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Design and Analysis of Two Wheeler Connecting Rod

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ABSTRACT: The connecting rod is the intermediate member between the piston and the crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. Existing connecting rod is manufactured by using iron. This project describes modeling and analysis of connecting rod. In this project connecting rod is replaced by chrome steel and titanium for Yamaha Fz-s motorbike. A 2d drawing is drafted from the calculations. A parametric model of connecting rod is modeled using creo parametric 2.0 software. Analysis is carried out by using ansys software. Connecting rod can be designed for weight and cost reduction also to increase the life time of connecting rod. Upto some level of extent the weight of the connecting rod is lighter and having more strength as compared to the original design. The maximum stress is within the allowable stress limit for chrome steel and titanium.

KEYWORDS: Connecting rod, Static analysis, creo parametric 2.0 software, chrome steel, titanium

NORMENCLATURE:

A = cross sectional area of the connecting rod.

L = length of the connecting rod.

C = compressive yield stress.

W_{cr} = crippling or buckling load.

I_{xx} = moment of inertia of the section about x-axis

I_{yy} = moment of inertia of the section about y-axis respectively.

K_{xx} = radius of gyration of the section about x-axis

K_{yy} = radius of gyration of the section about y- axis respectively.

D = Diameter of piston

r = Radius of crank

1.INTRODUCTION

Leela Krishna Vegi The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modeled using CATIA V5 R19 software and to that model,

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analysis is carried out by using ANSYS 13.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz... Forged steel. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two wheeler piston were done in ANSYS software. Forged steel has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material like carbon steel. With Fatigue analysis we can determine the lifetime of the connecting rod.

Tony George Thomas The connecting rod forms an integral part of an internal combustion engine. The connecting rod is acted upon by different types of loads while undergoing its operation. One of the main reasons contributing to its failure is fatigue. The aim of this study is to redesign the connecting rod by incorporating the manufacturing process effects into the analysis and obtain a better fatigue performance. The redesign is aimed at reducing the weight of the component. Heavy duty application's connecting rod was selected for the study. The analytically calculated loads acting on the small end of connecting rod were used to carry out the static analysis using ANSYS. A stress concentration was observed near the transition between small end and shank. A piston-crank-connecting rod assembly was simulated for one complete cycle (0.02 seconds) using ADAMS to obtain the loads acting on small end of connecting rod. This force vs. time graph was converted into an equivalent stress vs. time graph. This stress vs. time graph was used as loading graph for fe-safe. The fatigue life calculated using fe-safe is 6.94×10^6 cycles and these results are validated with the help of Palmgren-Miner linear damage rule. The fatigue life of connecting rod can be further enhanced by incorporating manufacturing process effects in the analysis stage. Fatigue life was estimated by incorporating the shot peening process effects. An in-plane residual stress for the selected surface elements were applied for obtaining the beneficial effect of shot peening. There was an increment of 72% in fatigue life cycles). We conclude that shot peening can significantly increase the fatigue life of a connecting rod component.

M.S. Shaari The objectives of this paper are to develop structural modeling, finite element analyze and the optimization of the connecting rod for robust design. The structure of connecting rod was modeled utilized SOLIDWORKS software. Finite element modeling and analysis were performed using MSC/PATRAN and MSC/NASTRAN software. Linear static analysis was carried out to obtain the stress/strain state results. The mesh convergence analysis was performed to select the best mesh for the analysis. The topology optimization technique is used to achieve the objectives of optimization which is to reduce the weight of the connecting rod. From the FEA analysis results, TET10 predicted higher maximum stress than TET4 and maximum principal stress captured the maximum stress. The crank end is suggested to be redesign based on the topology optimization results. The optimized connecting rod is 11.7% lighter and predicted low maximum stress compare to initial design. For future research, the optimization should cover on material optimization to increase the strength of the connecting rod.

II. SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyses of connecting rod made of Forged steel. Steel materials are used to design the connecting rod. In this project the material (carbon steel) of connecting rod replaced with Forged steel .Connecting rod was created in CATIAV5 R19. Model is imported in ANSYS 13.0 for analysis. After analysis a comparison is made between existing steel connecting rod viz., Forged steel in terms of weight, factor of safety, stiffens, deformation and stress.

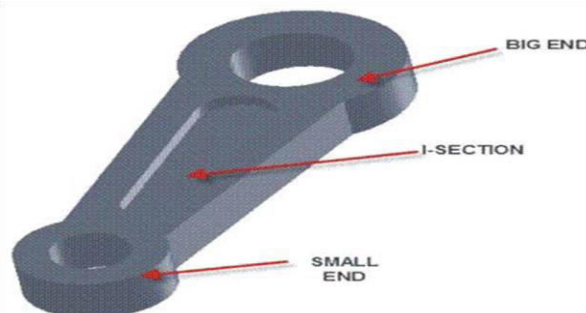


Fig 2.1 Schematic Diagram of Connecting Rod

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2.1 FORCE DUE TO GAS PRESSURE AND PISTON INERTIA:

The direct load on the piston due to gas pressure is transformed to the connecting rod. This force can be calculated with the help of indicator diagram. Otherwise, empirically

Force due to gas pressure, $F_G = (3.14 d^2/4) * \text{gas pressure}$ [ref.PSGDB 7.122]

Force due to inertia of reciprocating parts, $F_i = \frac{R}{g} \omega^2 \left[\cos \phi + \frac{\cos 2\phi}{l/r} \right]$

Where, d = diameter of piston

P = gas pressure

R = weight of the reciprocating Parts

r = radius of the crank

l = length of the connecting rod.

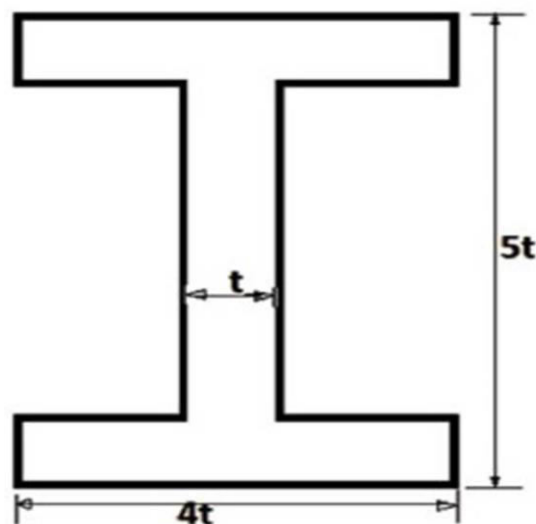
ω = angular velocity

The net force acting on the piston will be algebraic sum of the gas force and the inertia force.

$$F = F_G \pm F_i \quad [\text{ref.PSGDB 7.122}]$$

2.2 DESIGN OF SHANK OF THE CONNECTING ROD:

The shank of the connecting rod may be of circular section, rectangular section OR I-section. Connecting rods of circular and rectangular sections are generally used in the low speed engines where as in high speed engines connecting rod of I-section is preferred. In high-speed engines, the weight of the connecting rod should be as small as possible, without sacrificing strength, so that the inertia forces remain small. Considering these two aspects, the most suitable section for the shank is the I-section. the usual proportions chosen for the I-section are shown in figure 3.1 [ref.PSGDB 7.122]



In general

From standards,

Thickness of flange and web of the section = t

Width of the section $B = 4t$

Height of the section $H = 5t$

Area of the section $A = 11t^2$

Moment of inertia about x axis $I_{xx} = 34.91t^4$

Moment of inertia about y axis $I_{yy} = 10.91t^4$

Therefore $I_{xx}/I_{yy} = 3.2$

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So, in the case of this section (assumed section) proportions shown above will be satisfactory.

Length of the connecting rod (L) = 2 times the stroke

L = 117.2 mm

According to Rankine's – Gordon formula,

$$F = \frac{f_c A}{1 + a(1/K_{xx})}$$

Let,

A = C/s area of connecting rod,

L = Length of connecting rod

f_c = Compressive yield stress,

F = Buckling load

I_{xx} and I_{yy} = Radius of gyration of the section about x – x and y – y axis respectively

K_{xx} and K_{yy} = Radius of gyration of the section about x – x and y – y axis respectively.

III. MODELLING

3.1 STEPS MODELING OF CONNECTING ROD IN

Connecting Rod has been modelled with the help of CREO PARAMETRIC 2.0 Software. The Orthographic & final Solid Model of connecting rod is shown in figures below. The following is the list of steps that are use to create the required model.

- 1) The base feature is created on three orthogonal datum planes.
- 2) Creating two circular entities on either sides of rod crank and piston pin end (with the help of sketcher Option).
- 3) Filling the material between the crank and piston pin End
(With the help of EXTRUDE Option).
- 4) The second feature is also created on datum planes.
- 5) Using the EXTRUDE option the second feature is generated in between the two ends of the connecting rod.
- 6) Using the Protrude CUT option, the cut feature is generated on the second feature inorder to get the I section.
- 7) Then the creo file is converted into .iges file for exporting it into the ansys software for further processing.

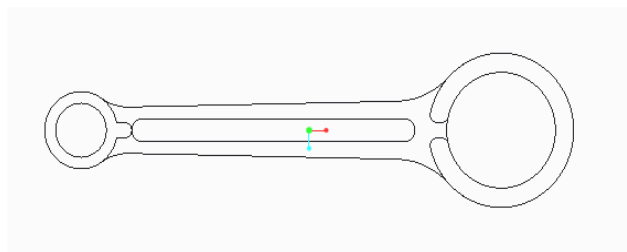


Fig.3. 1 2D Drawing for Connecting Rod.

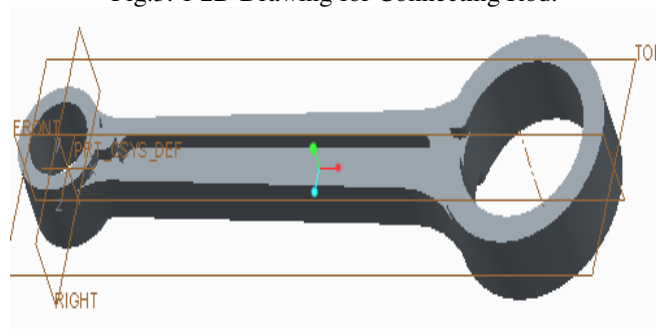


Fig 3.2 Solid Modelling of Connecting Rod

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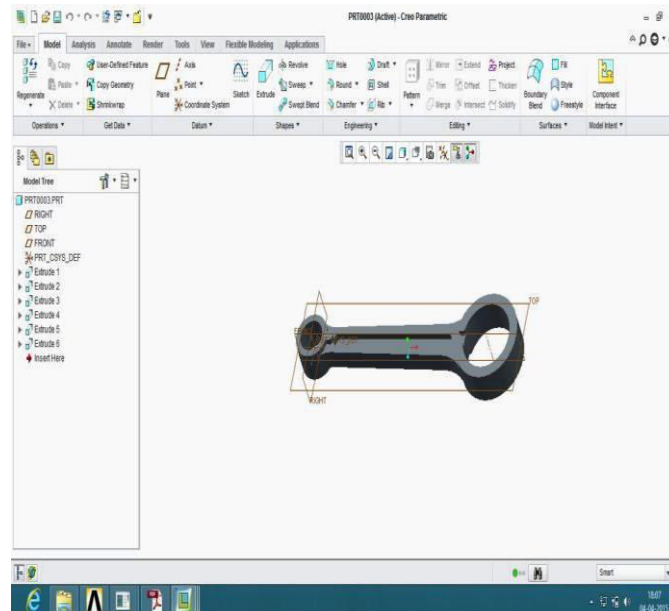


Figure 3.3: Solid Model of Connecting Rod with Work Sheet

IV. MATERIALS

4.1 MATERIALS USED FOR CONNECTING ROD

A) IRON



Fig. 4.1 Structure of Iron

CHARACTERISTICS:

- 1) Iron is a ductile, gray, relatively soft metal and is a moderately good conductor of heat and electricity.
- 2) It is attracted by magnets and can be readily magnetized.
- 3) The pure metal is chemically very reactive and rusts readily in moist air, forming red-brown oxides.
- 4) Alpha iron, also known as ferrite, is the stable form of iron at normal temperatures.

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B) CHROME STEEL



Fig. 4.2 Structure of Chromium Steel

CHARACTERISTICS:

Chromium is a lustrous, brittle, hard metal. Its colour is silver-gray and it can be highly polished. It does not tarnish in air, when heated it burns and forms the green chromic oxide. Chromium is unstable in oxygen, it immediately produces a thin oxide layer that is impermeable to oxygen and protects the metal below.

C) TITANIUM



Fig. 4.3 Structure of Titanium

CHARACTERISTICS:

Chemical element, Ti, atomic number 22 and atomic weight 47.90. Its chemical behaviour shows many similarities with that of silica and zirconium, as an element belonging to the first transition group. Its chemistry in aqueous solution, especially in the lower oxidation states, has some similarities with that of chrome and vanadium. Titanium is a transition metal light with a white-silvery-metallic colour. It is strong, lustrous, and corrosion-resistant. Pure titanium is not soluble in water but is soluble in concentrated acids. This metal forms a passive but protective oxide coating (leading to corrosion-resistance) when exposed to elevated temperatures in air but at room temperatures it resists tarnishing.

V.EXPERIMENTS

5.1 YAMAHA FZ-S

SPECIFICATION

Engine type	Air-cooled, 4-stroke, SOHC, 2-Valve
Displacement	153.0cc
Bore & Stroke	58.0 × 57.9mm
Compression ratio	9.5:1
Maximum output	14PS @ 7,500 rpm
Maximum torque	13.6 Nm @ 6,000 rpm

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Starting method	Electric & Kick
Lubrication type	Wet Sump
Fuel Supply	Carburetor
Clutch type	Wet, multiple-disc
Primary/secondary reduction ratio	3.409 / 2.857
Transmission type	Constant mesh 5-speed
Gear ratio	1st=2.714 2nd=1.789 3rd=1.318 4th=1.045 5th=0.875
Cylinder layout	Forward-inclined Single Cylinder
Battery	12 V, 5.0 Ah

Tab 5.1 Engine Specification

Frame type	Diamond
Suspension (front/rear)	Telescopic/ Monocross
Wheelbase	1,334mm
Brake type(front/rear)	Disc/Drum
Tire size (front/rear)	100/80-17 / 140/60-R17
Headlight	12 V, 35/35W
Caster / trail	25 degree/ 101 mm

Tab 5.2 Chassis Specification

Overall Length × Width × Height	2075 mm × 770 mm × 1,090 mm
Seat height	790 mm
Wheelbase	1,334 mm
Minimum ground clearance	160 mm

Tab 5.3 Vehicle Dimension

VI.DESIGN CALCULATIONS:

6.1 IRON

Young's modulus of iron = 211 Gpa
Yield strength of iron = 80-100 Mpa
Ultimate strength of iron = 350 Mpa
Poisson's Ratios = 0.25
Density = 7870 Kg/m³
Thickness of flange & web of the section = t
Width of section B= 4t
The standard dimension of I SECTION.

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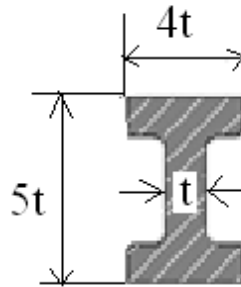


Fig. 6.1 Standard Dimension of I - Section.

Height of section $H=5t$

Area of section $A= 2(4t \times t) + 3t \times t$ $A=11t^2$

MI of section about x axis:

$$I_{xx} = \frac{1}{12} (4t (5t)^3 - 3t (3t)^3) = \frac{419}{12} t^4$$

MI of section about y axis:

$$I_{yy} = (2 + \frac{1}{12} t (4t)^3 + \frac{1}{12} (3t) t^3) \\ = \frac{131}{12} t^4$$

$$I_{xx}/I_{yy} = 3.2$$

Length of connecting rod (L) = 2 times the stroke $L = 115.8 \text{ mm}$

Total force acting $F = F_p - F_i$

F_p = force acting on piston

F_i = force by inertia

$$F_p = (3.14 \frac{d^2}{4}) \times \text{gas pressure}$$

$$F_p = \left(\frac{\pi d^2}{4} \right) \times 15.11 \text{ N/mm}^2$$

$$F_p = 39921.82 \text{ N}$$

$$F_i = \frac{R}{g} \omega^2 r \left[\cos \theta + \frac{\cos 2\theta}{l/r} \right]$$

R = weight of the reciprocating parts

r = radius of the crank

ω = angular velocity

L = length of the connecting rod

$$R = 15.696 \text{ N}$$

$$\omega = \frac{2\pi N}{60} \\ = \frac{2\pi * 7500}{60}$$

$$\omega = 785.39 \text{ rad/s}$$

θ = crank angle from dead center

$\theta = 0$ consider the connecting rod is at the TDC position

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$$\frac{l}{r} = \frac{115.8}{\text{stroke}}$$

$$r = \frac{2}{57.9}$$

$$r = \frac{2}{57.9} = 28.95 \text{ mm}$$

$$\frac{l}{r} = \frac{115.8}{28.95} = 4$$

$$F_i = \frac{R}{g} \omega^2 r \left[\cos \phi + \frac{\cos 2\phi}{l/r} \right]$$

$$F_i = \frac{15.696}{9.81} * 785.39^2 * 0.02895 \left[\cos 0 + \frac{\cos 0}{4} \right]$$

$$F_i = 35714.8 \text{ N}$$

$$F = F_p - F_i$$

$$F = 4206.9 \text{ N}$$

$$\text{Buckling load, } F = \frac{\sigma_c * A}{1 + a \left(\frac{l}{k_{xx}} \right)^2}$$

$$a = \frac{\pi^2 E}{\sigma_c}$$

$$a = 4.8 \times 10^{-5}$$

$$4206.9 = \frac{100 * 11t^2}{1 + 4.8 * 10^{-5} \left(\frac{115.8}{1.78t} \right)^2}$$

Solving the above equation,

$$t = 2.145 \text{ mm}$$

$$\text{Width of section B} = 4t = 8.58 \text{ mm}$$

$$\text{Height of section H} = 5t = 10.725 \text{ mm}$$

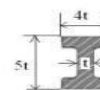
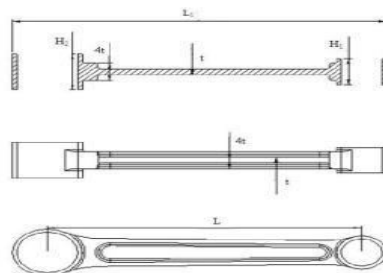
$$\text{Area A} = 11t^2 = 50.611 \text{ mm}^2$$

$$\text{Height at the big end (crank end)} = H_2 = 1.1H \text{ to } 1.25H$$

$$H_2 = 13.40 \text{ mm}$$

$$\text{Height at the small end (piston end)} = 0.9H - 0.75H$$

$$H_1 = 9.652 \text{ mm}$$



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6.2 CHROME STEEL

Young's modulus of iron = 203.395 Mpa
Yield strength of iron = 203.3 Mpa
Ultimate strength of iron = 224.07 Mpa
Poisson's Ratios = 0.25
Density = 7.833×10^{-6} Kg/mm³

$$\text{Buckling load, } F = \frac{\sigma_c \cdot A}{1 + a \left(\frac{l}{k_{xx}} \right)^2}$$

$$a = \frac{\sigma_c}{\pi^2 E}$$

$$a = 1.901699 \times 10^{-4}$$

$$4206.9 = \frac{203.3 \times 11t^2}{1 + 1.901699 \times 10^{-4} \left(\frac{115.8}{1.78t} \right)^2}$$

Solving the above equation,

$$t = 1.639 \text{ mm}$$

Width of section B = 4t = 6.556 mm

Height of section H = 5t = 8.195 mm

Area A = $11t^2 = 29.549 \text{ mm}^2$

Height at the big end (crank end) = $H_2 = 1.1H$ to $1.25H$

$H_2 = 10.24 \text{ mm}$

Height at the small end (piston end) = $0.9H - 0.75H$

$H_1 = 7.3758 \text{ mm}$

6.3 TITANIUM

Young's modulus of iron = 120 Gpa
Yield strength of iron = 100-225 Mpa
Ultimate strength of iron = 246-370 Mpa
Poisson's Ratios = 0.3
Density = 4.500×10^{-6} Kg/mm³

$$\text{Buckling load, } F = \frac{\sigma_c \cdot A}{1 + a \left(\frac{l}{k_{xx}} \right)^2}$$

$$a = \frac{\sigma_c}{\pi^2 E}$$

$$a = 1.0142 \times 10^{-4}$$

$$4206.9 = \frac{225 \times 11t^2}{1 + 1.0142 \times 10^{-4} \left(\frac{115.8}{1.78t} \right)^2}$$

Solving the above equation,

$$t = 1.558 \text{ mm}$$

Width of section B = 4t = 6.232 mm

Height of section H = 5t = 7.79 mm

Area A = $11t^2 = 26.701 \text{ mm}^2$

Height at the big end (crank end) = $H_2 = 1.1H$ to $1.25H$

$H_2 = 9.737 \text{ mm}$

Height at the small end (piston end) = $0.9H - 0.75H$

$H_1 = 7.011 \text{ mm}$

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VII.ANALYSIS

7.1 STEPS INVOLVED IN ANALYSING THE CONNECTING ROD

The analysis is done by using ANSYS software by importing the .iges file from creo parametric. The procedure followed is given below

- 1) First the .iges file is imported into the ansys, File>Import>IGES>filename.
- 2) In the Ansys main menu, the Structural analysis is set in the pre-processor section.
- 3) The appropriate element type is given.
- 4) The material properties are given.
- 5) Meshing of model was done.
- 6) One end of the connecting rod is fixed and the load is applied on the other end(big).
- 7) The solution was generated for current LS.
- 8) The result for von mises stress and deformed & undeformed shape was taken.

Solid>Tet 10 node

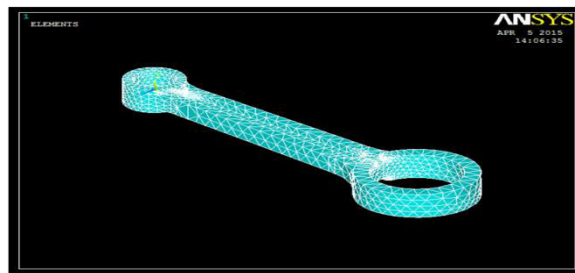


Fig 7.1 Meshing of Connecting Rod

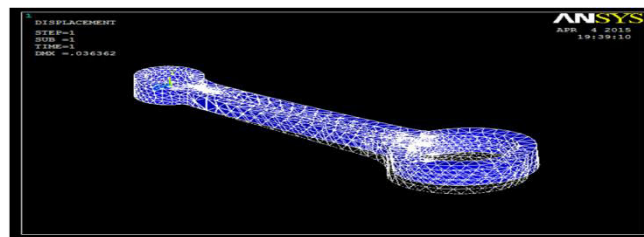


Fig 7. 2 Def+undef of Iron

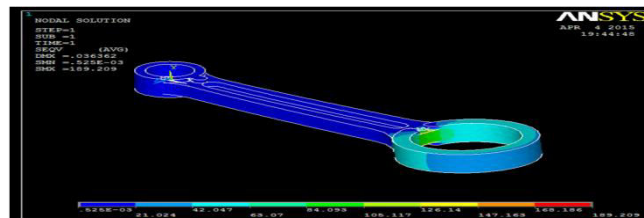


Fig 7. 3Vonmises Stress of Iron

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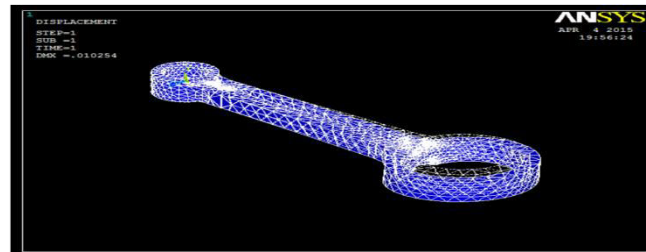


Fig 7.4 Def+undef of Chrome Steel

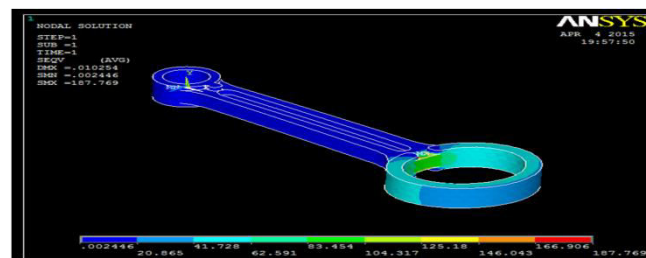


Fig 7.5 Vonmises Stress of Chrome Steel

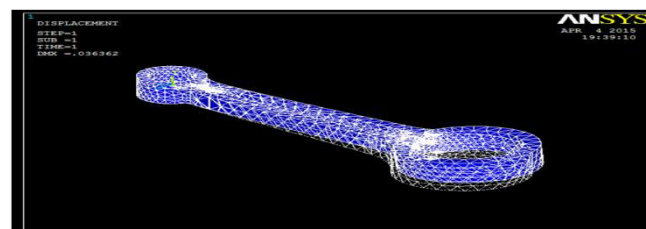


Fig 7.6 Def+undef of Titanium

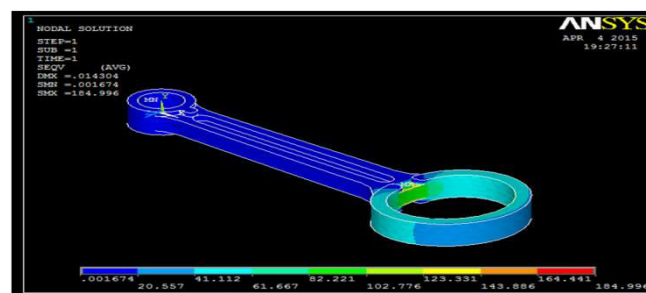


Fig 7.7 Vonmises Stress of Titanium

VIII. RESULTS AND DISCUSSION:

8.1 RESULTS FOR WEIGHT OF CONNECTING ROD

IRON

Density of iron = 7.87×10^{-6} Kg/mm³

Volume of connecting rod = 1.76911×10^4 mm³

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$$\begin{aligned}\text{Weight of connecting rod} &= \text{Density} \times \text{Volume} \\ &= 7.87 \times 10^{-6} \times 1.76911 \times 10^4 \\ &= 0.1392 \text{ kg}\end{aligned}$$

CHROME STEEL

$$\begin{aligned}\text{Density of chrome steel} &= 7.833 \times 10^{-6} \text{ kg/mm}^3 \\ \text{Volume of connecting rod} &= 1.76911 \times 10^4 \text{ mm}^3 \\ \text{Weight of connecting rod} &= \text{Density} \times \text{Volume} \\ &= 0.13857 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{Percentage of reduction in weight} &= \frac{\text{W of iron} - \text{W of chrome steel}}{\text{W of iron}} \\ &= \frac{0.1392 - 0.13857}{0.1392} \\ &= 0.452 \text{ kg} \\ \text{Titanium} &= \frac{\text{W of iron} - \text{W of titanium}}{\text{W of iron}} \\ &= \frac{0.1392 - 0.0796}{0.1392} \\ &= 0.42816 \text{ kg}\end{aligned}$$

8.2 RESULTS FOR STIFFNESS OF CONNECTING ROD IRON

$$\begin{aligned}\text{Weight of connecting rod} &= 0.1392 \text{ Kg} \\ \text{Deformation} &= 0.036362 \text{ mm} \\ \text{Stiffness} &= \frac{\text{Weight}}{\text{Deformation}} \\ &= \frac{0.1392}{0.036362} = 3.8221 \text{ kg/mm}\end{aligned}$$

CHROME STEEL

$$\begin{aligned}\text{Weight of connecting rod} &= 0.13857 \text{ Kg} \\ \text{Deformation} &= 0.010254 \text{ mm} \\ \text{Stiffness} &= \frac{\text{Weight}}{\text{Deformation}} \\ &= \frac{0.13857}{0.010254} = 13.5137 \text{ kg/mm}\end{aligned}$$

TITANIUM

$$\begin{aligned}\text{Weight of connecting rod} &= 0.0796 \text{ Kg} \\ \text{Deformation} &= 0.014304 \text{ mm} \\ \text{Stiffness} &= \frac{\text{Weight}}{\text{Deformation}} \\ &= \frac{0.0796}{0.014304} = 5.5648 \text{ kg/mm}\end{aligned}$$

MATERIAL PROPERTIES	IRON	CHROME STEEL	TITANIUM
Stress Max.	189.209	187.769	184.996
Stiffness	3.82817	13.5137	5.5648
Deformation	0.036362	0.010254	0.014304

Tab 8.1 Comparisons of Materials.

IX. CONCLUSION

By checking and comparing the results of materials in above tables, the finalized results are shown below.

It explains about the various stresses to be considered while designing the connecting rod and different materials used and comparing the result of all material. Also most of the researchers used the CREO PARAMETRIC 2.0 software for the modeling and ANSYS software for analysis. These can be used for designing the any connecting rod in Automobile. Connecting rod can be designed for weight and cost reduction also to increase the life time of

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connecting rod. Upto some level of extent the weight of the connecting rod is lighter and having more strength as compared to the original design.

The maximum stress is within the allowable stress limit for chrome steel and titanium.

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