DYNAMIC ANALYSIS OF CONNECTING ROD USING ANSYS-14.0

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ABSTRACT

Connecting rod is most important part of I.C. engine which provide link between piston and crankshaft to convert linear reciprocating motion of the piston to the rotary motion of the crankshaft and vice versa. Till now, many research is going on in the field of metallurgy and resulted in large number of newly developed materials are available to select materials for particular applications. Focusing on this issue, in this study the connecting rod modulate and simulated for the dynamic analysis by using CATIA software for 3D modelling-design of connecting rod and ANSYS 14.0 for dynamic analysis. Using available high strengthen alloy is used for the connecting rod for the weight reduction to reduce moment of inertia. Dynamic analysis is carried out for determine the stress, strain, and total deformation is calculated under loading conditions of compression and tension at crank and pin end of connecting rod.

Keyword: - *Dynamic analysis, Finite element modeling, Connecting rod, weight reduction.*

1. Introduction

In an automotive engines connecting rods are most important components which are used for the convert linear, reciprocating motion of the piston into rotating motion of the crank shaft and vice versa. During the working and its life connecting rods are made for sustain cyclic and complex loading. That is axial tension forces at the time of exhaust stroke, compression forces occurs at the power stroke, bending stresses which are caused by the thrust, piston pulling and the centrifugal force generated by rotating crankshaft. To sustain cyclic and complex loading, the connecting rods must have the highest possible rigidity at the lowest weight. I-section of the connecting rods are designed to provide maximum rigidity with minimum weight. It is observed that maximum stress is produced near the piston end, and it is decreased by increasing the material near the piston end. To keep the inertia forces as low as possible in case of high speed engines, I-section of the connecting rod is used and it can also withstand high gas pressure [2]. The connecting rods are manufactured by different modern processes, there are sand cast [3], wrought forged [4], and powder metallurgy [5]. The materials used for connecting rods are mild carbon steels (having 0.35 to 0.45 percent carbon), alloy steels (chromium-nickel or chromium-molybdenum steels) and different alloys like aluminum alloys, magnesium alloys, titanium alloys and polymeric materials. All these alloys are used for different applications depending upon the ultimate tensile strength required for the particular application [6]. Till now, vast research is going on in the field of metallurgy and resulted in large number of newly developed materials are available to select materials and its particular applications. Focusing on this issue, in this study the connecting rod is modulate and simulated for the dynamic analysis by using CATIA software for 3D modeling-design of connecting rod and ANSYS 14.0 for dynamic analysis.

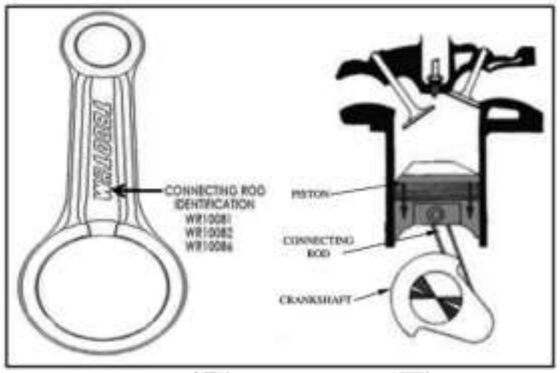


Fig. 1: Schematic diagram of a connecting rod with cross section of IC engine [1]

2. Force Acting on Connecting Rod

The following are the forces acting on the connecting rod:

1. Force on the piston due to gas pressure and inertia of the reciprocating parts,
2. Force due to inertia of the connecting rod or inertia bending forces,
3. Force due to friction of the piston rings and of the piston, and
4. Force due to friction of the piston pin bearing and the crank-pin bearing.

An expression for the forces acting on a vertical engine is discussed below.

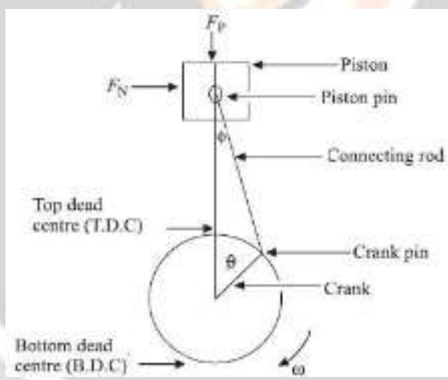


Fig. 2: Forces acting on the connecting rod.

Let,
P = Maximum pressure of gas,
D = Dia of the piston
A= cross-sectional area of the piston
m_R = Mass of reciprocating parts
ω = Angular speed of crank,
ϕ = Angle of inclination of the connecting rod with the line of stroke
θ = Angle of inclination of the crank from top dead center
r = Radius of crank
l = length of connecting rod
n = Ratio of length of connecting rod to the Radius of crank

Fc= Force acting on piston pin (force due to gas pressure ± inertia pr.)
Force on the piston due to gas pressure is
Fg = Area× Pressure
Rankine's formula and buckling load acting on the piston is [7]

$W_B = (\sigma_c \times A)/(1+a(L/K\_xx)\char`^2)$

3. Configuration of 150cc Engine (Pulsar 150 model)

Engine type air cooled 4-stroke
Bore × Stroke (mm) = 58 × 56.4
Displacement = 149.01 cc
Maximum Power = 15.1ps @ 9000 rpm
Maximum Torque = 12.45 Nm @6500rpm
Compression Ratio = 9.5 ± 0.5:1
Density of Petrol C_8H_{18} = 737.22 kg/m^3
= 737.22E^{-9} kg/mm^3
Temperature T = 60 F = 288.855 K

In this particular study, following the values of (Bajaj Pulsar 150cc) engine parameters are calculated by using related formula and these are Mass (M)-0.11 kg, molecular Weight of Petrol- 0.11422 kg/mole, R-72.76 and pressure (P) -15.494 Mpa [2].

4. Dimension of Cross-Section of the Connecting Rod

In an I.C. engine the connecting rod is subjected to alternating forces i.e. direct compressive and tensile forces and the compressive forces acted on the connecting rod are much higher than that of tensile forces. Therefore, the cross-section of the connecting rod is designed by using a Strut and the Rankine's formula [2]
As Fig. 3 shows the buckling of the connecting rod, which is subjected to an axial load W which can be buckle with X- axis i.e, in the plane of motion of connecting rod or Y-axis i.e, in the plane perpendicular to the plane of motion. The connecting rod of X- axis considered like both ends hinged for buckling and both ends fixed for buckling about *Y*-axis (AS shown in Fig.3)[25].

According to Rankine's formula,

WB about X-axis = $\frac{\sigma_c \times A}{1+a\left(\frac{L}{K_{xx}}\right)^2}$

$= \frac{\sigma_c \times A}{1+a\left(\frac{l}{K_{xx}}\right)^2}$ (For both ends hinged L=l)

W_B about Y-axis = $\frac{\sigma_c \times A}{1+a\left(\frac{L}{K_{yy}}\right)^2}$

$= \frac{\sigma_c \times A}{1+a\left(\frac{l}{2K_{yy}}\right)^2}$ (For both ends hinged L=l/2)

In order to have a connecting rod equally strong in the buckling about both the axes, the buckling loads must be equal, i.e.

$$\frac{\sigma_c \times A}{1+a\left(\frac{l}{K_{xx}}\right)^2} = \frac{\sigma_c \times A}{1+a\left(\frac{l}{2K_{yy}}\right)^2}$$

$$\left(\frac{l}{K_{xx}}\right)^2 = \left(\frac{l}{2K_{yy}}\right)^2$$

$K^2_{xx} = 4K^2_{yy}$ or $I_{xx} = 4I_{yy}$ ($I = A.K^2$)

By this assumption it is declare that the connecting rod is four times strong in buckling about YY-axis as compare to XX- axis (If Ixx > 4 Iyy then buckling takes place about YY- axis. And if Ixx < 4 Iyy then buckling takes place about XX- axis). However, in actual practice, Ixx is kept slightly less as compare to 4Iyy. It is usually taken between 3 to 3.5 and the connecting rod design for buckling about XX-axis.

The Design will always be satisfactory buckling about YY-axis. The most suitable section for the connecting rod with the proportions shows in Fig 3.

Let,
A = cross sectional area of the connecting rod.
L = length of the connecting rod.
σc = compressive yield stress.
W_B = crippling or buckling load.
Ixx and Iyy = moment of inertia of the section about x- axis and y-axis respectively.
Kxx and Kyy = radius of gyration of the section about x-axis and y- axis respectively [2, 8-17].
The standard dimension of I section:
The standard dimensions are calculated using standard formulas and it is reported in the table No. 1. These dimensions are recalculated by introducing different materials and its properties.
These different materials are reported in the table 2 with its composition.

Table 1: All analytical data of all I-section alloys:

Materials	**20CrMo**	**30CrMo**
Total thickness (t) of I-section of	2.71 mm	2.56 mm
Width of section **B**	10.86 mm	10.24 mm
Height of section **H**	13.57 mm	12.80 mm
Height of I-section of small end H1	11.21 mm	10.29mm
Height of I-section of big end H2	15.95 mm	15.04 mm

Table 2: Chemical composition of steel alloys used for the analysis.

Materials	**20CrMo**	**30CrMo**
C	0.17~0.24 %	0.26~0.34 %
Si	0.17~0.37 %	0.17~0.37 %
Mn	0.40~0.70 %	0.40~0.70 %
Cr	0.80~1.10 %	0.80~1.10 %
Mo	0.15~0.25 %	0.15~0.25 %

5. Designing Process of Connecting rod for 20CrMo:

Mechanical Properties of 20CrMo:
Density: 7860 kg/m3
Elastic Modulus: 210 GPa

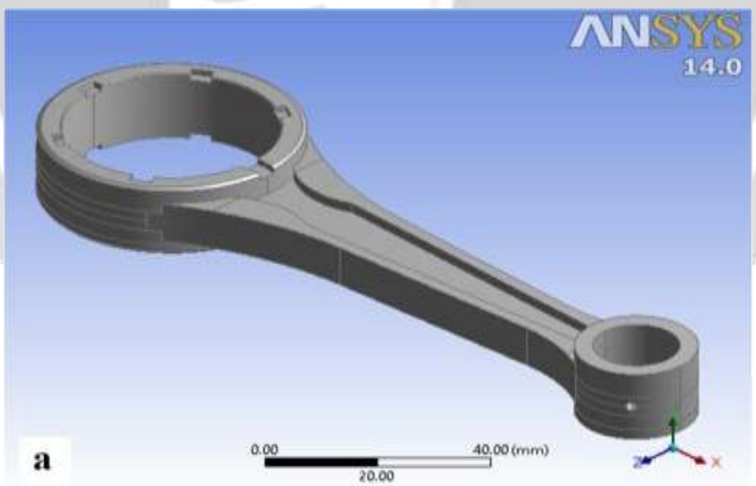
Poisson's Ratio: 0.3
Tensile Strength: 885 MPa
Yield Strength: 685 MPa
Percent Elongation: ≥12%
Reduction of area (%): 50
Heating-up Temperature (℃): 500
Designing process:

Thickness of flange & web of the section = **t**
Width of section **B= 4t**
Height of section **H=5t**
Area of section A= 2(4t×t) +3t×t
A=11t²
MI of section about X-axis:
$IG = \frac{bh^3}{12} = \frac{bredth \times hight^3}{12}$
$Ixx = \frac{409t^4}{12}$
Now, moment of inertia of a rectangle about the YY-axis passing through its C.G.
$I_{YY} = [IG]\,Y = \frac{bh^3}{12} = \frac{bredth \times hight^3}{12}$
$I_{yy} = \frac{131t^4}{12}$
$\frac{I_{xx}}{I_{yy}} = \frac{\frac{409t^4}{12}}{\frac{131t^4}{12}} = 3.2$
Since the value of Ixx / Iyy lies between 3 and 3.5, therefore, I-section chosen is quite satisfactory.
Now,
P = 15.494 Mpa
Bore Diameter (D) = 58 ×10^{-3}m
Gas Force (Fg) = $\frac{\pi D^2}{4} \times P$
D = Cylinder bore or piston diameter in mm, and
p= Maximum gas pressure in N/mm²
Fg= 40936.37 N
By considering the buckling of the rod about *X*-axis and applying the Rankine's formula.
We know that buckling load, (assuming both ends hinged).
W_B = Max. gas force (Fg) × Factor of safety
Factor of safety assume 1.15 for this designing process.

W_B= 40936.37 × 1.15
W_B= 47076.8255 N
Whereas the buckling load (W_B) may be calculated by using the following relation,
$W_B = \frac{\sigma_c \times A}{1+a\left(\frac{L}{K_{xx}}\right)^2}$
Where,
Constant, a = σc / π²E
a = 0.0004028,

Kxx = Radius of gyration about X- axis.
= $\sqrt{Ixx/A}$
Kxx = 1.78 t,
A=11t²,
From W_B equation,
[σ_c× A × [Kxx] ²] - [W_B × [Kxx] ²] - [a × W_B × L ²]
= 0
t = 2.715 × 10^{-3} m
t = 2.715mm,
Now cross section of I section,
Width of section **B= 4t =** 4×2.715 =10.86 mm,
Height of section **H=5t =** 5×2.715 = 13.575 mm,
So height (H) of mid-section = 13.575 mm,
Height of I-section of small end = 0.75H to 0.9H
H1 = 10.18mm to 12.21mm
Height of I-section of big end = 1.1H to 1.25H
H2 = 14.93mm to 16.986 mm
Same procedure is flowed for the three different materials summary is reported in the table No. 3. From this table No. 3 it is noticed that as material properties increased dimensions of the connecting rod reduces, ultimately weight of the connecting rod reduces [2, 9-12].

6. Analysis of Connecting Rod Made up of 20CrMo:



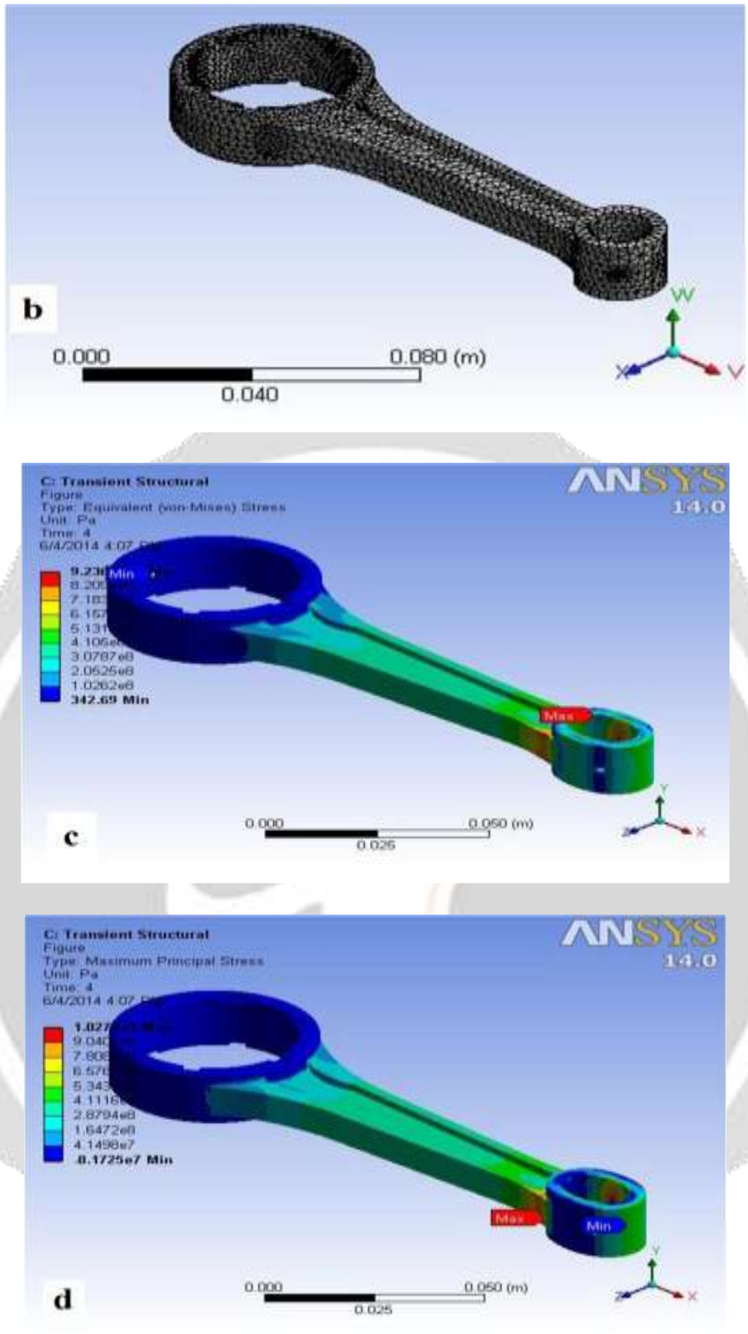


Fig. 6: Analysis For 20CrMo Connecting rod (a) design model of C.R (b) meshed model of connecting rod (c) von mises stress analysis (d)maximum principal stress analysis

7. Analysis of connecting rod made up of 30CrMo:

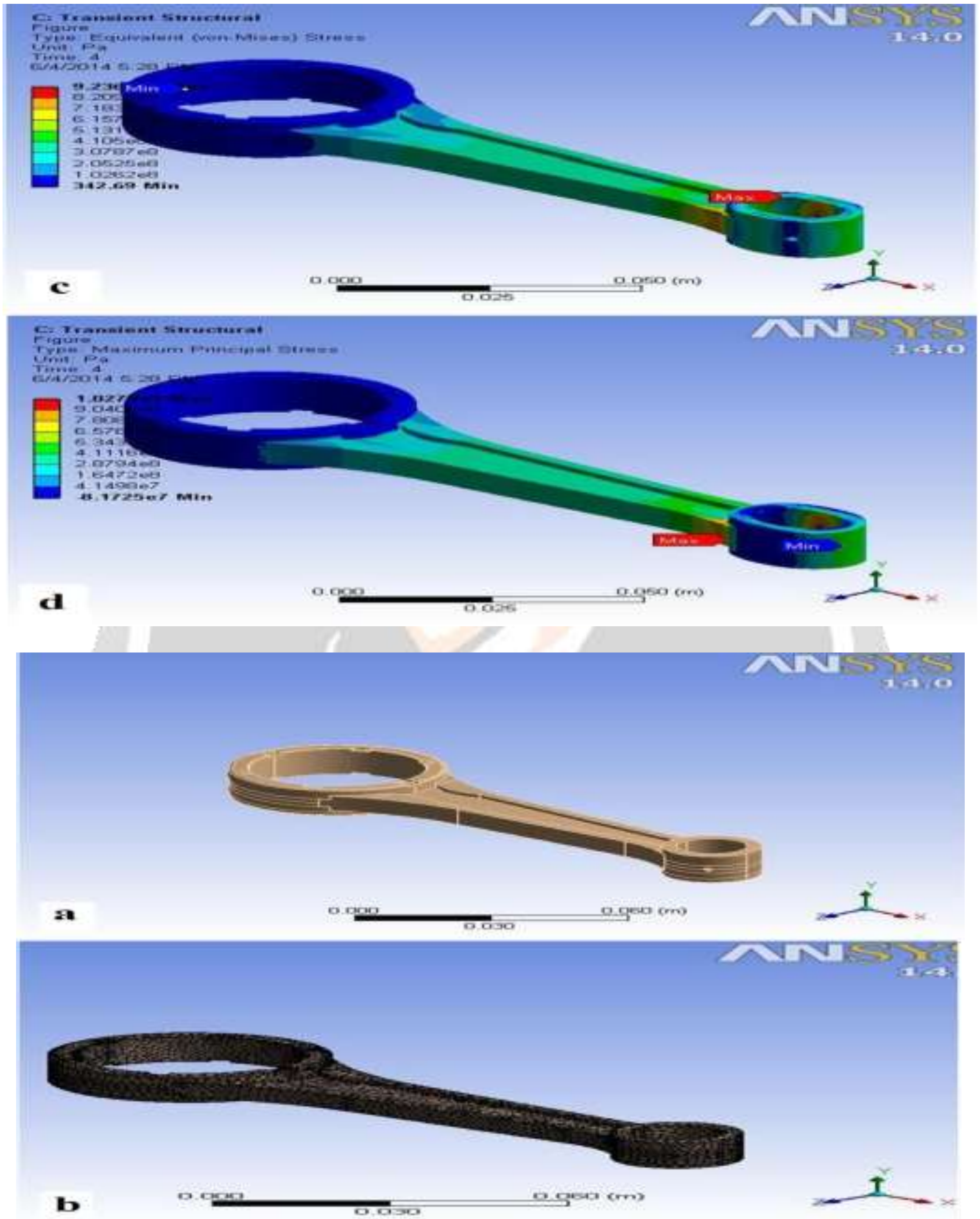


Fig 7: of 30CrMo connecting rod, (a) design model of C.R (b) meshed model of connecting rod (c) von mises stress analysis (d) maximum principal stress analysis.

Table3:Comparative dynamic Analysis of Bajaj Pulsar 150cc connecting rod using ANSYS for the three different materials

Materials	20CrMo	30CrMo
Yield Strength(MPa)	685	785
Ultimate strength(MPa)	885	930
Value of t (mm)	2.71	2.56
Mass(Kg)	0.203	0.190
Deflection (mm)	0.23715	0.23715
Equivalent (von- Mises) Stress (MPa)	923.62	923.62
Maximum Principal Stress (Gpa)	1.0273	1.0273

Fig. 6 shows the ANSYS analysis carried out on 20CrMo materials connecting rod, Fig.7a, shows design model of connecting rod, Fig. 7b shows meshed model of connecting rod, and von mises stress analysis, maximum principal stress analysis are shown in fig 6 c and d. Same analysis is carried out for 30CrMo connecting rod represented in fig 7 Table 1 and 2 are shows summary of different properties of 20CrMo, 30CrMo it is observed that as materials properties increases, (like yield strength and ultimate strength) decreases in the dimension and as well as mass of connecting rod is observed it is noticed that mass of the connecting rod reduces and maximum principal stress is also reducing. In the dynamic analysis equivalent (von-Mises) Stress are increased and maximum principal stress are decreasing as materials properties increasing that is 20CrMo to 30CrMo.

8. CONCLUSION

30CrMo steel alloy which required less material and less dimensions to sustain required pressure generated inside the cylinder compared with 20CrMo For the same amount of forces acting on the connecting rod, the steel alloy 30CrMo is 6.42 % less as compare to 20CrMo conceding rod.

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