys16.0 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 16.0.

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 connecting rod

II - LITERATURE REVIEW

1. Park et al. (2003) investigated microstructural behavior at various forging conditions and recommend fast cooling for finer grain size and lower network ferrite content. From their research they concluded that laser notching exhibited best fracture splitting results, when compared with broached and wire cut notches. They optimized the fracture splitting parameters such as, applied hydraulic pressure, jig set up and geometry of cracking cylinder based on delay time, difference in cracking forces and roundness. They compared fracture splitting high carbon micro-alloyed steel (0.7% C) with carbon steel (0.48% C) using rotary bending fatigue test and concluded that the former has the same or better fatigue strength than the later. From a comparison of the fracture splitting high carbon micro-alloyed steel and powder metal, based on tension-compression fatigue test they noticed that fatigue strength of the former is 18% higher than the later.

2. Sarihan and Song (1990), for the optimization of the wrist pin end, used a fatigue load cycle consisting of compressive gas load correspond ing 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. For optimization, they generated an approximate design surface, and performed optimization of this design surface. The objective and constraint functions were updated to obtain precise values. This process was repeated till convergence was achieved. They also included constraints to avoid fretting fatigue. The mean and the alternating components of the stress were calculated using maximum and minimum values of octahedral shear stress.

3.Yoo et al. (1984) used variational equations of elasticity, material derivative idea of continuum mechanics and an adjoint 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. 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.

III - RESEARCH DESIGN OF CONNECTING ROD

3.1. Introduction

NX 10.0 Software mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows TM graphical user interface. We can create fully associate 3-D solid models with or without while utilizingautomatic or user defined relations to capture design intent. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent

A Solid Works model consists of parts, assemblies, and drawings.

- Typically, we begin with a sketch, create a base feature, and then add more features to the model. (One can also begin with an imported surface or solid geometry).
- We are free to refine our design by adding, changing, or reordering features

3.2 Design procedure of Connecting Rod

For designing the Connecting Rod the following procedure has to be follow

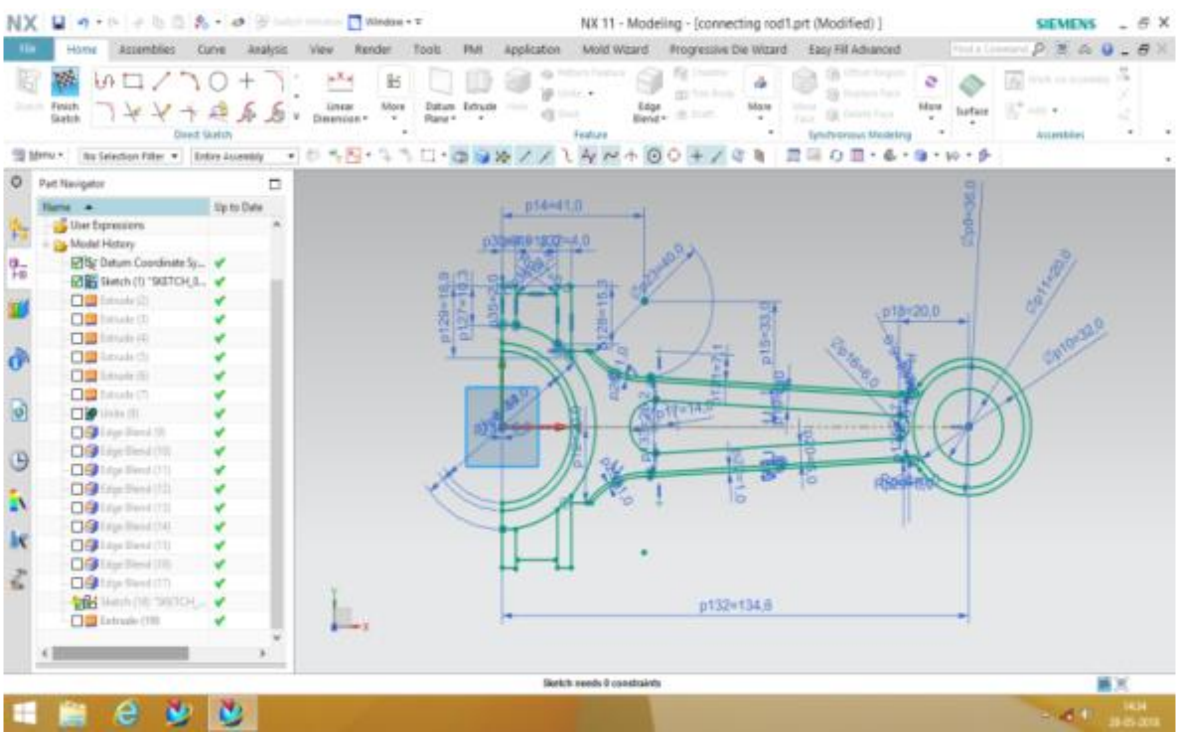

Fig :2 2d sketch of a connecting rod

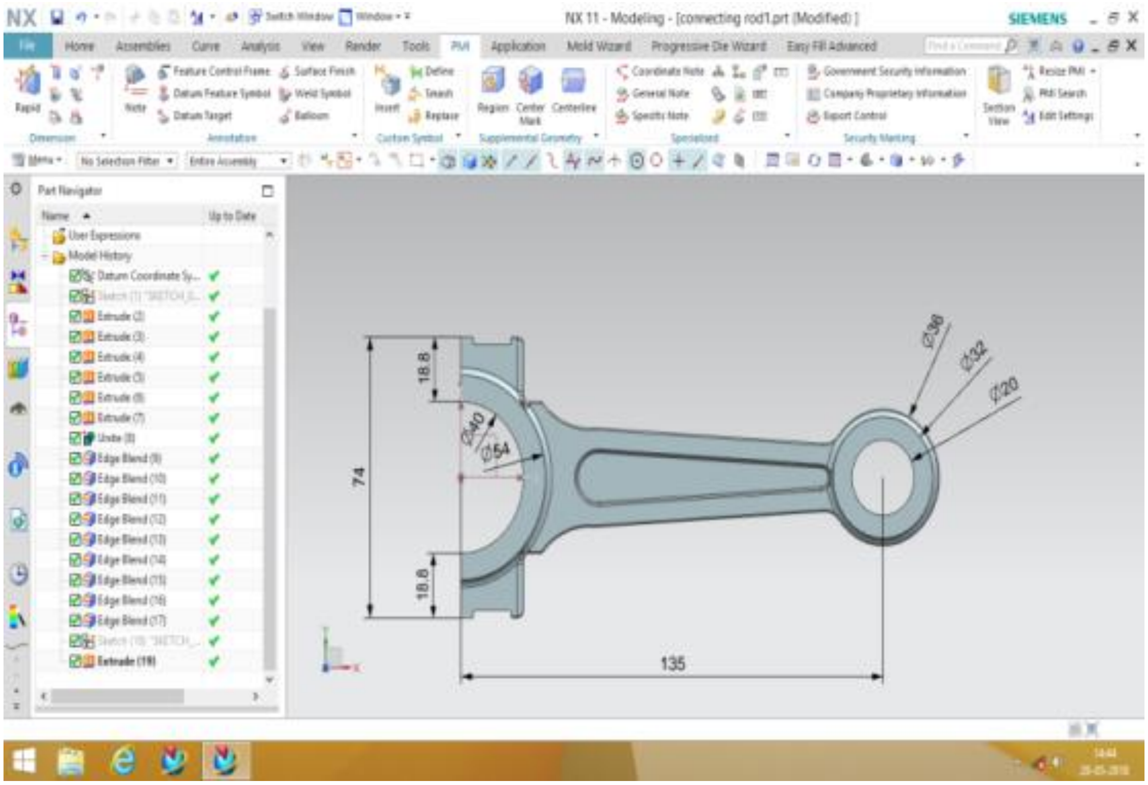

Fig : 3 Sketch & extrude

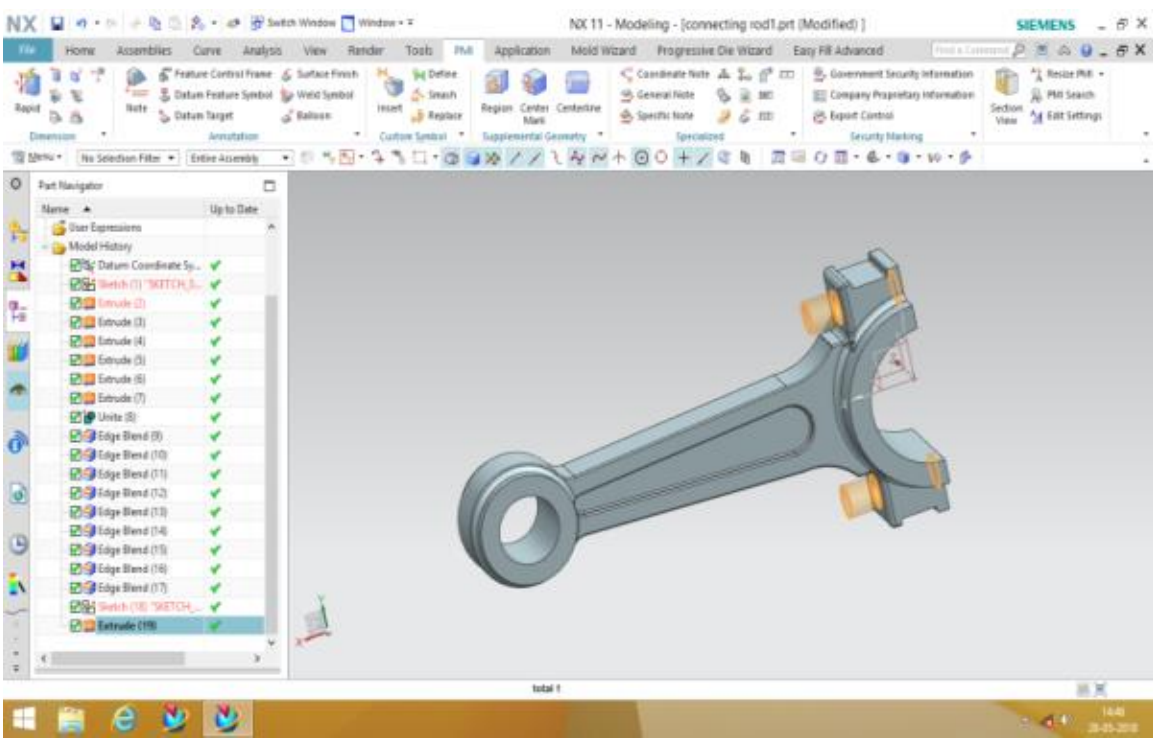

Fig : 4 Make Holes

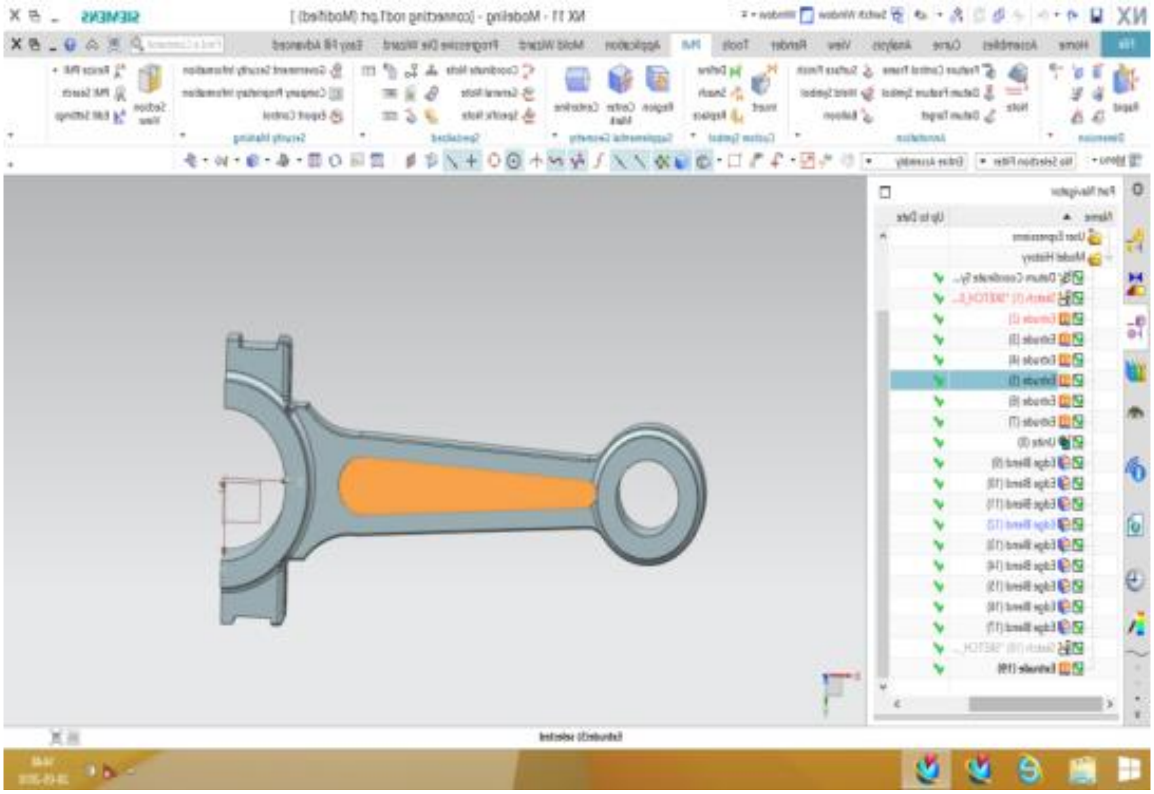

Fig : 5 I-Section of connecting rod

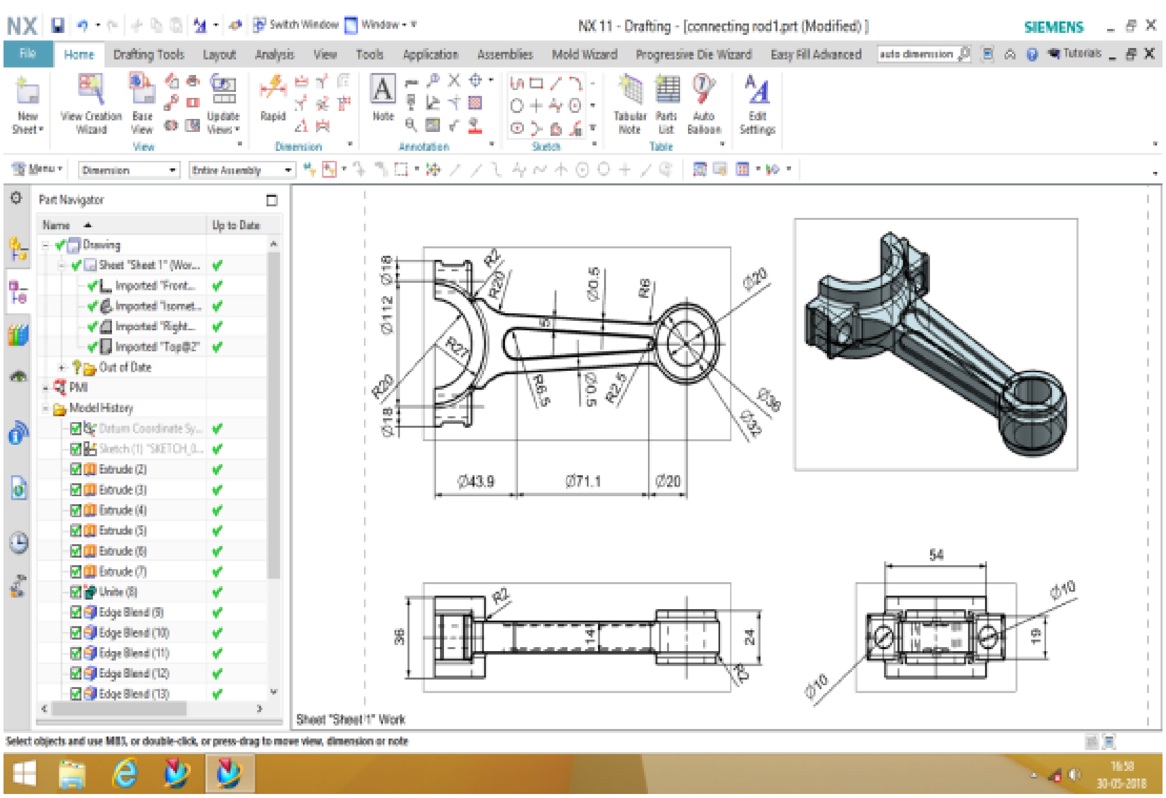

Fig 6 Drafting part of top view, front view, bottom view

CALCULATION OF CONNECTING ROD

P- Pressure calculation for connecting rod

Engine type 4-strok air cooled

$Bore \times stroke = 68.5 \times 72.0$

$Displacement = 796\text{cc}$

$maximum\ power(bhp@rpm) = 48\ bhp\ @\ 6000\ rpm$

$maximum\ torque\ (Nm@rpm) = 69\ Nm\ @\ 3500\ rpm$

$Compression\ Ratio = 10.3 \pm 0.4$

$Density\ of\ Petrol\ (C_8H_{18}) = 737.22\ kg/M^3 = 737.22\ E-9\ Kg/MM^3$

$Auto\ ignition\ temp. = 280°C\ (536°F) = 553°k$

$Mass = Desity\ of\ petrol \times Volume$

$Mass = 737.22 \times 796 = 586{,}827.12\ kg/m^3$

$$Molecular\ Weight\ of\ Petrol = 114.228\ g/mole = 0.11423\ kg/mole$$

IV - ANALYSIS AND HYPOTHESIS TESTING

4.1 Introduction

The connecting rods are most usually made of steel for production engines, but can be made of aluminum (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

4.2 Material Properties

A. Problem Formulation

The objective of the present study is to design and analysis of four-wheeler connecting rod and to find the best alternative material of connecting rod.

B. Properties of Material

Table 4.1

Aluminium 360 Composition	
Aluminum	Bal.
Copper	.6
Magnesium	0.4-0.6
Iron	13
Lead	---
Tin	0.15
Nickle	0.50
Zinc	0.50
Manganese	0.35
Silicon	9.0 -10.0

Table 4.2

Physical properties						
Material	Alloy	Density	Melting point (c)	Thermal conductivity (w/mK)	Coefficient of thermal expression (µm / mK)	Electrical Conductivity
Aluminum	Al 360	2.63	577	113	21	29

Table 4.3

Mechanical Properties						
Material	Alloy	Tensile strength	Yield strength	Shear strength	Hardness	Elongation
		MPa	MPa	MPa	Brinell(HB)	
Aluminum	Al 360	317	170	180	75	35

Table 4.4

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

Table 4.5

Physical Properties	
Properties	Metric
Density	4.84 g / cm^3
Thermal expansion	9.4×10^{-6} / c

Table 4.6

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

Table 4.7

Forged Steel	
Chemical Properties	
Carbon	0.612 – 0.68 %
Sulphur	0.02 – 0.04 %
Manganese	0.50 – 1.20 %
Phosphorus	0.04 %
Chromium	0.90 – 1.20 %

Table 4.8

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
Poisson Ratio	0.21

Table 4.9

Magnesium Alloy	
Composition	
Aluminium	0.3 - 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 4.10

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 4.11

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

Table 4.12

Mild Steel				
Chemical composition (%)				
Fe	Mn	S	P	C
98.81 - 99.26	0.6 – 0.9	0.05	0.04	0.14 – 0.2

Table 4.13

Physical properties					
Yield strength (MPa)	Tensile strength (MPa)	Thermal conductivity (w / mK)	Melting point (℃)	Hardness (HB)	Specific heat capacity (J/g ℃)
275	475	51.9	1523	143	0.472

Table 4.14

Mechanical properties				
Normal strain rate	Upper yield stress	0.2% proof stress	Ultimate stress	Ultimate strain
1 / sec	$\sigma_y\ (uys)$ (MPa)	σ_y (0.2%) (MPa)	σ_u (MPa)	ε_u
$3.3e^{-4}$	366.6	345.7	503.6	19.6
1	437.5	390.8	546.3	16.1
10	500.1	512.8	580.6	2.2

V- COMPARISON OF MATERIAL

1) **Density of comparison:** The connecting rod has tremendous field of research. In addition to this, automobile construction led theinvention 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. In this study materials compared are Forged Steel, Beryllium 25, Aluminium 360, Titanium alloy, high speed steel, mild steel.

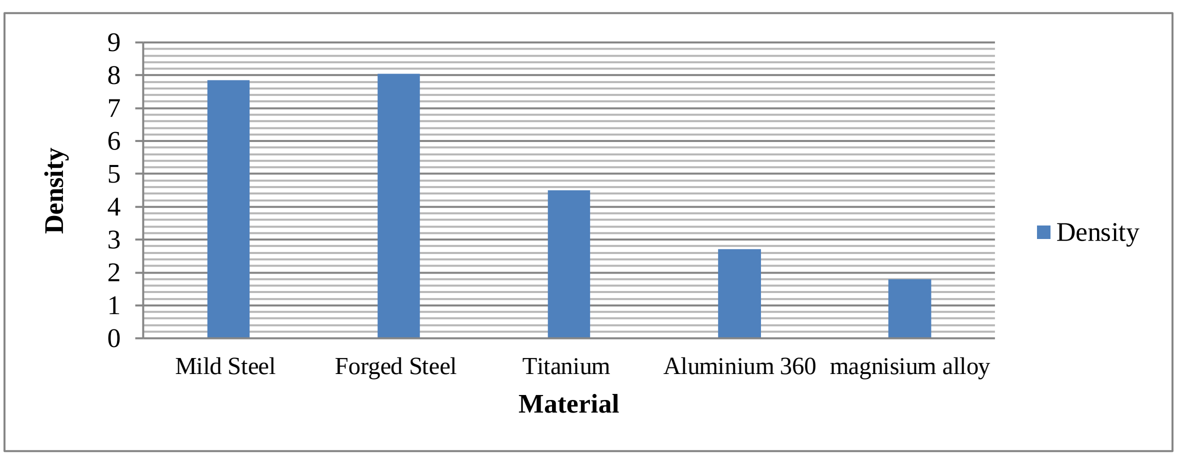

Fig-4 Density comparison chart

2. Weight Comparison: Compared five materials used for manufacturing of connecting rod these are AL360, Magnesium Alloy, Forged Steel, Titanium Alloy, Mild Steel. The modeling and analysis of connecting rod was done. FEM analysis was carried out by considering three materials AL360, Magnesium Alloy, Forged Steel, Titanium Alloy, Mild Steel. In study he found out that out of above three Magnesium Alloy, Forged Steel, Titanium Alloy, Mild Steel is the best suitable material for connecting rod of four-wheeler. Compering the different result obtained from the analysis, it is concluded that the stress included in the beryllium alloy is less than the aluminum and magnesium alloy.

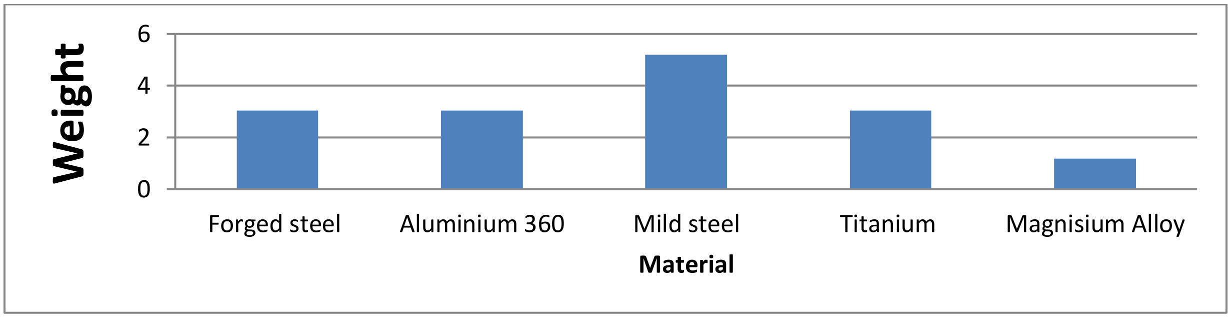

Fig-5 Weight comparison chart

B.**Comparison of Different Materials**

1) Strain comparison

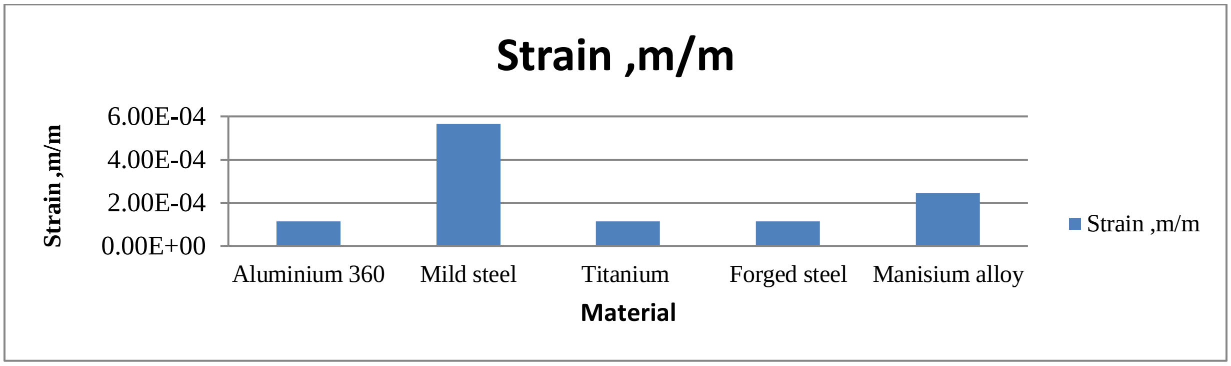

Fig-18 Strain comparison chart

2. Stress comparison

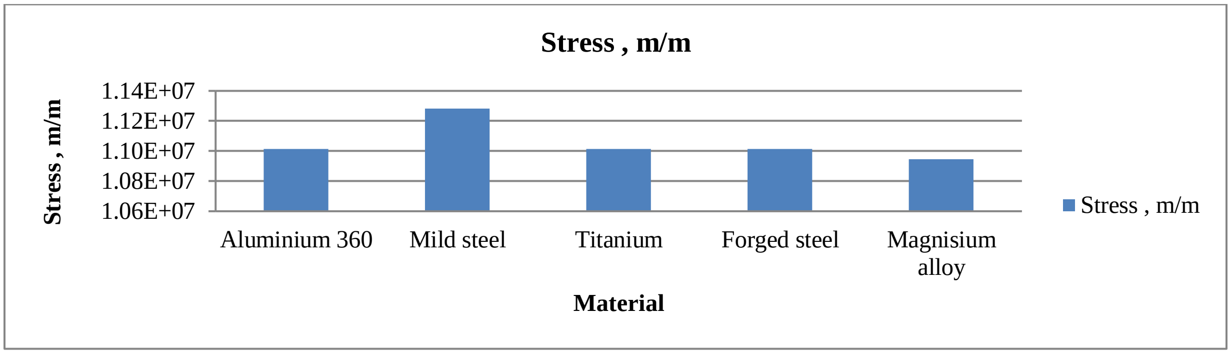

Fig-17 Stress comparison chart

3. Deformation comparison

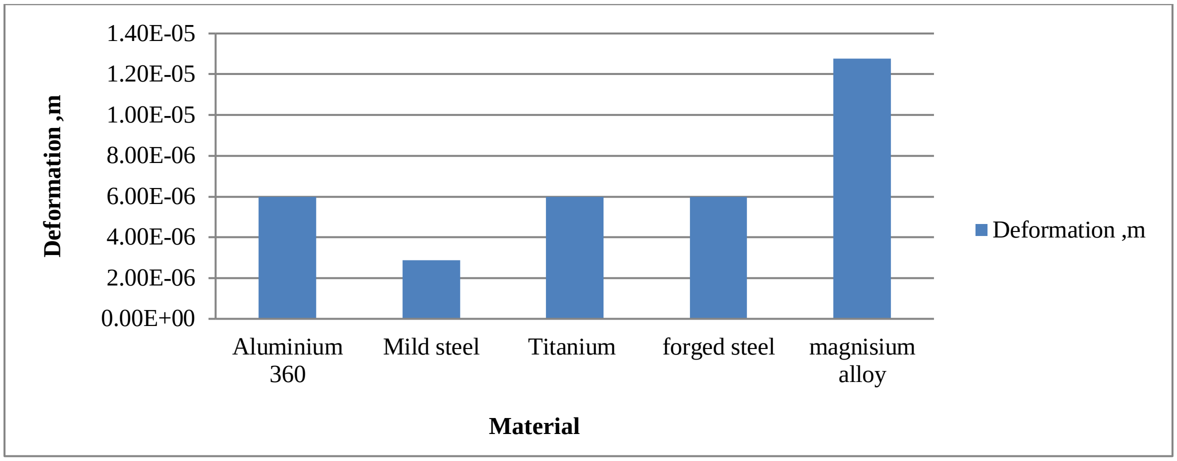

Fig-19 Deformation comparison chart

VI - RESULT AND DISCUSSION

A. Analysis of Connecting Rod of Forged Steel

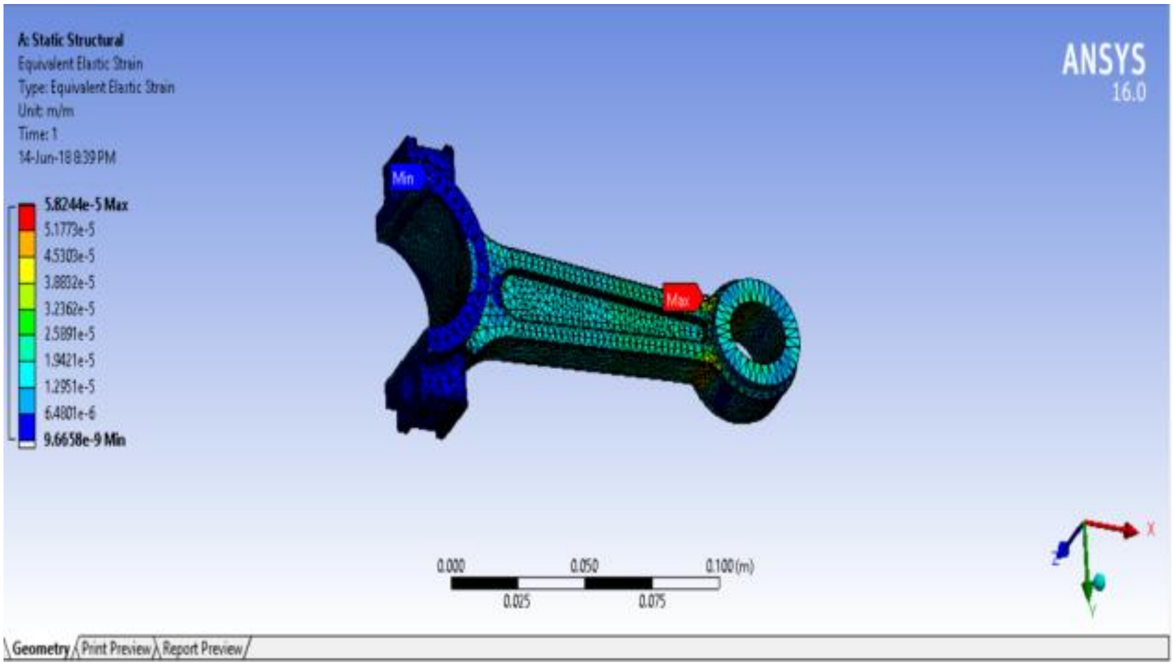

Fig-24 Equivalent Strain Analysis

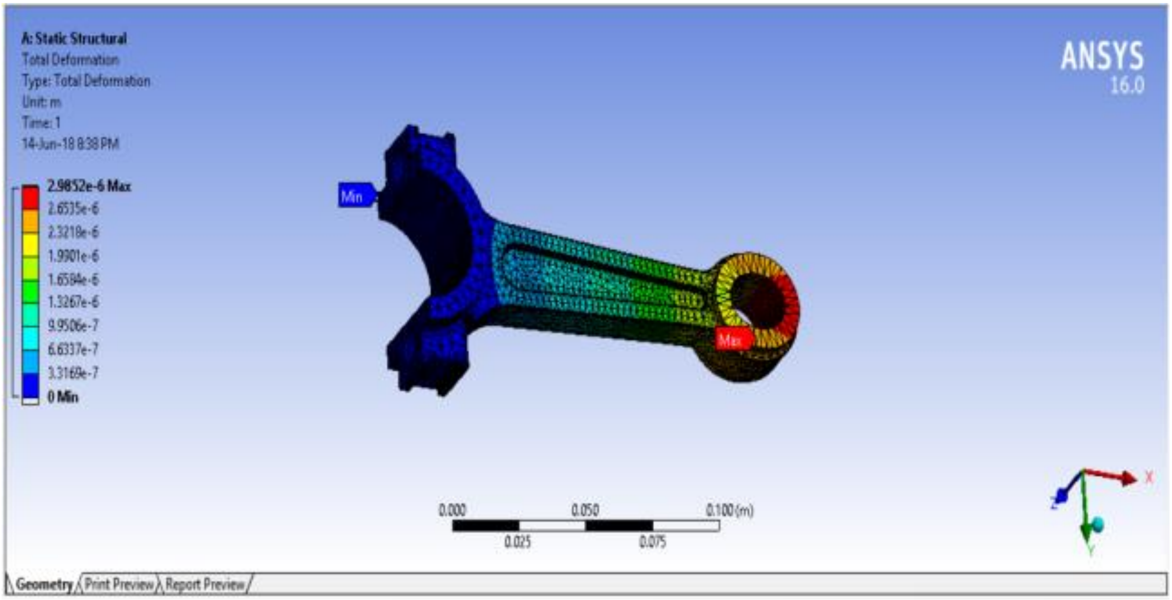

Fig-25 Equivalent Deformation Analysis

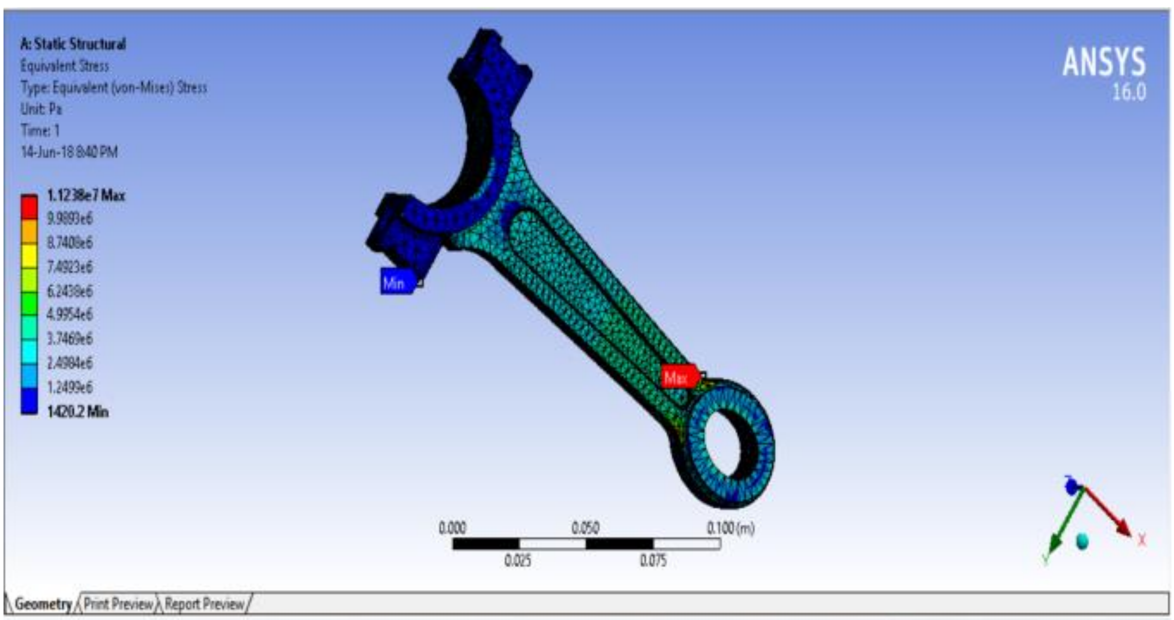

Fig-23 Equivalent Stress Analysis

Table-4.2 Result and Analysis Forged Steel

	Minimum	Maximum
Stress	1.224.4 Pa	1.1015e-007Pa
Strain	1.8385e-008m/m	1.1477e-004m/m
Deformation	0.m	0.m

B. Analysis of Connecting Rod of Magnesium Alloy

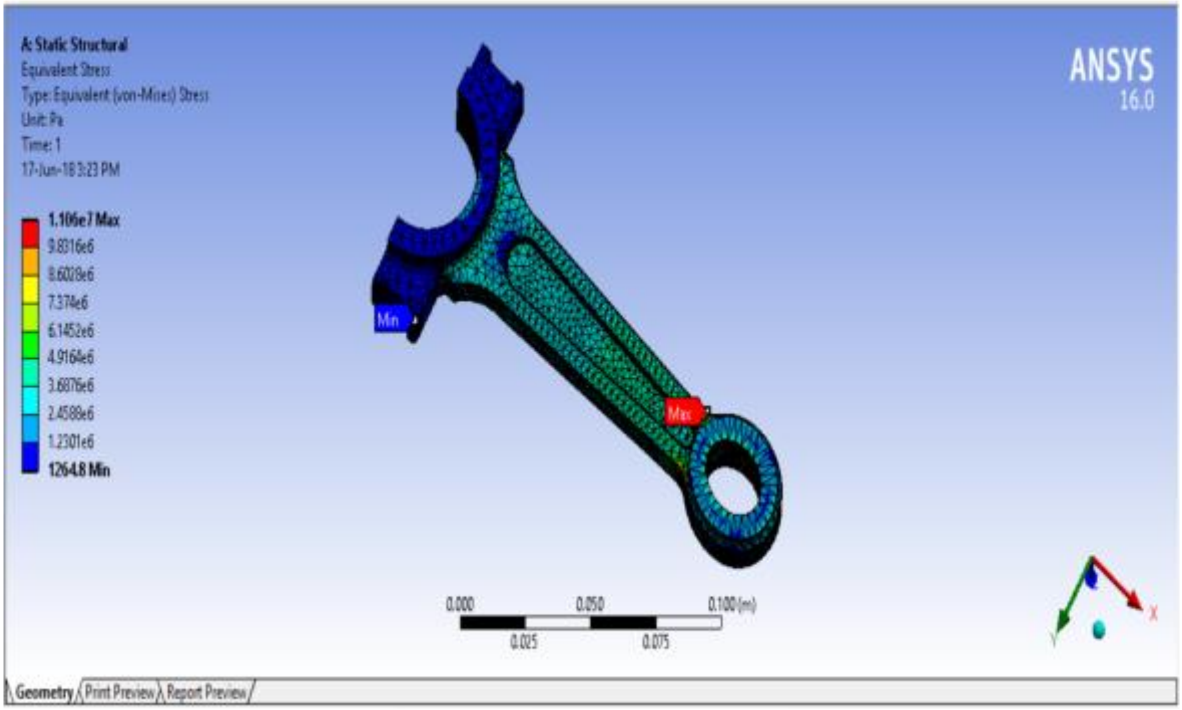

Fig-23 Equivalent Stress Analysis

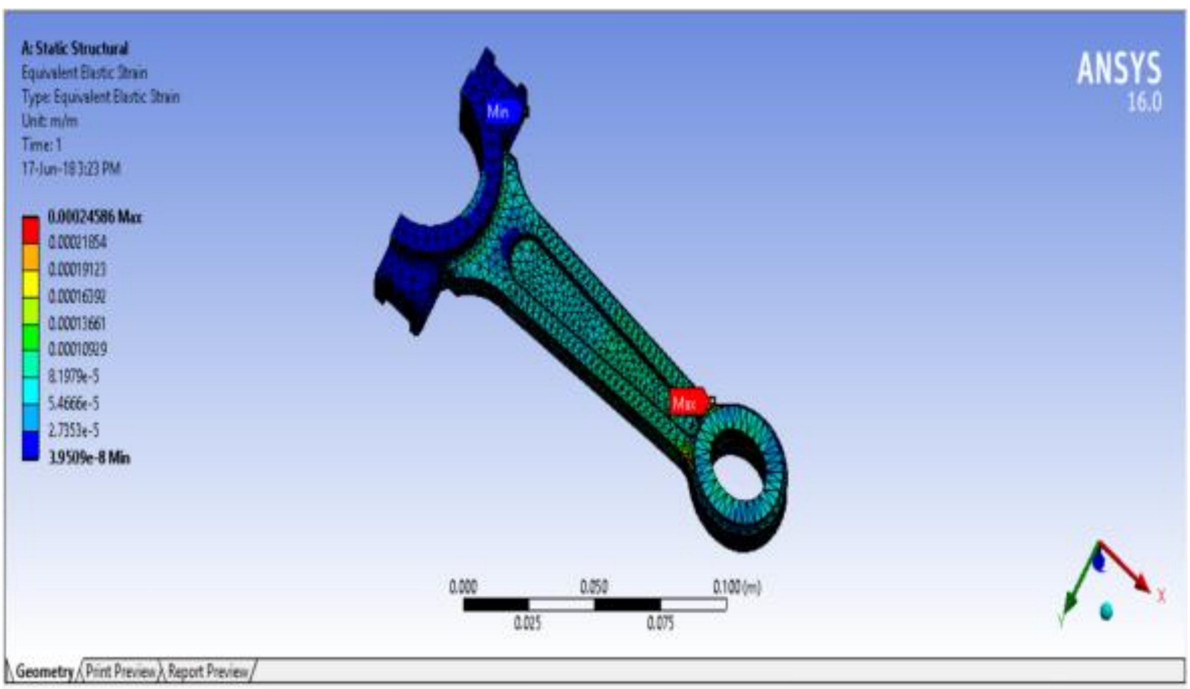

Fig-24 Equivalent Strain Analysis

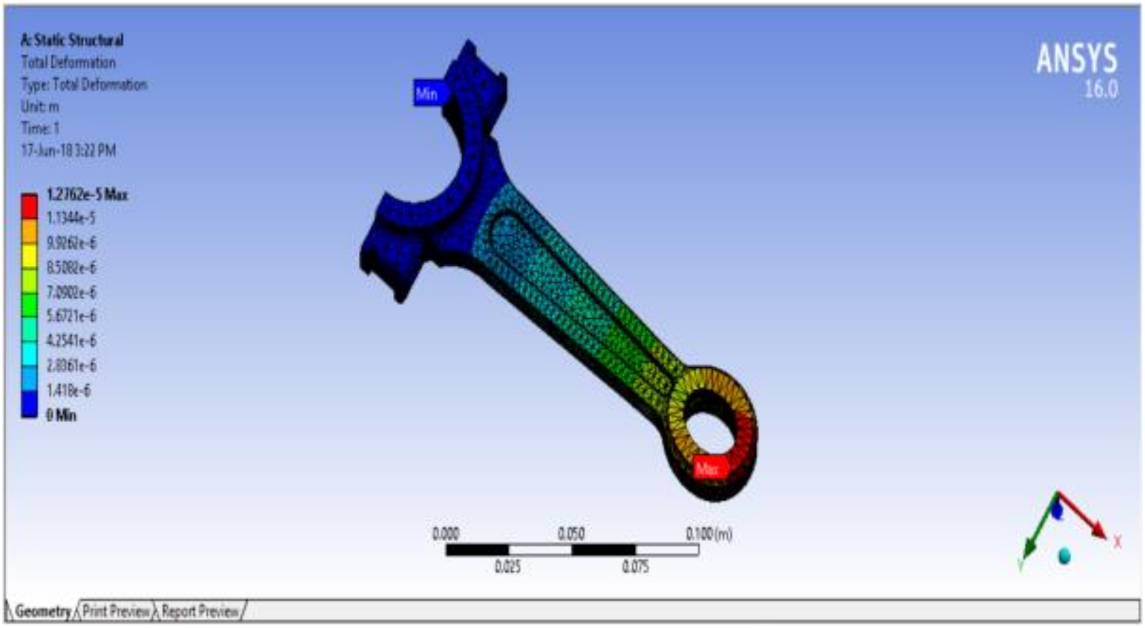

Fig-25 Equivalent Deformation Analysis

Table-4.2 Result and AnalysisMagnesium Alloy

	Minimum	Maximum
Stress	1264.8 Pa	1.106e+007Pa
Strain	3.9509e-00m/m	2.4586e-004 m/m
Deformation	0.m	1.2762e-005 m

B. Analysis of Connecting Rod of Titanium

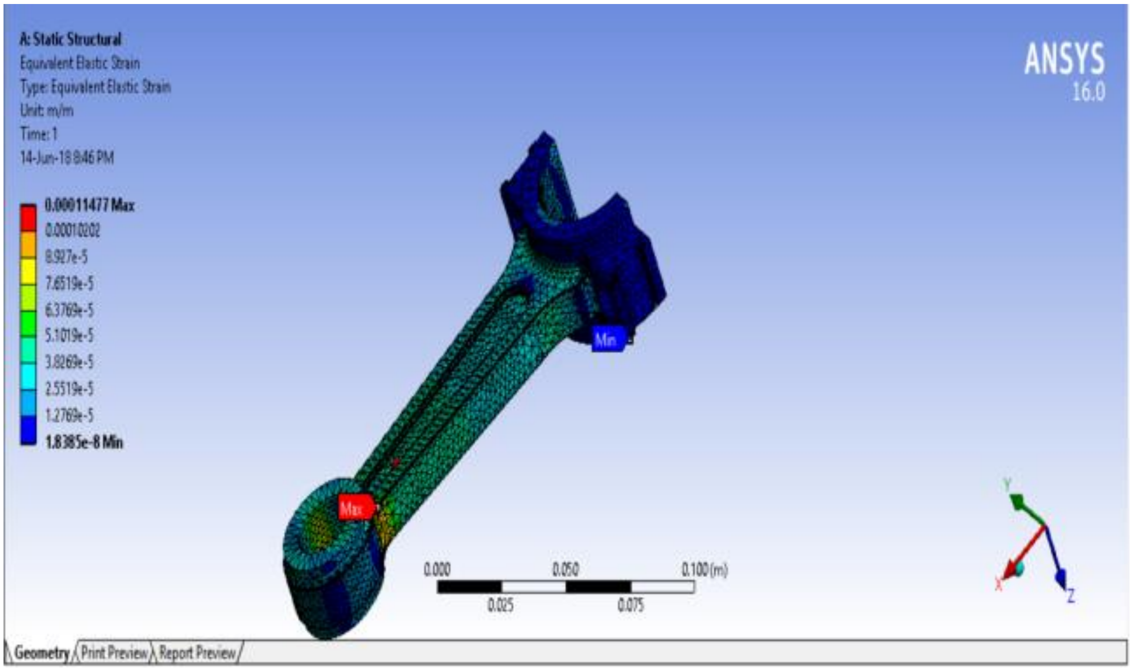

Fig-24 Equivalent Strain Analysis

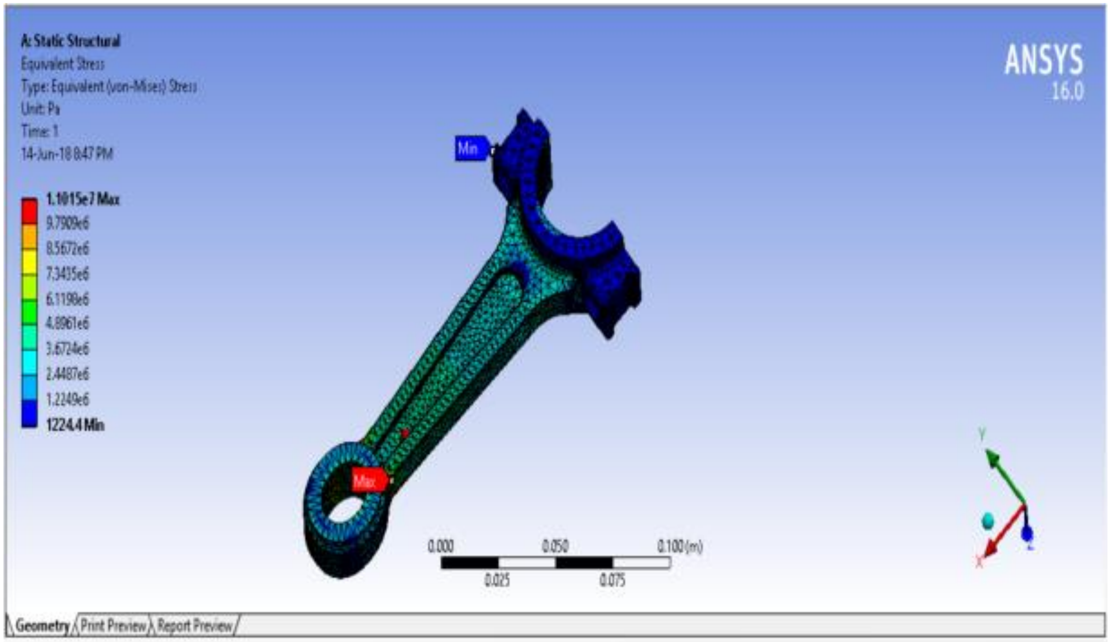

Fig-23 Equivalent Stress Analysis

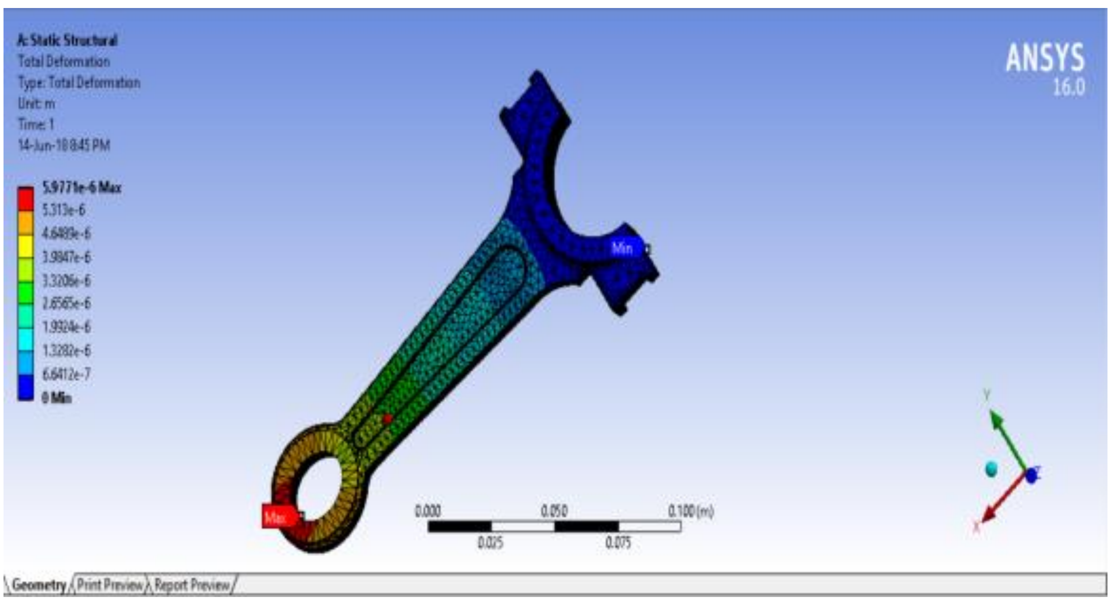

Fig-25 Equivalent Deformation Analysis

Table-4.2 Result and AnalysisTitanium

	Minimum	Maximum
Stress	12224.4 Pa	1.1015e+007Pa
Strain	1.8385e-008 m/m	1.1477e-4 m/m
Deformation	0.m	5.9771e-005 m

B. Analysis of Connecting Rod of Mild Steel

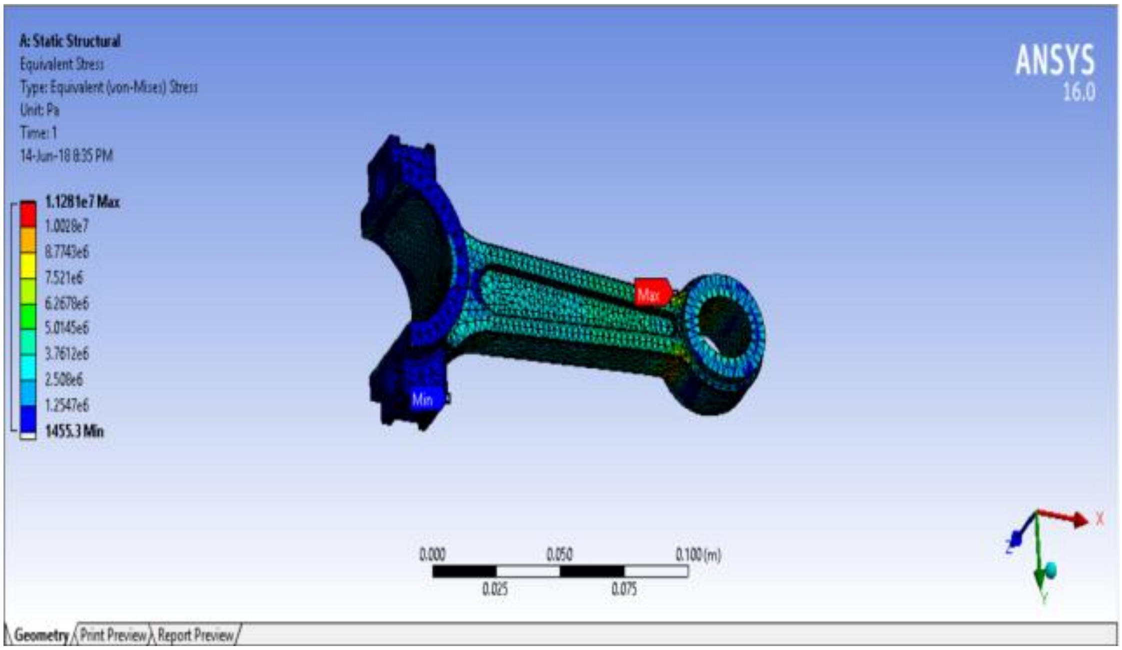

Fig-23 Equivalent Stress Analysis

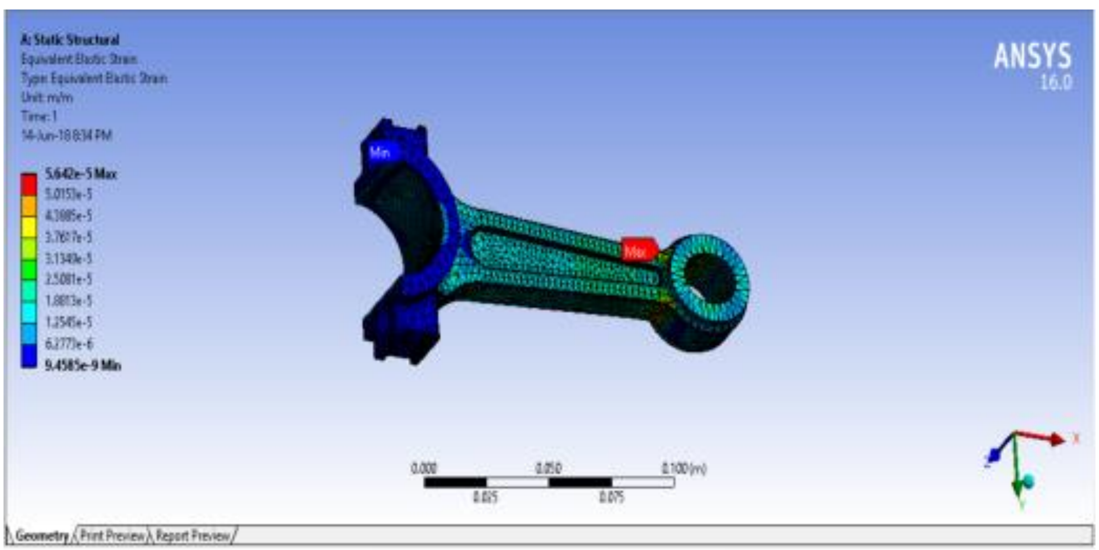

Fig-24 Equivalent Strain Analysis

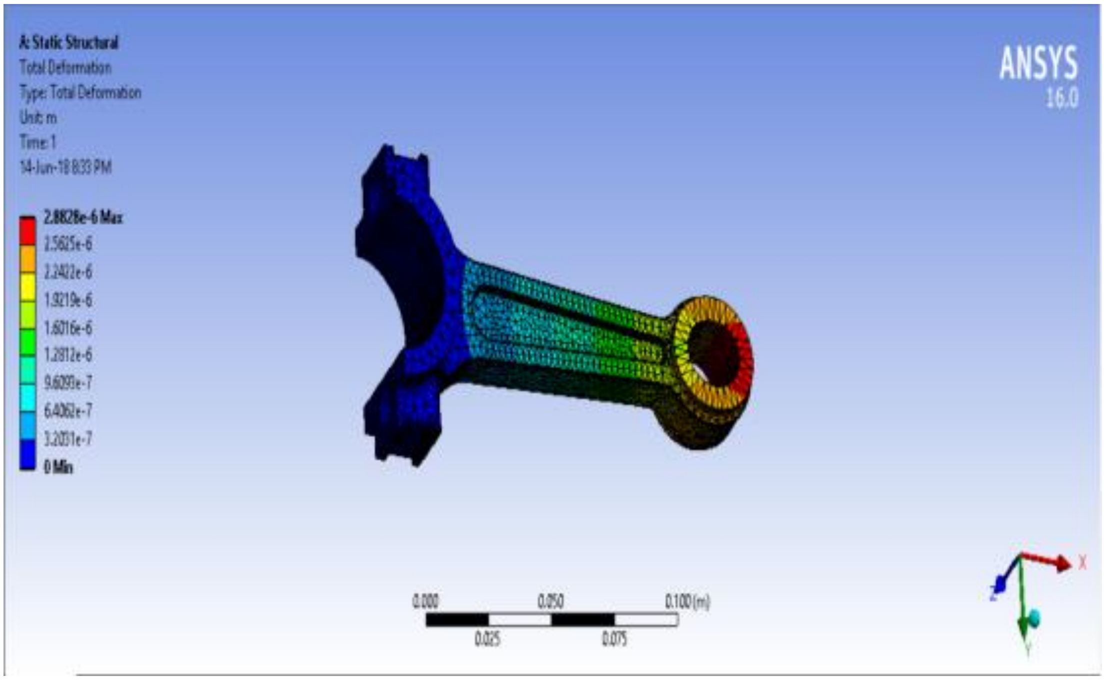

Fig-25 Equivalent Deformation Analysis

Table-4.2 Result and Analysis Mild Steel

	Minimum	Maximum
Stress	1455.3 pa	1.1281e+007 Pa
Strain	1.8385e-008m/m	1.1477e-004 m/m
Deformation	0.m	9.9771e-006 m

B. Analysis of Connecting Rod of Aluminum 360

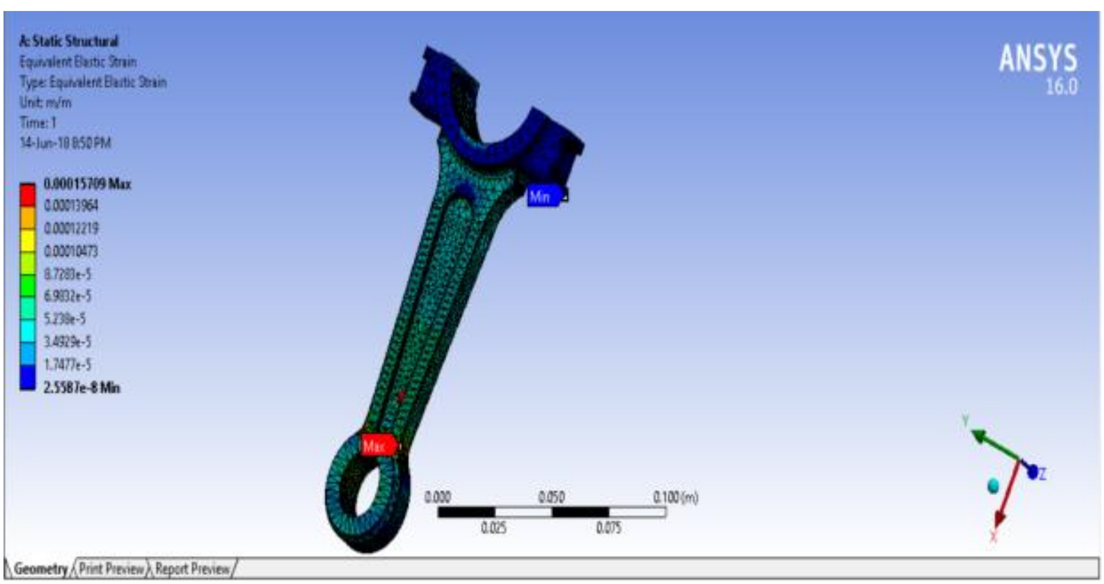

Fig-24 Equivalent Strain Analysis

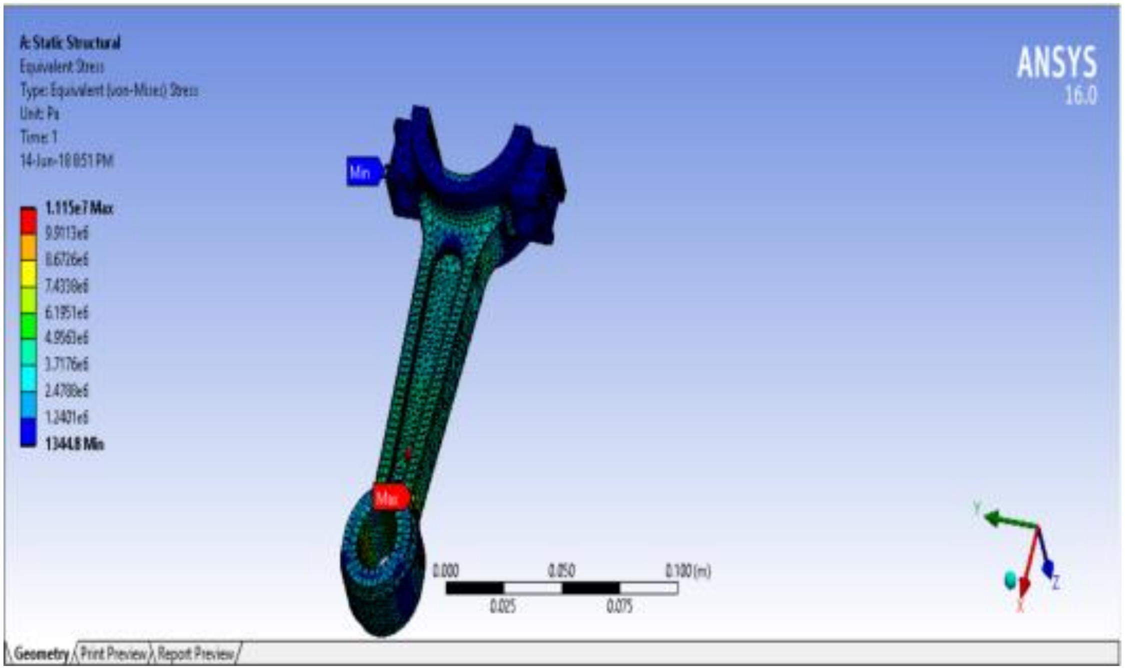

Fig-23 Equivalent Stress Analysis

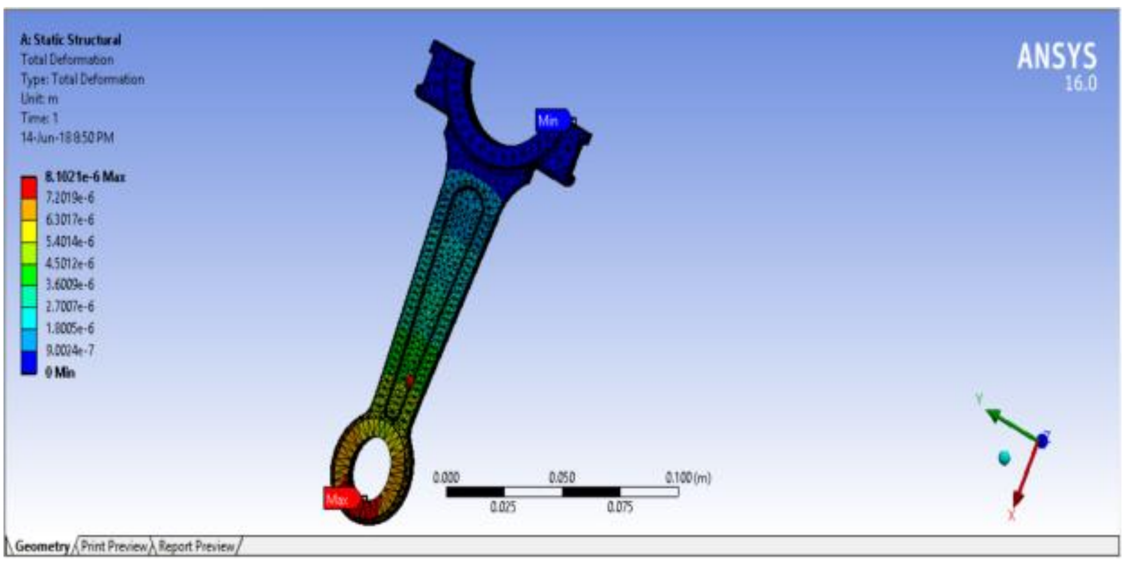

Fig-25 Equivalent Deformation Analysis

Table-4.2 Result and AnalysisAluminum 360

	Minimum	Maximum
Stress	1224.4 Pa	1.1015e+007 Pa
Strain	1.8385e-008 m/m	1.1477e-004 m/m
Deformation	0.m	5.9771e-006 m

VII - CONCLUSION

1. Solid modeling of connecting rod was made in NX 10.0 according to production drawing specification and analysis under the effect of tensile and compressive loads in terms of pressure is done in ANSYS Workbench.
2. 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.
3. 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. 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.
4. The section modulus of the connecting rod should be high enough to prevent high bending stresses due to inertia forces.
5. 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.
6. From the static analysis the stress is found maximum at the small end of the connecting rod.
7. Maximum von mises stress, Maximum von mises strain and Maximum displacement are minimum in connecting rod.
8. Comparing the different data, it is observed that stress, strain and displacement is minimum in connecting rod. So, beryllium alloy can be used for production of connecting rod for longer life.

VIII - FUTURE SCOPE

1. When we use this design of connecting rod our component life increases and minimizing maintenance.
2. Vibrational analysis can be done at ANSYS for minimizing the premature failure.
3. Dynamic analysis of connecting rod can also be performed on ANSYS to get the better analysis.
4. Thermal analysis can be done of connecting rod to minimize the thermal stress effect on connecting rod.
5. Torsional analysis can be done due to presence of small amount of torsional moment at the end points.
6. Design modification can be done to minimize the weight of connecting rod and the inertia force.
7. 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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2. Design data by PSG.