Machine Design –II

IC Engine Components Design

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IC Engine Components Overview

- Introduction .
- Components of IC engine & its Function.
- Design of Cylinder liners, cylinder head, number of studs
- Design of Piston
- Design of connecting rod
- Design of crankshaft
- Valve gear mechanism

Engine components and its function

Cylinder head

The main function of cylinder is to guide the piston.

Material :

- Grey cast iron – Wear and Corrosion
- Aluminium alloy – Aluminium –silicon - Better casing properties

Cast iron is mainly used because of the following advantages:

- It is a good foundry material
- It has high machinability
- It does not wrap under the high temperature and pressures developed in the cylinders
- Due to its slightly porous nature, it retains better the lubricating oil film
- It does not wear too much
- It has sound - damping properties
- It has a low value of coefficient of thermal expansion
- It is relatively cheap.

Cylinder head

- The main function of cylinder head is to seal the cylinder block and not to permit entry and exit of gases on cover head valve engine.

Types:

- Loop flow type cylinder head
- Off set cross – flow type cylinder head
- In-line cross-flow type cylinder head

Pistons & Piston rings

Functions:

- To transmit the force of explosion to the crankshaft.
- To form a seal so that the high pressure gases in the combustion chamber do not escape in to the crankcase.
- To serve as guide and a bearing for small end of the connecting rod.

Material:

Cast iron and aluminium alloy (Aluminium – silicon)

Piston rings

Functions:

- Prevention of leakage of gas into the crank case.
- Prevention of lubricating oil film
- Prevention of lubricant entry into the combustion chamber above the piston head.
- Removing unnecessary and excessive lubricating oil from cylinder wall.
- Prevention of carbon deposit and other impurities.
- Easy transmission of heat from piston to cylinder wall.
- Balancing of side thrust of the piston

Piston rings are made of cast iron of fine grain and high elastic material which is not affected by the working heat. Sometimes it is made by alloy spring steel.

Compression ring , Oil ring

Connecting rod

The function of connecting rod is to convert the reciprocating motion of the piston in to the rotary motion of the crankshaft.

Material:

- Drop forging of steel or duralumin.
- Malleable or Spheroidal graphite cast iron.

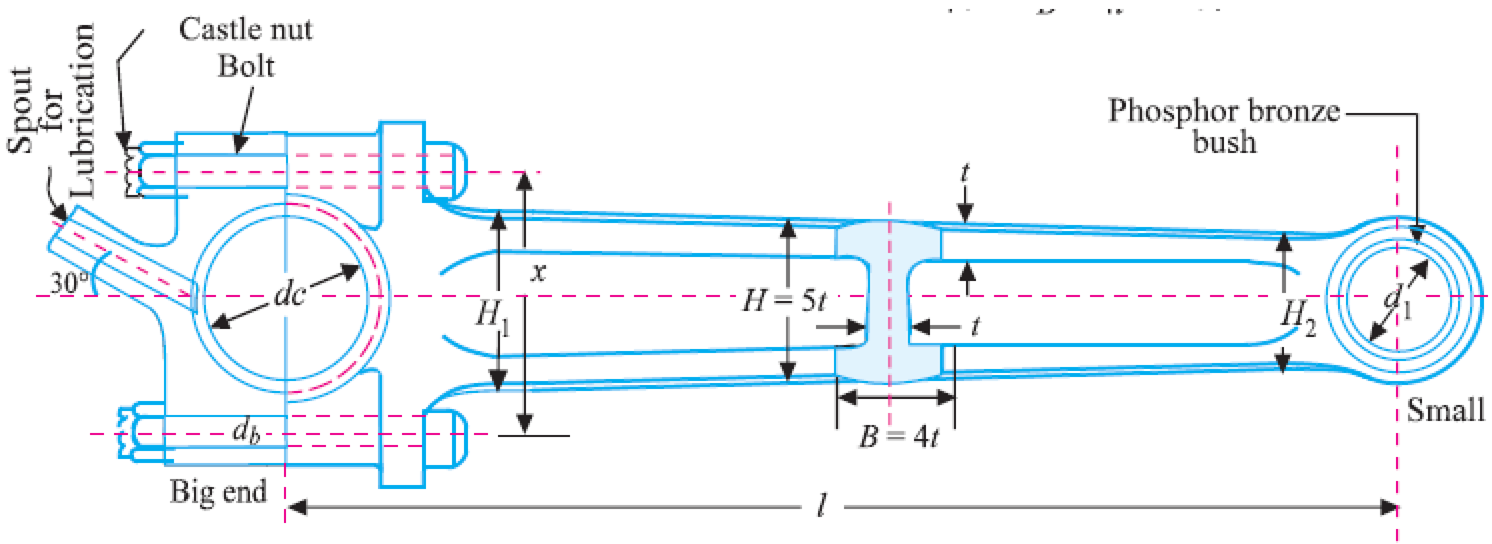
Why I section is Preferred to round section ??

High speed engine – **weight reduction** is important .

I section have **higher section modules** per unit area as compared to circular elliptical or rectangular sections- better resistance bending as well as buckling.

I-section connecting rod has less mass as compared to rectangular connecting rod **bearing pressure is reduced** due to less mass.

higher moment of inertia- reduced the vibration of connecting rod and also reduced side thrust acting on the cylinder.
Easy to manufacture compared to other section .

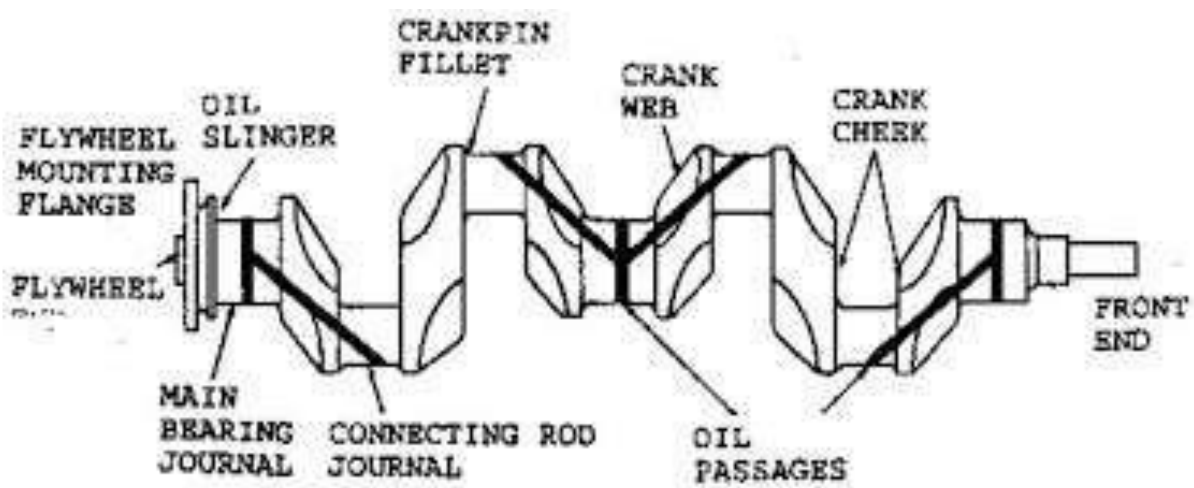


Crank shaft

The function of crank shaft is receives the efforts or thrust supplied by piston to the connecting rod and converts the reciprocating motion of piston into rotary motion of crankshaft

Material:

- Forging steel
- Spheroidal graphitic
- Nickel alloy castings



Crankcase (or) Oil sump (or) Oil pan

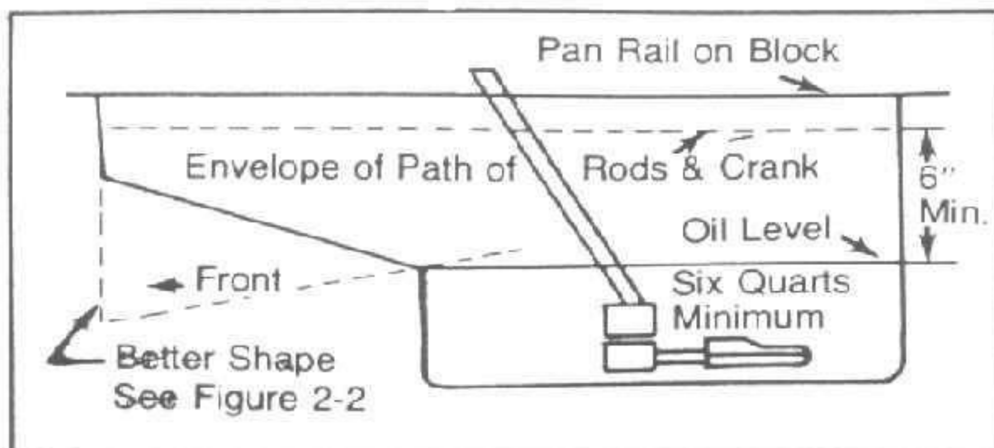
The main body of the engine to which the cylinder are attached and which contains the crankshaft and crankshaft bearing is called crankcase.

Function:

- To store the oil for the engine lubricating system.
- To collect the return oil draining from the main bearings or from the cylinder walls.
- To serve as a container in which any impurities or foreign matter.
- To enable the hot churned up lubricating oil to settle for a while before being circulated.
- To provide for cooling of the hot oil in the sump by transfer of heat to the outside air stream.

Material:

- Pressed steel sheet
- Aluminium alloy casting (stiffness & rigidity) – higher thermal conductivity.

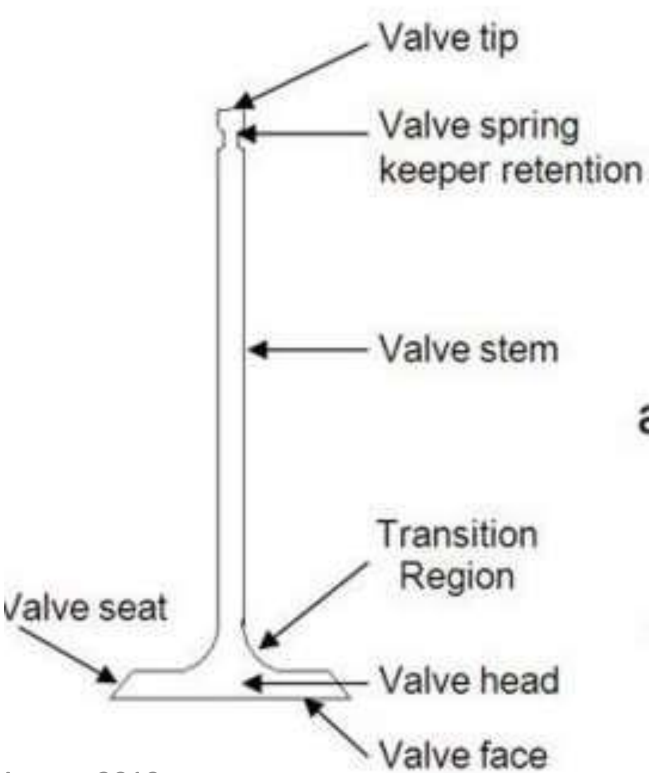


Pan Rail on Block
Envelope of Path of Rods & Crank
6" Min.
Oil Level
Front
Six Quarts Minimum
Better Shape
See Figure 2-2

FIGURE 2-1

Valves

- To control the inlet and exhaust of internal combustion engine, valves are used.
- Two valves are used for each cylinder one for inlet of air-fuel mixture inside the cylinder and other for exhaust of combustion gases.



Spark plug

- It is used in spark ignition engine. The main function of a spark plug is to conduct the high potential from the ignition system into the combustion chamber to ignite the compressed air fuel mixture.

Injector

- Injector is usually used in compression ignition engine. It sprays the fuel into combustion chamber at the end of compression stroke. It is fitted on cylinder head.

Manifold

- The main function of manifold is to supply the air fuel mixture and collects the exhaust gases equally form all cylinder.
- In an internal combustion engine two manifold are used, one for intake and other for exhaust.
- They are usually made by aluminium alloy.

Camshaft

- Camshaft is used in IC engine to control the opening and closing of valves at proper timing.
- It is drive by the timing belt which drives by crankshaft.
- It is placed at the top or at the bottom of cylinder.
- They are usually made by cast iron with an addition of 1% chrome.

Flywheel

- The main function of flywheel is to rotate the shaft during preparatory stroke.
- It also makes crankshaft rotation more uniform.

They are usually made by cast iron.

Design of Cylinder

- Step -1 **Bore (D) & length (L) of cylinder liner**

$$\mathrm{IP} = \frac{\mathrm{BP}}{\eta} \qquad \mathrm{IP} = \frac{p_m l A n}{60} \qquad A = \left(\frac{\pi D^2}{4}\right)$$

- Step -2 **Thickness of cylinder liner (t_c)** $\sigma_c = \sigma_t = \frac{S_{ut}}{(fs)}$

$$\sigma_c = \frac{p_{\max.} D}{2t} \qquad \sigma_l = \frac{p_{\max.} D^2}{(D_o^2 - D^2)} \qquad (\sigma_c)_{\mathrm{net}} = \sigma_c - \mu\sigma_l \quad (\sigma_l)_{\mathrm{net}} = \sigma_l - \mu\sigma_c \qquad t = \frac{p_{\max.} D}{2\sigma_c} + C$$

- step -3 **Thickness of cylinder head (t_h)** $t_h = D\sqrt{\frac{K p_{\max.}}{\sigma_c}}$ $\sigma_c = \sigma_t = \frac{S_{ut}}{(fs)}$

- Step -4 **No of studs ($z = Z_{min} + Z_{max}/2$), nominal dia of stud , pitch of studs**

$$\sigma_t = \frac{S_{yt}}{(fs)}$$

$$\text{Minimum number of studs} = 0.01D + 4$$

$$\text{Maximum number of studs} = 0.02D + 4$$

$$\left(\frac{\pi}{4}\right) D^2 p_{\max} = \left(\frac{\pi}{4}\right) d_c^2 z \sigma_t$$

Design of Cylinder

Assumptions for Designing cylinder liner , head , studs

- Length of cylinder liner (L) is 15 % greater than stroke length(l)

  L= 1.15 l

- Mechanical Efficiency is assumed **80 %** if not given

- Number of cycle **n= N/2** for 4-stroke engine
- Number of cycle **n= N** for 2-stroke engine

- For thickness of cylindrical head (t_h) take **K= 0.162** (constant)
- For studs ,

$$d = \frac{d_c}{0.8} \qquad \text{Pitch circle diameter of studs } (D_p) = D + 3d$$

Numerical –Design of cylinder

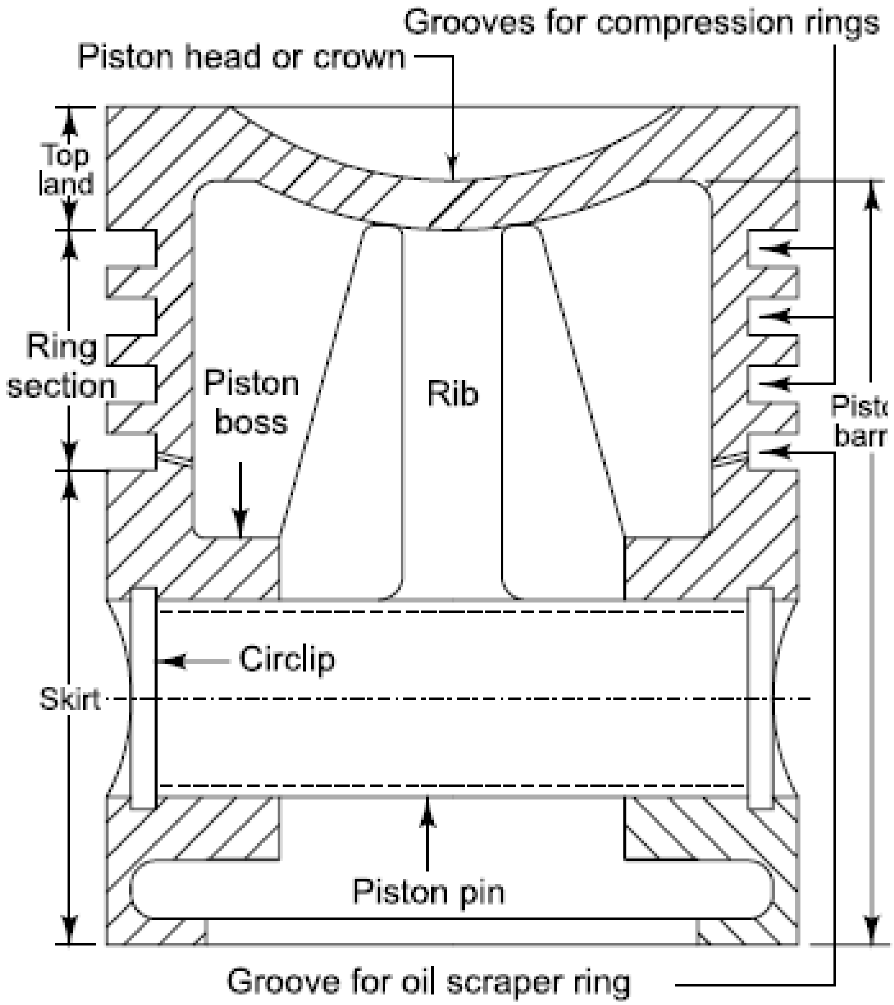
A four stroke diesel engine has the following specifications :
Brake power = 5 kW ; Speed = 1200 r.p.m. ; Indicated mean effective pressure = 0.35 N / mm ^{2} ;
Determine :

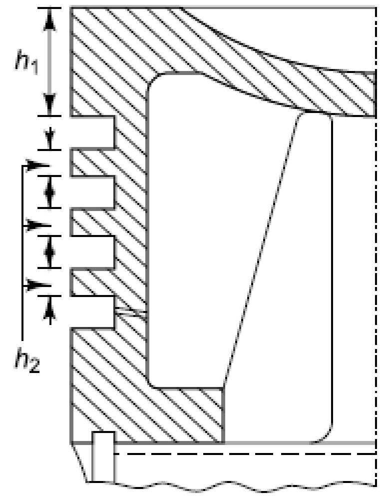
1. bore and length of the cylinder
2. thickness of the cylinder head
3. No of studs , pitch dia & nominal dia of studs

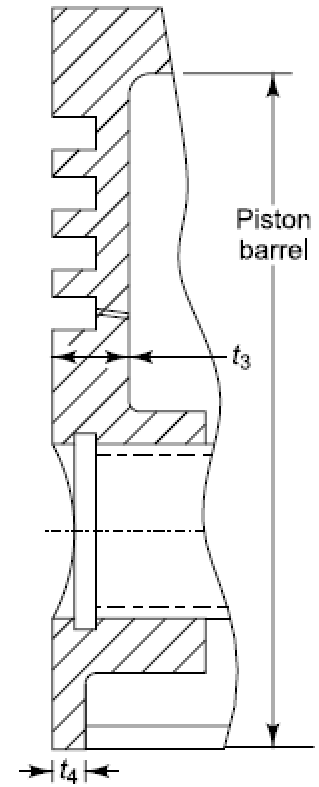
Table 32.1. Allowance for reboring for I. C. engine cylinders.

D (mm)	75	100	150	200	250	300	350	400	450	500
C (mm)	1.5	2.4	4.0	6.3	8.0	9.5	11.0	12.5	12.5	12.5

Design of Piston







Design of Piston

- Step -1 **Thickness of piston head**

$$\sigma_t = \frac{S_{ut}}{(fs)} \qquad t_h = D\sqrt{\frac{3}{16}\frac{p_{max.}}{\sigma_b}}$$

- Step -2 **Thickness of piston head by thermal consideration**

$$t_h = \left[\frac{H}{12.56k(T_c - T_e)}\right]\times 10^3 \qquad H = [C \times \text{HCV} \times m \times \text{BP}] \times 10^3$$

- step -3 **Take greater among step-1 & step-2**

- Step **-4 Ribs & cup**

$$t_h \le 6 \text{ mm} \quad (\text{ no ribs})$$
$$t_h > 6 \text{ mm} \quad (\text{provide ribs})$$

$$t_R = \left(\frac{t_h}{3}\right) \text{to} \left(\frac{t_h}{2}\right)$$

$$(l/D) \le 1.5 \text{ (cup required)}$$
$$(l/D) > 1.5 \text{ (no cup required)}$$

$$\text{radius of cup} = 0.7D$$

Design of Piston

Assumptions for Designing cylinder liner , head , studs

- Ribs are required if thickness of piston head is more than 6 mm
- If (l/D) ratio is less than 1.5 cup is required .
- Calorific value & mass of fuel

For diesel, $\quad HCV = 44 \times 10^3$ kJ/kg
For petrol, $\quad HCV = 47 \times 10^3$ kJ/kg

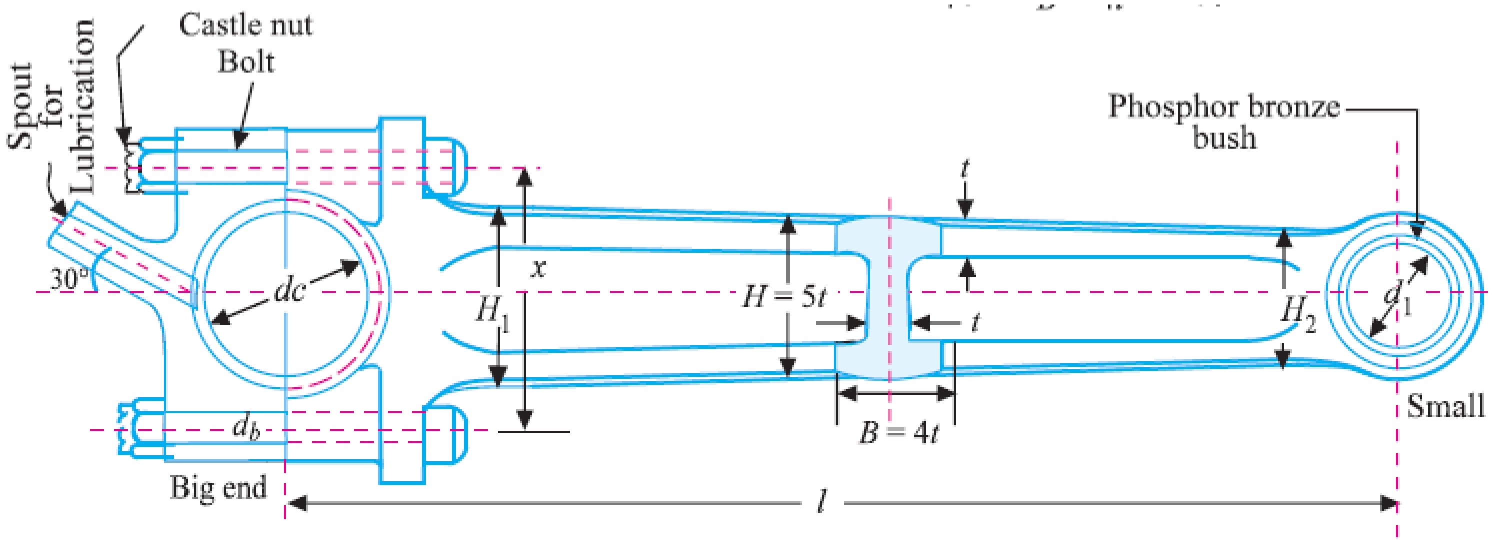
$$m = \left[\frac{0.24 \text{ to } 0.3}{60 \times 60}\right] \text{kg/kW/s}$$

Numerical –Design of Piston

The following data is given for a four-stroke diesel engine:
Cylinder bore = 250 mm; Length of stroke = 300 mm
Speed = 600 rpm ;Indicated mean effective pressure = 0.6 Mpa
Maximum gas pressure = 4 MPa
Fuel consumption = 0.25 kg per BP per h
Higher calorific value of fuel = 44 000 kJ/kg .The piston is made of grey cast iron FG 200 (Sut = 200 N/mm^2 and k = 46.6 W/m/°C) and the factor of safety is 5.
The temperature difference between the centre and the edge of the piston head is 220°C.
Determine (i) Thickness of cylinder head
(ii) Ribs & cup are required or not ? If yes find radius of cup

Design of connecting rod

- Step -1 **cross section of rod (t, B, H)**
- It fails under bucking so taking bucking load **(Pcr)**



$$P_{cr} = \frac{\sigma_c A}{1 + a\left(\frac{L}{k_{xx}}\right)^2}$$

$A = 11t^2$ $k_{xx} = 1.78t$ $a = \frac{1}{7500}$ $\sigma_c = 330 \text{ N/mm}^2$

$$P_{cr} = P_c\,(fs) \qquad P_c = \left(\frac{\pi D^2}{4}\right) p_{max.}$$

$B = 4t$
$H = 5t$

Design of connecting rod

- Step -2 **Dia of bolts for Cap**

$$r = \left(\frac{l}{2}\right)$$

$$n_1 = \left(\frac{L}{r}\right)$$

$$\omega = \left(\frac{2\pi N}{60}\right)$$

$$(P_i)_{max.} = m_r \omega^2 r \left[1 + \frac{1}{n_1}\right]$$

$$(P_i)_{max.} = 2\left(\frac{\pi d_c^2}{4}\right)\sigma_t$$

$$d = \left(\frac{d_c}{0.8}\right)$$

- Step -3 **Thickness of Cap**

$$\sigma_b = \frac{M_b y}{I}$$

$$I = \left[\frac{(b_c)(t_c)^3}{12}\right]$$

$$y = \left(\frac{t_c}{2}\right)$$

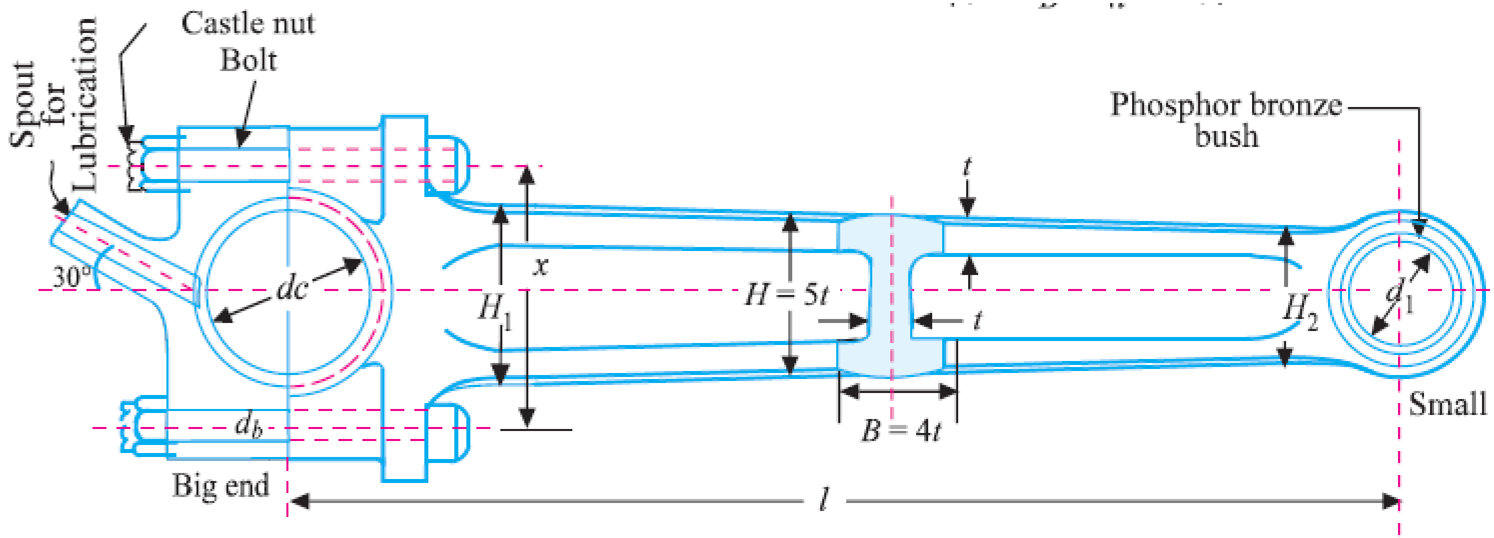
$$\sigma_t = \frac{S_{yt}}{(fs)}$$

l = diameter of crank pin + 2 (thickness of bush) + nominal diameter of bolt (d) + clearance (3 mm)

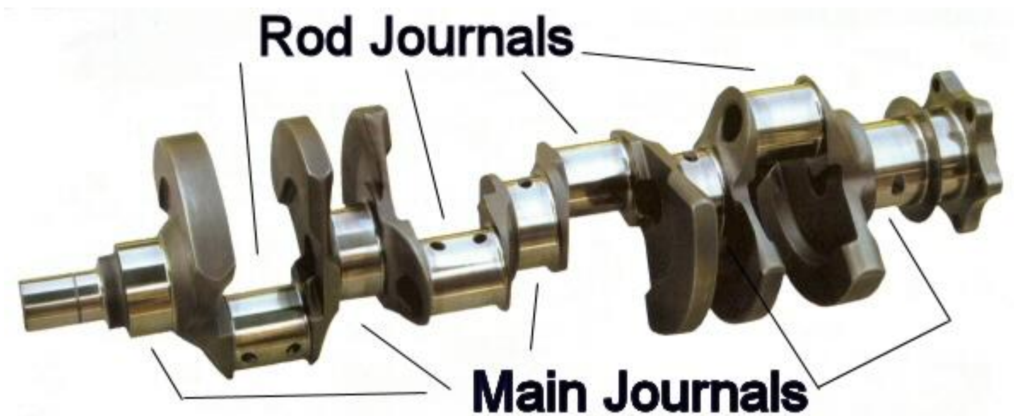
Numerical –Design of connecting rod

Design a connecting rod for a high-speed IC engine using the following data: Cylinder bore = 125 mm; Length of connecting rod = 300 mm Maximum gas pressure = 3.5 MPa; Length of stroke = 125 mm; Mass of reciprocating parts = 1.6 kg ;Engine speed = 2200 rpm .

Calculate (i) Cross section of connecting rod (ii)Nominal Dia of bolts for the cap (iii) Thickness of cap



Design of Crankshaft

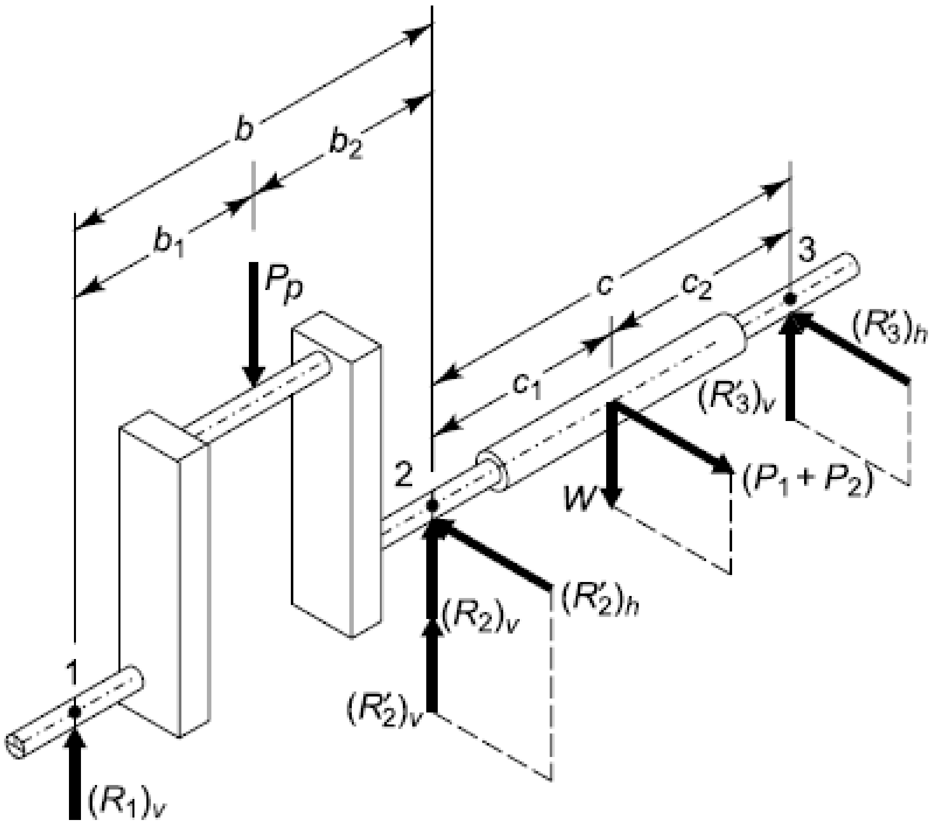


Design is based on two cases –

(i) For maximum bending – top dead & bottom dead centre position

(ii) For maximum twisting – at some angle of rotation

Design of Crankshaft (case-1)



b = 2 d , as symmetric

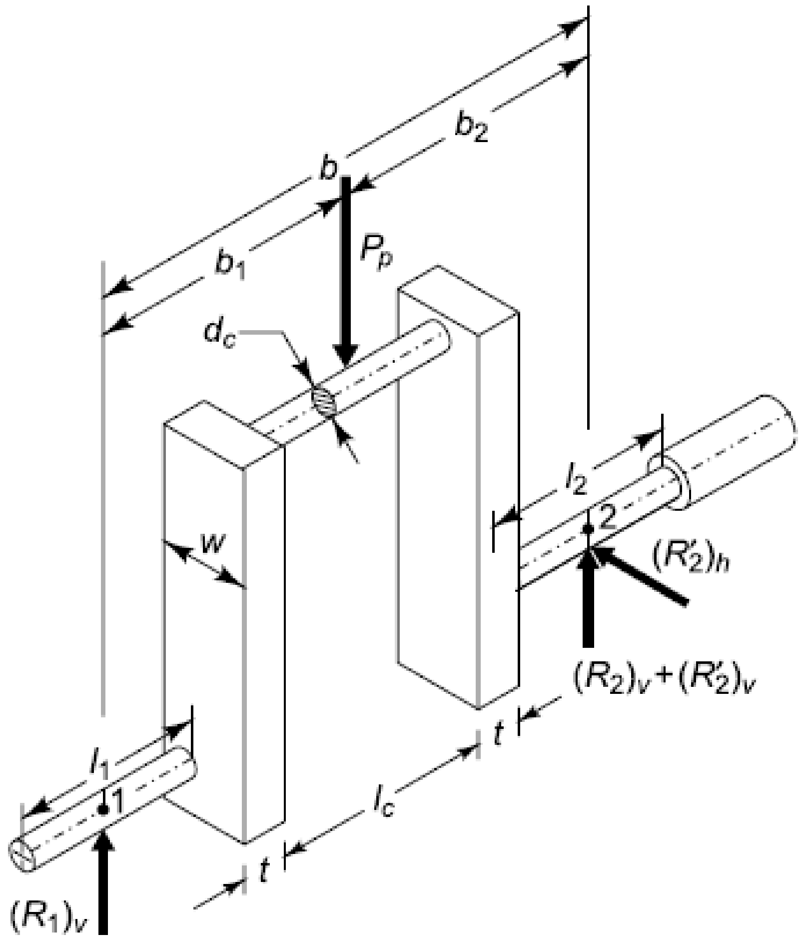
$b_1 = b_2 = d$ & $C_1 = C_2$

$$R_1 = (R_1)_v$$

$$R_2 = \sqrt{[(R_2)_v + (R_2')_v]^2 + [(R_2')_h]^2}$$

$$R_3 = \sqrt{[(R_3')_v]^2 + [(R_3')_h]^2}$$

Design of Crankshaft (case -1)



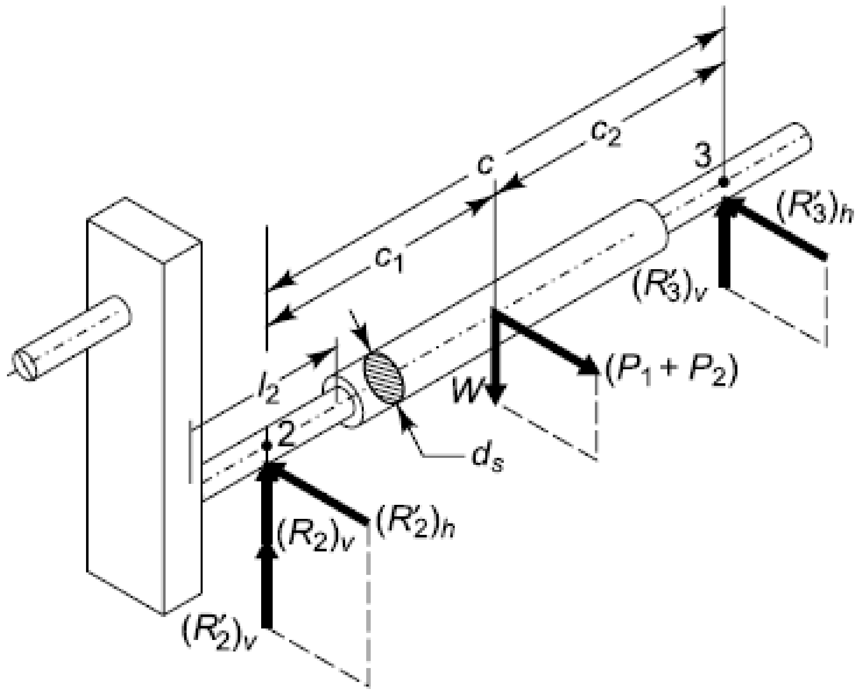
Design of Web (Left & Right)

$$(M_b)_c = (R_1)_v b_1$$

$$(M_b)_c = \left(\frac{\pi d_c^3}{32}\right)\sigma_b$$

$$t = 0.7\, d_c$$
$$w = 1.14\, d_c$$

Design of Crankshaft (case -1)



Design of shaft under flywheel

$$M_b = \left(\frac{\pi d_s^3}{32}\right)\sigma_b$$

$$(M_b)_v = (R'_3)_v\, c_2$$

$$(M_b)_h = (R'_3)_h\, c_2$$

$$M_b = \sqrt{(M_b)_v^2 + (M_b)_h^2}$$
$$= \sqrt{[(R'_3)_v c_2]^2 + [(R'_3)_h c_2]^2}$$

Design of Crankshaft

Case -1

Step -1 Reaction forces , Crank radius r= l/2

$$(R_2)_v = \frac{P_p \times b_1}{b} \qquad (R_3')_v = \frac{W \times c_1}{c} \qquad (R_3')_h = \frac{(P_1 + P_2) \times c_1}{c}$$

$$(R_1)_v = \frac{P_p \times b_2}{b} \qquad (R_2')_v = \frac{W \times c_2}{c} \qquad (R_2')_h = \frac{(P_1 + P_2) \times c_2}{c}$$

Step -

$$I = \left(\frac{\pi d_c^4}{64}\right) \qquad y = \left(\frac{d_c}{2}\right) \text{ and } \sigma_b = \frac{(M_b)_c\, y}{I}$$

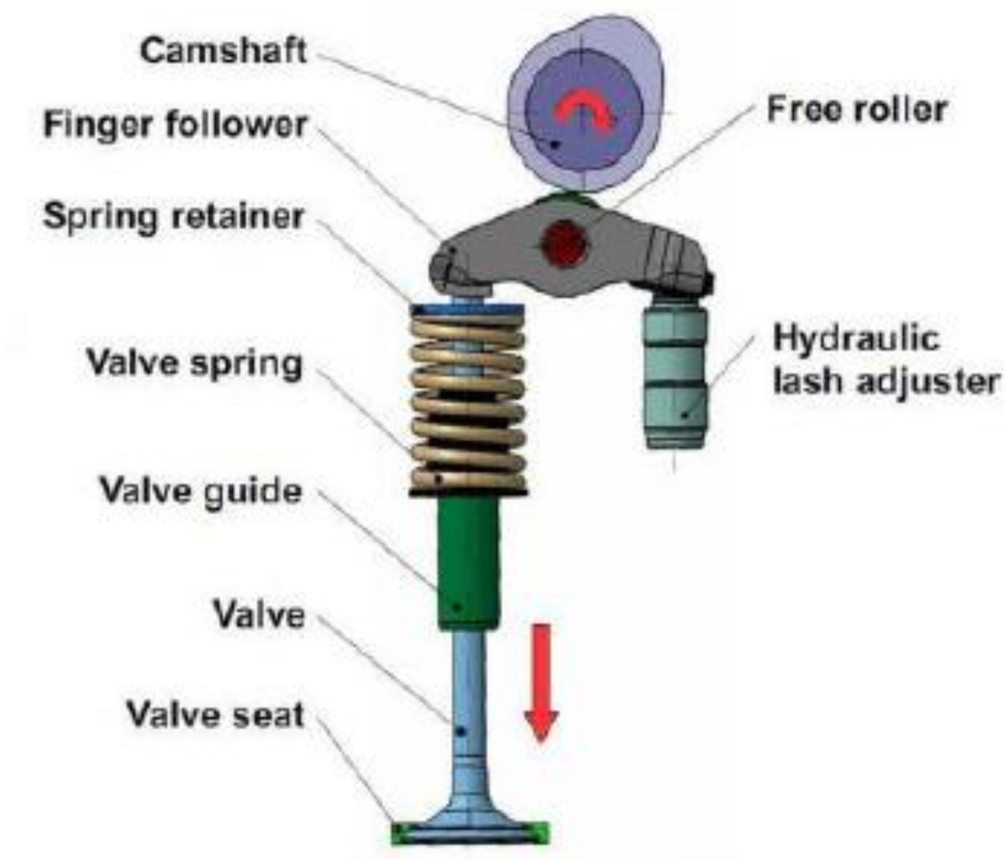
Step -3 Design of Web (Left & Right)

Step -4 Design of shaft under flywheel (belt drive & flywheel)

Numerical –Design of Crankshaft

Design a centre crankshaft for a single-cylinder vertical engine using the following data for the crank is at the top dead centre :
Cylinder bore = 125 mm;(L/r) ratio = 4.5 ;Maximum gas pressure = 2.5 Mpa ; Length of stroke = 150 mm; Weight of flywheel cum belt pulley = 1 kN; Total belt pull = 2 KN; Width of hub for flywheel cum belt pulley= 200 mm. The torque on the crankshaft is maximum when the crank turns through 25° from the top dead centre and at this position the gas pressure inside the cylinder is 2 MPa. The belts are in the horizontal direction.

Valve gear mechanism



Valve gear mechanism

Valve Mechanism means simply the sequence of **operation** of opening and closing of the **valve**. ... In a four-stroke **internal combustion engine**, the “Poppet **Valve**” performed the opening of the cylinder to inlet or exhaust manifold at the correct moment.

In the valve mechanism, the valve spring plays an important role in the system dynamics and its accurate modeling is required. A multi-body model makes it possible to study the dynamic behavior of the timing system, considering the elasticity of the bodies and evaluating the stress, strain and vibration states of the components under different operating conditions in a more accurate way.