Design and Simulation of Connecting Rod using Finite Element Analysis

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Abstract – *A connecting rod is the core component of an I.C. engine that has a function to transmit power released from combustion by the piston to the crankshaft. During the combustion process, deformation is the most commonly occurring damage in the connecting rods. The connecting rods made of aluminium alloy and alloy steel are designed & assembled using PTC CREO 7.0 software and analysed using the Finite Element Analysis (FEA) method in ANSYS. The simulation has shown the result of stress, strain, and total deformation in the connecting rod occur during the operating load condition. This article compares and discusses the various obtained results and selects the best material for the connecting rod.*

Keywords: – **Connecting Rod, Calculations, PTC CREO, Modelling, Assembly, Simulation, Finite Element Analysis.**

1. INTRODUCTION

Internal Combustion engine has many parts like cylinder block, piston, connecting rod, crank, and crankshaft. The connecting rod is very important part of an I.C. engine. It comprises of an eye at the small end to assemble with a piston with the help of a piston pin, a long shank, and a big end opening split into two parts to assemble with the crank pin. The main function of the connecting rod is to transmit power from the piston pin to the crank pin. The connecting rod converts the reciprocation motion developed by the piston to the rotary motion of the crankshaft. It also carries the lubrication oil from the oil sump (pan) to the piston assembly through the crank pin.

The drop forging process is used to make the connecting rod of an I.C. engine and its external surfaces are omitted unfinished. Mostly split type or two-piece connecting rod is used in internal combustion engines. The eye and shank are forged in a single piece; the rod cap is cut off, the outer surface and bolt portion left for the machining process of the big end. The small end of the connecting rod is usually made in the form of a solid eye and then machined.

The connecting rod is subjected to gas pressure by the force of combustion fuel and inertia force by its reciprocation parts. It is one of the most heavily stressed components of I.C. engines. The length of the connecting rod is a primary consideration. When the connecting rod is smaller than the crank radius, it has maximum angular swing, consequently greater side thrust on the piston. In low-speed engines, the length of connecting rod and radius of crank (L/r) is usually 4 or less than 4. In high-speed engines, the (L/r) ratio differ from 4 to 5.

In high-speed engines, mostly I-section connecting rods are used and it helps to reduce the weight as well as inertia forces. The I-section will also be easier for the forging process. For circulating lubricant oil, most of the connecting rod has a rifled-drilled hole in the whole length from the big end to the small end for transfer oil from the rod cap to the piston pin. While circular cross-section is used in low-speed engines [1].
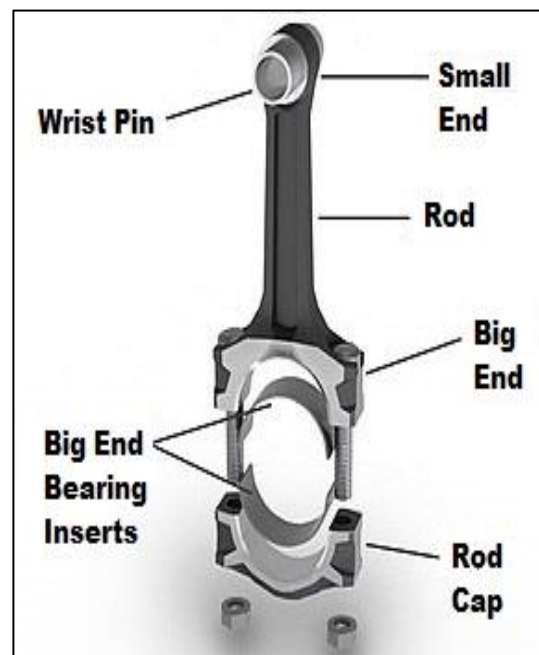

Fig -1: Connecting Rod Nomenclature [2]
Source: Wikipedia

1.1. Introduction to PTC CREO Software

CREO is a family or suite of Computer-Aided Design (CAD) apps supporting product design for discrete manufacturers and is developed by Parametric Technology Corporation (PTC). It is upgraded version for Pro/ENGINEER (Pro/E) software used for modelling, analysis and simulation. It is widely used for product design and development in automobile firms and manufacturing plants. It differs from AutoCAD in that it is based on

parametric, this means all dimensions are parametric which affects the actual portion [3].

1.2. Introduction to Ansys Software

ANSYS is a general-purpose finite element modelling packages for numerically different types of solutions to mechanical problems. Simulation of a system is the operation of a model in terms of time or space, which helps analyse the performance of an existing or a proposed system. In other words, simulation is the process of using a model to study the performance of a system. It is an act of using a model for simulation [4,5].

2. OBJECTIVES

i. To learn and get familiar with the PTC CREO and Finite Element Analysis.

ii. To create a 3D model of the connecting rod in PTC CREO 7.0 and imported into ANSYS software for further analysis.

iii. Study the effects of the loads acting on the connecting rod under the considered loading conditions.

iv. To evaluation of the comparison between results.

3. DESIGN OF CONNECTING ROD

Taking the following data of four-stroke internal combustion engine for designing a connecting rod.

Bore x Stroke	-	100mm x 190mm
The compression ratio of the engine	-	6:1
Engine speed	-	1800 RPM
Maximum pressure (Pmax.)	-	3.15 N/mm²
Mass of reciprocating parts	-	2.25 kg
Length of connecting rod	-	380 mm
Factor of safety (FOS)	-	6
Length of dia. ratio for Big End	-	1.3
Length of dia. ratio for Small End	-	2
Bearing pressure at Big End	-	10 N/mm²
Bearing pressure at Small End	-	15 N/mm²
Allowable stress in Bolts	-	60 N/mm²
Allowable stress in Cap	-	80 N/mm²
Elastic limit in compression	-	320 N/mm²
Constant (a)	-	1/7500

3.1. Dimensions of Cross-Section of the Connecting Rod

The connecting rod is a component that is subjected to the axial compressive force which is equal to the maximum gas force acting on the piston. The compressive stress is of significant magnitude. Hence, the design of the connecting rod is as a column or a strut [1].

- For buckling, the connecting rod is four times stronger about *YY*-axis than the about *XX*-axis.
- If a rod is designed just like that it is equal resistant to buckling on both planes, then,

$$4I_{yy} = I_{xx}$$

We know that,

$$k = \sqrt{\frac{I}{A}}$$

$$k^2 = \frac{I}{A}$$

$$I = Ak^2$$

So that,

$$4\,k_{yy}^2 = k_{xx}^2$$

$$k_{yy}^2 = \frac{1}{4}\,k_{xx}^2$$

- The above relation justifies that the I-section of the connecting rod is ideally useful. While a circular cross-section for connecting rod is not suitable for buckling about the *YY*-axis [1].
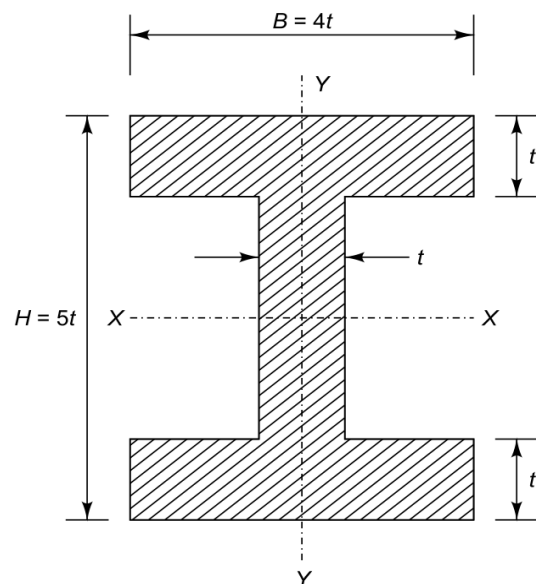

Fig -2: I – Section
Source: Design of machine elements, third edition, page no. 869, fig. 25.14

- **Moment of Inertia about *XX*-axis:**

$$I_{xx} = \frac{1}{12}(4t) \times (5t)^3 - \frac{1}{12}(4t - t) \times (5t - 2t)^3$$

$$= \frac{1}{12}(500t^4 - 81t^4)$$

$$= \left(\frac{419}{12}\right) t^4$$

$$\boldsymbol{I_{xx} = 34.91\, t^4}$$

And,

$$k_{xx}^2 = \frac{I_{xx}}{A}$$

$$= \left(\frac{419\, t^4}{12}\right) \times \left(\frac{1}{11\, t^2}\right)$$

$$k_{xx}^2 = 3.17\, t^2$$

$$\boldsymbol{k_{xx} = 1.78\, t}$$

- **Moment of Inertia about *YY*-axis:**

$$I_{yy} = 2\left[\frac{1}{12}(t) \times (4t)^3\right] + \frac{1}{12}(5t - 2t) \times (t)^3$$

$$= \frac{1}{12}(128t^4 + 3t^4)$$

$$= \left(\frac{131}{12}\right) t^4$$

$$\boldsymbol{I_{yy} = 10.91\, t^4}$$

And,

$$k_{yy}^2 = \frac{I_{yy}}{A}$$

$$= \left(\frac{131\, t^4}{12}\right) \times \left(\frac{1}{11\, t^2}\right)$$

$$\boldsymbol{k_{yy}^2 = 0.992\, t^2}$$

Therefore,

$$\frac{I_{xx}}{I_{yy}} = \frac{\left(\frac{419}{12}\right) t^4}{\left(\frac{131}{12}\right) t^4}$$

$$= \frac{419}{131}$$

$$\frac{I_{xx}}{I_{yy}} = 3.2$$

$$\boldsymbol{3.2\, I_{yy} = I_{xx}}$$

Chosen of I-section is quite satisfactory because the values of I_{xx}/I_{yy} is coming between 3 and 3.5.

- **Area of the Cross-section:**

$$A = 2(4t \times t) + (5t - 2t) \times t$$

$$= 8t^2 + 3t^2$$

$$\boldsymbol{A = 11t^2}$$

➤ **Load Acting on Connecting Rod by Gases**

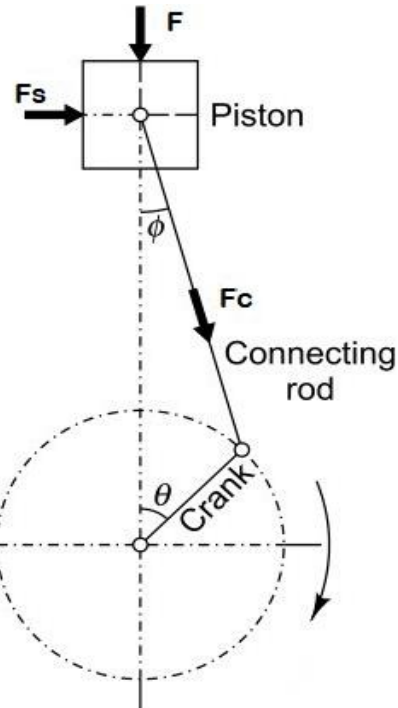A mechanism diagram of the connecting rod and crank are shown below:

Fig -3: Crank and Connecting Rod Mechanism
Source: Design of machine elements, third edition, page no. 870, fig. 25.15

$$F_C = \frac{\pi}{4} \times D^2 \times P_{max.}$$

$$= \frac{\pi}{4} \times (100)^2 \times 3.15$$

$$\boldsymbol{F_C = 24740\, N}$$

➤ **Critical Buckling Load on Connecting Rod**

$$F_{CB} = F_C \times FOS$$

$$= 24740 \times 6$$

$$\boldsymbol{F_{CB} = 148440\, N}$$

➤ **Dimensions of Cross- section**

By Rankine Formula,

$$F_{CB} = \frac{\sigma_C\, A}{1 + a\left(\frac{L}{k_{xx}}\right)^2} \qquad \therefore \text{ Due to the both ends hinged, L = l}$$

$$148440 = \frac{320 \times 11t^2}{1 + \frac{1}{7500} \times \left(\frac{380}{1.78\, t}\right)^2}$$

$$148440 \left[1 + \frac{1}{7500} \times \left(\frac{380}{1.78\,t}\right)^2\right] = 320 \times 11t^2$$

$$148440 + \frac{148440 \times (380)^2}{7500 \times (1.87)^2 \times t^2} = 320 \times 11t^2$$

$$148440 + \frac{902021.5}{t^2} = 320 \times 11t^2$$

$$148440\,t^2 + 902021.5 = 320 \times 11t^4$$

$$\frac{148440}{320 \times 11}t^2 + \frac{902021.5}{320 \times 11} = t^4$$

$$42.17\,t^2 + 256.26 = t^4$$
$$t^4 - 42.17\,t^2 - 256.26 = 0$$

The above function is a quadratic equation in terms of (t^2).

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t^2 = \frac{42.17 \pm \sqrt{(-42.17)^2 + 4 \times 1 \times 256.26}}{2 \times 1}$$

$$= \frac{42.17 \pm 52.95}{2}$$
$$t^2 = 47.56$$
$$t = 6.9 \text{ mm OR}$$
$$\boldsymbol{t = 7 \text{ mm}}$$

- The width B of the connecting rod is kept constant throughout its length.

  Width (B) $= 4\,t = 4 \times 7 = \textbf{28 mm}$

- The height H varies from the big end to the small end in the in the following way:

  i. At the middle section, Height (H) = 5 t
  H = 5 t = 5 × 7 = **35 mm**
  ii. At the small end, H1 = 0.75 H to 0.9 H
  H1 = 0.75 H = 0.85 × 35 = 29.75 mm OR
  H1 = **30 mm**
  iii. At the big end, H2 = 1.1 H to 1.25 H
  H2 = 1.1 H = 1.2 × 35 = **42 mm**

3.2. Dimensions of the Big End and Small End Bearing of Connecting Rod

➤ **Crank Pin Bearing**

$$F_C = d_C \times l_C \times (P_b)_C$$

Relation, $l_C = 1.25\,d_C$ to $1.5\,d_C$

$$F_C = d_C \times 1.3\,d_C \times (P_b)_C$$
$$24740 = d_C \times 1.3\,d_C \times 10$$
$$d_C^2 = 1903.08$$
$$d_C = 43.63 \text{ OR}$$
$$\boldsymbol{d_C = 44 \text{ mm}}$$

$$l_C = 1.3\,d_C = 1.3 \times 44$$
$$l_C = 57.2 \text{ mm OR}$$
$$\boldsymbol{l_C = 57 \text{ mm}}$$

➤ **Piston Pin Bearing**

$$F_C = d_P \times l_P \times (P_b)_P$$

Relation, $l_P = 1.5\,d_P$ to $2\,d_P$

$$F_C = d_P \times 2\,d_P \times (P_b)_P$$
$$24740 = d_P \times 2\,d_P \times 15$$
$$d_P^2 = 824.67$$
$$d_P = 28.71 \text{ mm OR}$$
$$\boldsymbol{d_P = 29 \text{ mm}}$$

$$l_P = 2\,d_P = 2 \times 29$$
$$\boldsymbol{l_P = 58 \text{ mm}}$$

3.3. Size of Bolts for Securing the Big End Cap

The maximum inertia force acting on the cap and bolts at the top dead centre during exhaust stroke. The inertia force action on cap and bolt which is given by,

$$F_I = m_r r \omega^2 \times \left[Cos\theta + \frac{Cos2\theta}{n}\right]$$

At the top dead centre position, the inertia force will be maximum. where ($\theta = 0$).
When ($\theta = 0$),
$$Cos\theta = 1 \text{ and } Cos2\theta = 1$$
So,

$$= m_r r \omega^2 \times \left[1 + \frac{1}{n}\right]$$

$$F_I = m_r r \omega^2 \times \left[1 + \frac{r}{l}\right] \qquad \therefore \quad \text{Here, n = l/r}$$

As we know, the crank radius is found by,
$$r = \frac{l}{2} = \frac{190}{2}$$
$$\boldsymbol{r = 95 \text{ mm}}$$

And then,

$$F_I = 2.25 \times 0.095 \times \left(\frac{2 \times \pi \times 1800}{60}\right)^2 \times \left(1 + \frac{0.095}{0.37}\right)$$

$$= 2.25 \times 0.095 \times 35530.58 \times 1.257$$
$$\boldsymbol{F_I = 9546.49 \ N}$$

➢ **Diameter of Bolts**

$$F_I = \frac{\pi}{4} \times (d_{CB})^2 \times n_s \times \sigma_t$$

$$9546.49 = \frac{\pi}{4} \times (d_{CB})^2 \times 2 \times 60$$

$$(d_{CB})^2 = \frac{9546.49 \times 4}{2 \times \pi \times 60}$$

$$(d_{CB})^2 = 101.29$$

$$d_{CB} = 10.064 \quad \text{OR}$$

$$\boldsymbol{d_{CB} = 10\ mm}$$

The nominal diameter (d) of the bolt is calculated by,

$$d = \frac{d_{CB}}{0.8} = \frac{10}{0.8}$$

$$d = 11.94\ mm \quad \text{OR}$$

$$\boldsymbol{d = 12\ mm}$$

3.4.   Thickness of the Big End Cap

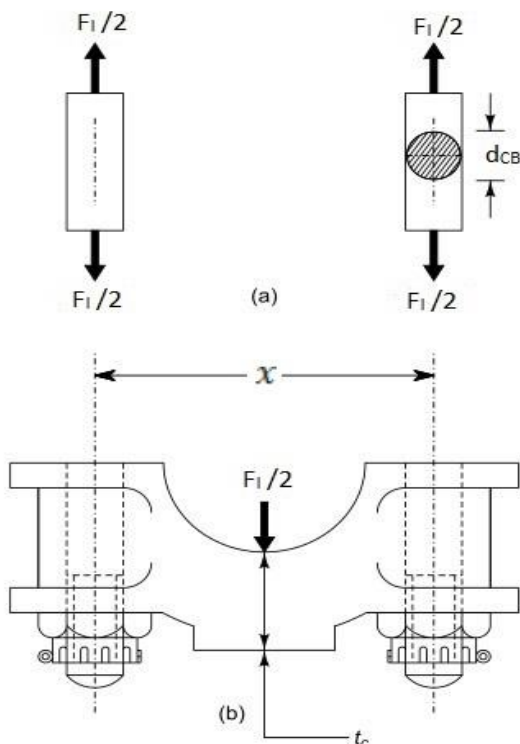The rod cap is subjected to inertia force (F_I) as mentioned in figure 4 (b).

Fig -4: Forces acting on the Cap and Bolts
Source: Design of machine elements, third edition, page no. 874, fig. 25.18

It is considered as a freely supported beam at the bolt centres and loaded in an intermediate manner between centrally concentrated load and a uniformly distributed load that have a bending moment (Wl/6) [1].

Therefore,

$$M_b = \frac{F_I \times x}{6}$$

let's find x,

$x =$ dia. of crank pin (d_C) + 2 times of thickness of bearing (3mm) + nominal dia. of bolt (d) + Clearance (3mm)

$$x = 44 + 2 \times 3 + 12 + 3$$

$$\boldsymbol{x = 65\ mm}$$

So,

$$M_b = \frac{9546.49 \times 65}{6}$$

$$\boldsymbol{M_b = 103420.3\ \text{N-mm}}$$

$$I = \frac{b_c \times t_C^3}{12} = \frac{57 \times t_C^3}{12}$$

$$I = 4.75\ t_C^3$$

And,

$$y = \frac{t_C}{2}$$

$$y = 0.5\ t_C$$

We know that,

$$Z_C = \frac{I}{y} = \frac{4.75\ t_C^3}{0.5\ t_C}$$

$$\boldsymbol{Z_C = 9.5\ t_C^2}$$

The thickness of cap (t_C) is obtained by,

$$\sigma_b = \frac{M_b}{Z_C}$$

$$80 = \frac{103420.3}{9.5\ t_C^2}$$

$$t_C^2 = \frac{103420.3}{9.5 \times 80}$$

$$t_C^2 = 136.08$$

$$t_C = 11.67\ mm \quad \text{OR}$$

$$\boldsymbol{t_C = 12\ mm}$$

4.   PROPERTIES OF MATERIALS

4.1.   Aluminium

Aluminium is obtained from mineral bauxite from which it is extracted by Bayer's process. Aluminium material can be used for manufacturing of connecting rod due to its light weight (approx. 1/3 of steel) preferred over steel material and also has high shocking absorbing capacity. It possesses superior strength ratio than steel. Aluminium alloys like aluminium 6061, aluminium 7075 can also be used instead of steel. Connecting rods made up of aluminium are also preferred in drag cars because of lightness and cheap coasting than steel.

Aluminium alloy 7075 is composed of 90.0% Al, 5.6% Zn, 2.5% Mg, 0.23% Cr, and 1.6% Cu, though these numbers nominally fluctuate depending upon manufacturing factors. That is relatively lighter than other metals [6,7].

4.2.   Steel

Steel is obtained by alloying of iron with other elements like tungsten, chromium, manganese, nickel, cobalt, titanium etc. The strength of steel depends upon the chemical composition of the alloying elements and the percentages of carbon content in it. Comparing the properties of aluminium and steel, steel is less compatible than aluminium in cold regions. Steel also corrosion resistance and the ability of steel to resist corrosion also depends upon the percentage of the alloying elements which are resistant to corrosion. Steel is advantageous for vehicles during driving, manufacturing and can be recycled. Pollution cause by steel products is comparatively low than other materials and hence environmentally effective.

Grade 4340 is one of the alloy steel-grades that name 'Nickel-Chromium-Molybdenum Steel'. Nickel helps to Increases strength & toughness and improves corrosion resistance. Chromium adds hardness in steel, increased toughness and wear resistance. Molybdenum is a major factor which is increases strength and improves resistance to shock and heat. The combination of these materials makes alloy steel 4340. This alloy steel can obtain much deeper harden-ability than 4100 series steel. High strength in heavy sections is possible with maximum toughness and ductility. This material has a high fatigue/tensile ratio and maintains strength, ductility, and toughness at relatively high temperatures. Also has excellent non-distorting properties for alloy steel.

These two materials i.e., Aluminium Alloy 7075 and Alloy Steel 4340 grade have been selected for the study of analysis. The results of the analysis of stress, strain, and total deformation will be obtained using the tools of ANSYS [8,9].

Table -1: Material Properties [10,11]

Properties	Materials	
	Aluminium Alloy 7075	Alloy Steel 4340
Ultimate Tensile Strength	572 MPa	745 MPa
Tensile Yield Strength	503 MPa	470 MPa
Shear Strength	331 MPa	430 MPa
Fatigue Strength	159 MPa	330 MPa
Young's Modulus	71.7 GPa	200 GPa
Shear Modulus	26.9 GPa	80 GPa
Machinability	70 %	50 %
Density	2.81 g/cm³	7.85 g/cm³
Poisson's Ratio	0.33	0.29

5. MODELLING OF CONNECTING ROD

PTC CREO 7.0 software has been used for modelling a
connecting rod with the calculated dimensions.

Table -2: Parameters of Connecting Rod

Parameters	Dimensions (in MM)
Outer dia. of big end	Inner dia. of big end + t_C + 2 times of thickness of bearing (3mm) = 62
Inner dia. of big end	44
Length of big end	57
Length of connecting rod	380
Outer dia. of small end	Inner dia. of small end + t_C + 2 times of thickness of bush (2mm) = 45
Inner dia. of small end	29
Length of small end	58
Width of middle section	28
Height of middle section	35
Height of middle section at big end	42
Height of middle section at small end	30
Diameter of bolt	12
Length of bolt	70
Radius of bolt's head	12
Height of bolt's head	10

Radius of nut	12
Height of nut	10

5.1. Connecting Rod

Step 1. Started PTC CREO 7.0 Software.

Step 2. Clicked on "New" then NEW dialog box open.

Step 3. Selected the PART option in Type and SOLID option in Sub-Type for creating a new model.

Step 4. To specify the sketch plane in the Model Tree, selected the datum plane TOP.

Step 5. On the Model Tab, clicked sketch in the Shapes group. Then opened an Extrude or Sketch tab for creating a sketch on a planar reference.

Step 6. Selected the CIRCLE option and drew a circle (Circle 1). (Inner dia. of big end – 44).

Step 7. Again, selected the CIRCLE option and drew a circle (Circle 2) for same centre as that of previous circle. (Outer dia. of big end – 62).

Step 8. Selected the LINE option and drew a line in the middle of the circles and also drew bolted section and then selected the DELETE SEGMENT option and trimmed the left half circle and unwanted lines of the sketch.

Step 9. Selected the EXTRUDE option and selected the remaining sketch and extruded it symmetrically. (Length of big end – 57).

Step 10. Selected the datum plane RIGHT and drew a circle on the bolt portion and then extruded it symmetrically. Then clicked on the REMOVE MATERIAL option to create a bolt's hole. (Bolt hole dia. – 12).

Step 11. Selected the previous created bolt hole in MODEL TREE and clicked the MIRROR option for creating to be the same hole on other side by selecting the FRONT plane.

Step 12. Again, selected the datum plane TOP for drew the remaining portion. Then selected the CENTERLINE option and drew a centerline from the center of the previous circle.

Step 13. Again, selected the CIRCLE option and drew a circle (Circle 3) at distance (380) from the previous circles at the same centerline. (Inner dia. of small end – 29).

Step 14. Drew another circle (Circle 4) on the centre of previous circle (Circle 3). (Outer dia. of small end – 45).

Step 15. Selected the EXTRUDE option and selected circle 3 and circle 4 and extruded it symmetrically. (Length of small end – 58).

Step 16. Similarly, again selected the datum plane TOP for drew the Rod portion of the connecting rod.

Step 17. Selected the LINE option and drew two parallel lines on both sides of the centerline and connected to circles with help of the REFERENCES option. Then drew middle section of connecting rod. (Height of middle section at big end and at small end – 42 & 30).

Step 18. Selected the DELETE SEGMENT option and trimmed the unwanted lines.

Step 19. Selected the EXTRUDE option and extruded the Rod portion symmetrically. (Width of middle section – 28).

Step 20. Selected the ROUND option to give the shapes and finishing on the edges of the connecting rod.

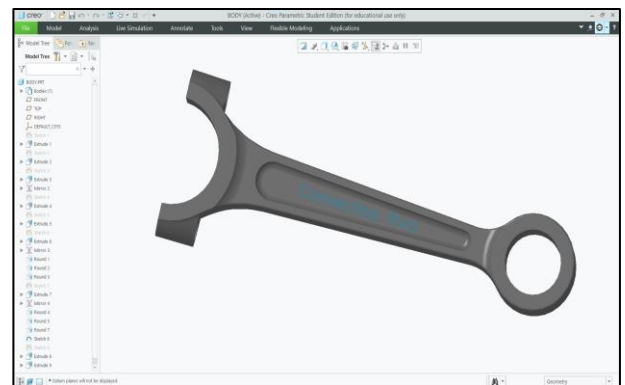**Step 21.** Saved the model as a name "Connecting Rod" using the SAVE option.

Fig -5: Connecting Rod

5.2. Rod Cap

Step 1. Clicked on "New" then NEW dialog box open.

Step 2. Selected the PART option in Type and SOLID option in Sub-Type for creating a new model.

Step 3. To specify the sketch plane in the Model Tree, selected the datum plane TOP.

Step 4. On the Model Tab, clicked sketch in the Shapes group. Then opened an Extrude or Sketch tab for creating a sketch on a planar reference.

Step 5. Selected the CIRCLE option and drew a circle (Circle 1). (Inner dia. of big end – 44).

Step 6. Again, selected the CIRCLE option and drew a circle (Circle 2) for same centre as that of previous circle. (Outer dia. of big end – 62).

Step 7. Selected the LINE option and drew a line in the middle of the circles and also drew bolted section and then selected the DELETE SEGMENT option and trimmed the right half circle and unwanted lines of the sketch.

Step 8. Selected the EXTRUDE option and selected the remaining sketch and extruded it symmetrically. (Length of big end – 57).

Step 9. Selected the datum plane RIGHT and drew a circle on the bolt portion and then extruded it symmetrically. Then clicked on the REMOVE MATERIAL option to create a bolt's hole. (Bolt hole dia. – 12).

Step 10. Selected the previous created bolt hole in MODEL TREE and clicked the MIRROR option for creating to be the same hole on other side by selecting the FRONT plane.

Step 11. Selected the ROUND option to give the shapes and finishing on the edges of the rod cap.

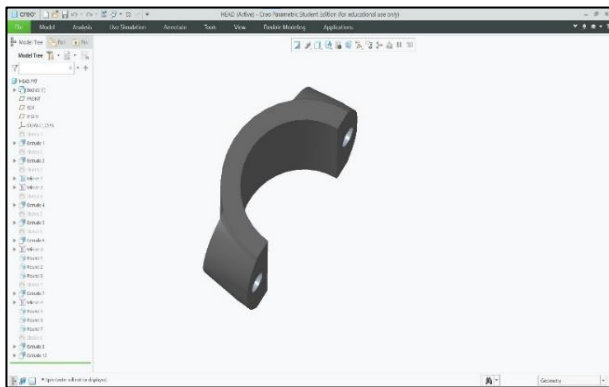**Step 12.** Saved the model as a name "Rod Cap" using the SAVE option.

Fig -6: Rod Cap

5.3. Bolt

Step 1. Clicked on "New" then NEW dialog box open.

Step 2. Selected the PART option in Type and SOLID option in Sub-Type for creating a new model.

Step 3. To specify the sketch plane in the Model Tree, selected the datum plane RIGHT. Which will make it easy to assembly.

Step 4. On the Model Tab, clicked sketch in the Shapes group. Then opened an Extrude or Sketch tab for creating a sketch on a planar reference.

Step 5. Selected the CIRCLE option and drew a circle (Circle 1). (Circle dia. – 12).

Step 6. Selected the EXTRUDE option and extruded the circle symmetrically. (Length of the bolt – 70).

Step 7. Selected the extruded surface at the right end and clicked on the SKETCH to draw the bolt's head.

Step 8. Imported pre-built "Octagon" shape using PALETTE and dragged and dropped at the centre of the extruded surface and gave the radius. (Bolt's head radius – 12)

Step 9. Selected the EXTRUDE option and extruded the Octagon sketch towards the bolt. (Height of bolt's head – 10)

Step 10. Created outside thread on the bolt surface by using the HELICAL SWEEP option.

Step 11. Selected the ROUND option to give the shapes and finishing on the edges of the bolt.

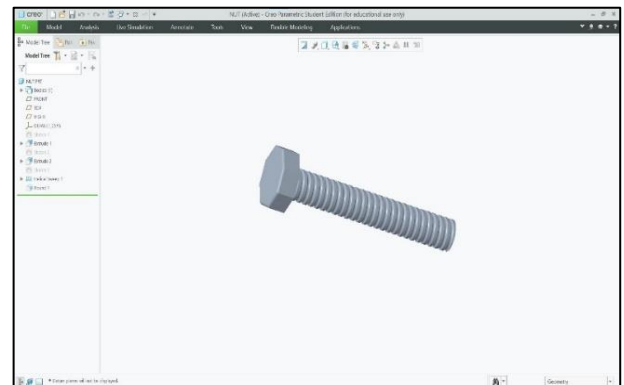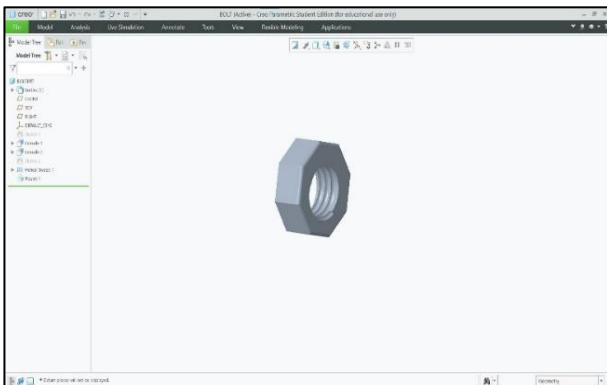**Step 12.** Saved the model as a name "Bolt" using the SAVE option.

Fig -7: Bolt

5.4. Nut

Step 1. Clicked on "New" then NEW dialog box open.

Step 2. Selected the PART option in Type and SOLID option in Sub-Type for creating a new model.

Step 3. To specify the sketch plane in the Model Tree, selected the datum plane RIGHT.

Step 4. On the Model Tab, clicked sketch in the Shapes group. Then opened an Extrude or Sketch tab for creating a sketch on a planar reference.

Step 5. Imported pre-built "Octagon" shape using PALETTE and dragged and dropped to

Graphics window and gave the radius. (Nut radius – 12)

Step 6. Selected the EXTRUDE option and extruded the Octagon sketch. (Height of Nut – 10)

Step 7. Selected the extruded surface at the right end and clicked on the SKETCH to draw a circle. (Dia. of circle – 12)

Step 8. Selected the EXTRUDE option and extruded the circle sketch symmetrically throughout the Nut, and created a hole inside the Nut by using the REMOVE MATERIAL option.

Step 9. Created inside thread in Nut by using the HELICAL SWEEP option.

Step 10. Selected the ROUND option to give the shapes and finishing on the edges of the Nut.

Step 11. Saved the model as a name "Nut" using the SAVE option.

Fig -8: Nut

6. ASSEMBLY

Step 1. Clicked on "New" then NEW dialog box open.

Step 2. Selected the ASSEMBLY under Type and DESIGN under Sub-Type for assembly the connecting rod.

Step 3. In Model Tab, Selected the ASSEMBLY option from the Component Group, then the OPEN dialog box was open.

Step 4. Imported the "Connecting Rod" part from the saved file onto the graphics window and then selected DEFAULT CONSTRAINT.

Step 5. Again, Imported the "Rod Cap" part from the saved file onto the graphics window and then coincided by selecting the front planes of both parts. After that, selected the Connecting Rod's surface and then the Rod Cap's surface for matching coincident. Its assembly completed now.
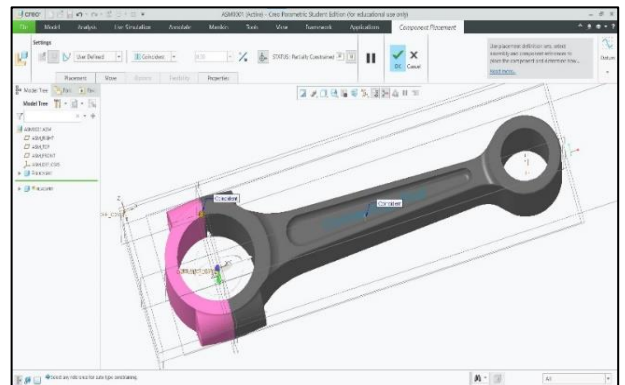

Fig -9: Assembly of Cap through matching coincident

Step 6. Imported its "Bolt" part then selected the centerlines of Bolt and Bolt's hole then it became align, after that selected the Rod Cap's surface and then Bolt's inside surface for matching coincident.

Step 7. Now, imported its "Nut" part then selected the centerlines of Bolt & Nut and it became align, after that selected the Connecting Rod's surface and then Nut's surface for matching coincident. One side Bolt assembly completed now.

Step 8. Similarly, assembled its other side's Bolt and Nut. (Repeat steps - 6 and 7)

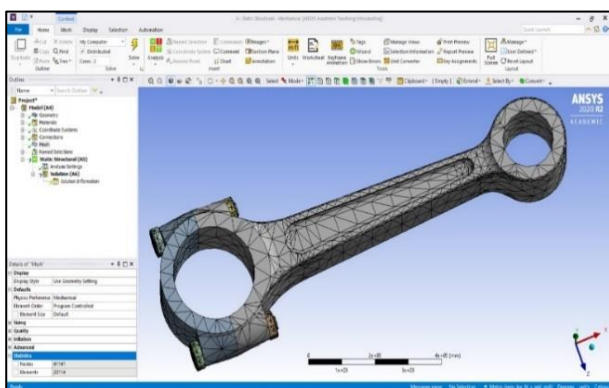**Step 9.** Saved the model as a name "Connecting Rod" using the SAVE option.

Fig -10: Assembled of Connecting Rod in PTC Creo

Step 10. Selected the SAVE AS option and save the model in ACIS FILE format for further analysis on ANSYS Software.

7. SIMULATION
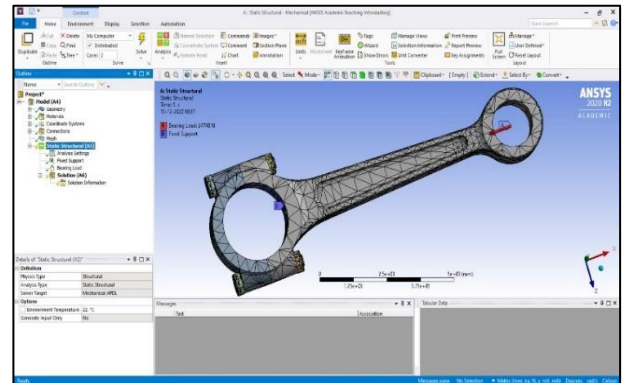
Step 1. Started Ansys Workbench.

Step 2. Double clicked on Static Structural in the toolbox window to add it to the Project Schematic window.

Step 3. Renamed the Static Structural analysis system as "Connecting Rod".

Step 4. In the connecting rod analysis system, we double clicked the "Geometry" cell; the "Design Modeler" window along with the ANSYS Workbench dialog box is displayed.

Step 5. Set the units in milimetres and imported the external geometry file of the connecting rod which designed in PTC Creo 7.0 software (As per the steps mentioned above).

Step 6. Exit the "Design Modeler" window.

Step 7. Then we defined "Engineering Data". In this section material for the current project is assigned. In ANSYS by default structural steel is selected. To assign new material we turned on the engineering data source. Then we generated new library for connecting rod and made a tick mark on the new generated library named connecting rod to convert it into edit mode. After this, we added different two materials which are kept under study. After giving all required properties for connecting rod we saved them into the Library. In the same way we saved the information about all consideration and then added all the two materials in the content by clicking on the plus sign.

Step 8. After importing the external geometry, we meshed the connecting rod. Triangle (default) meshing has been done for quick result. The numbers of nodes are 41141 and the numbers of elements are 22114.

Fig -11: Mesh Generation

Step 9. After Meshing we double clicked the "Setup" cell, where we provided fixed support and Load (Force) on connecting rod. A fixed

support has applied to the big end and a bearing load of 24740N has applied to the small end of the connecting rod for both materials condition.
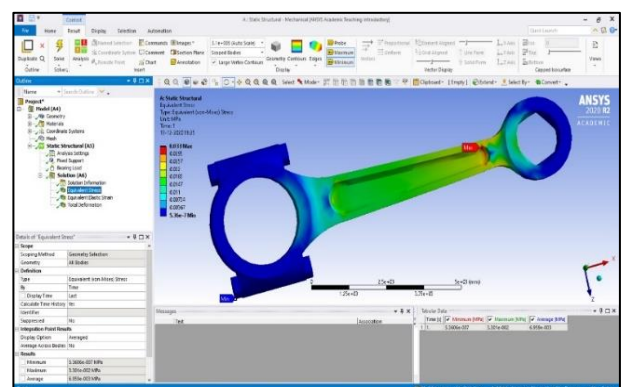
Fig -12: Applied bearing load and fixed support to the connecting rod

Step 10. After providing force and fixed support to the connecting rod, we double clicked the "Solution" cell; where the solutions to be obtained from ANSYS Workbench were found.

Step 11. Then the various results such as equivalent stress, equivalent strain, and deformation were obtained.

8. RESULTS

8.1. Aluminium Alloy 7075
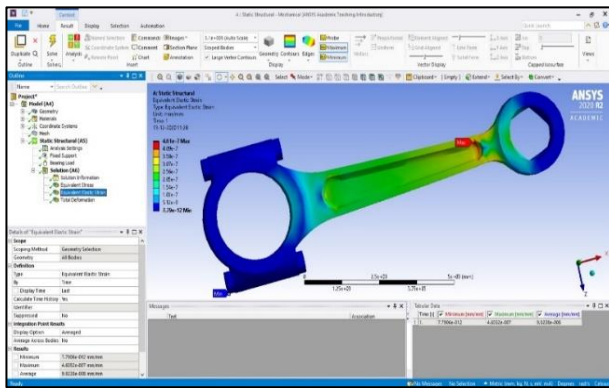
Fig -13: Equivalent (Von-Mises) Stress
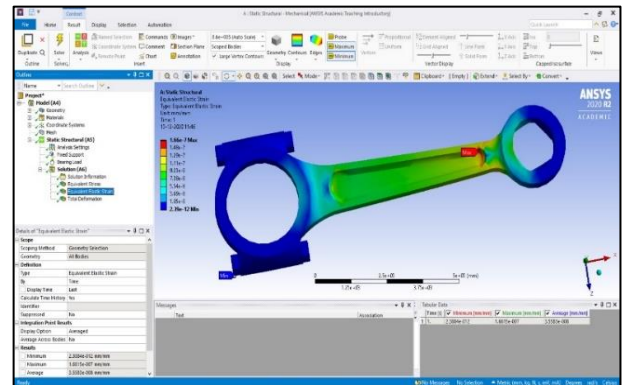
Fig -14: Equivalent (Von-Mises) Elastic Strain

Fig -15: Total Deformation

Table -3: Result of Aluminium Alloy 7075

Load applied = 24740 N		
Name	**Maximum**	**Minimum**
Stress	0.0330 MPa	5.36 x 10^{-7} MPa
Elastic Strain	4.61 x 10^{-7}	7.79 x 10^{-12}
Total Deformation	0.00229 mm	0

8.2.　Alloy Steel 4340

Fig -16: Equivalent (Von-Mises) Stress

Fig -17: Equivalent (Von-Mises) Elastic Strain

Fig -18: Total Deformation

Table 4: Result of Alloy Steel 4340

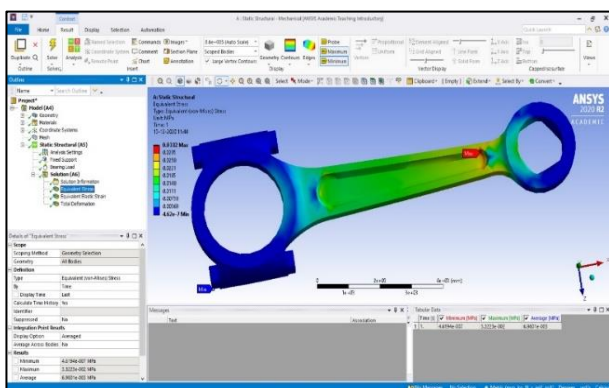| Load applied = 24740 N		
Name	**Maximum**	**Minimum**
Stress	0.0332 MPa	4.36 x 10^{-7} MPa
Elastic Strain	1.66 x 10^{-7}	2.39 x 10^{-12}
Total Deformation	0.000824 mm	0

9.　CONCLUSION

A connecting rod is subjected to large and repetitive axial as well as compressive load by the gas pressure on the piston, due to this the failure takes place in the connecting rod. Most commonly damage occurring in the connecting rod is deformation. The results of the simulation of connecting rod for two different materials is shown [12]:

Table -5: Comparison of Simulation Results

Material	Stress (MPa)		Strain		Total Deformation (mm)	
	Max	Min	Max	Min	Max	Min
Aluminium Alloy 7075	0.0330	5.36×10^{-7}	4.61×10^{-7}	7.79×10^{-12}	0.00229	0
Alloy Steel 4340	0.0332	4.36×10^{-7}	1.66×10^{-7}	2.39×10^{-12}	0.000824	0

The connecting rod made of alloy steel 4340 has a slightly higher maximum stress of 0.0332MPa as compared to an aluminium alloy 7075 that is 0.0330MPa. The connecting rod made of Aluminium Alloy 7075 has a higher maximum deformation of 0.00229mm as compared to an alloy steel 4340 that is 0.000824mm. In addition, the connecting rod made of aluminium alloy 7075 has a higher maximum strain of 4.61 x 10-7 as compared to an alloy steel 4340 that is 1.66 x 10-7.

We have noticed from the above discussion that if the stress is the main factor in the material, then I will prefer Aluminium Alloy 7075 because in this material stress is produced slightly less as compared to the alloy steel 4340. If we have neglect stress and the main factor is deformation then alloy steel 4340 is the best material for the connecting rod. In addition, if slightly stresses difference is neglected, and assume stress in alloy steel 4340 is almost equal to the stress in aluminium alloy 7075, then the overall comparison shows that alloy steel 4340 is the best material for connecting rod [13,14].

10. FUTURE SCOPE

i. The whole analysis can be repeated with more material used for connecting rods.

ii. The vibration analysis of connecting rod can be helpful for further study of the vibrations produced in the engine.

iii. Transient structure can be done instead of the static structure of the connecting rod.

iv. Determine dynamic analysis and buckling load of the connecting rod.

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ABBREVIATION

I	Moment of inertia of cross-section
k	Radius of gyration
t	Thickness of connecting rod
A	Cross-section area of connecting rod
F	Force acting on piston due to pressure
F_S	Side thrust on the cylinder wall
F_C	Force acting on connecting rod
$\emptyset$	Angle of inclination of connecting rod with line of stroke
θ	Angle of inclination of crank from top dead centre position
F_{CB}	Critical buckling load

σ_c	Compressive yield stress
L	Length of connecting rod
k_{xx}	Radius of gyration about XX axis
d_C	Diameter of the crank pin
l_C	Length of the crank pin
$(P_b)_C$	Allowable bearing pressure for the crank pin bush
d_P	Diameter of the piston pin
l_P	Length of the piston pin
$(P_b)_P$	Allowable bearing pressure for the piston pin bush
F_I	Inertia force on the cap or bolts
m_r	Mass of reciprocating parts
r	Crank radius
ω	Angular speed of the engine
n	Ratio of length of the connecting rod to the crank radius
l	Length of stroke
d_{CB}	Core diameter of bolts
n_s	Number of bolts
σ_t	Permissible tensile stress for bolt
d	Nominal diameter of bolts
M_b	Bending moment acting on cap
x	Span length or distance between the bolt centres
b_C	Width of cap; equal to the length of big end bearing (l_C)
t_C	Thickness of big end cap
Z_C	Section modulus
σ_b	Whipping stress

BIOGRAPHIES

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