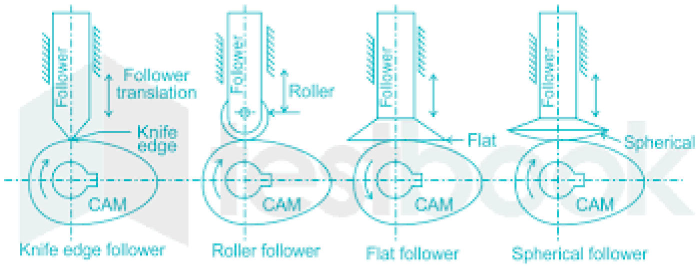
CO4(DAC)

Followers and cams are essential components in mechanical systems designed for converting rotary motion into reciprocating or oscillatory motion. They are commonly used in various applications, including engines, machines, and manufacturing equipment. Here's a classification and comparison of followers and cams:

Classification of Followers and Cams:

Followers:

Follower Types:



Different types of follower

1. **Knife-Edge Follower**: This type of follower has a sharp, knife-like edge that makes point contact with the cam profile.
2. **Roller Follower:** Roller followers have a cylindrical or conical roller at the end that rolls along the cam profile, reducing friction.
3. **Flat-Faced Follower:** Flat-faced followers have a flat surface that maintains contact with the cam profile.

Cams:

Cam Types:

1. **Disk or Plate Cams**: These cams are flat, disk-shaped components with the cam profile cut into their surface.
2. **Cylindrical Cams:** Cylindrical cams have a curved, cylindrical shape with the cam profile cut into the surface.
3. **Translating or Linear Cams:** These cams move linearly to create motion in the follower without rotation.
4. **Heart-Shaped Cams:** Heart-shaped cams have a profile resembling a heart and are used for specific applications requiring varying follower motion.

Comparison of Followers and Cams:

1. Purpose:

Followers: Followers are the components that directly contact the cam and experience the motion generated by the cam profile.

Cams: Cams are the components with specially shaped profiles that determine the motion of the follower.

2. Contact:

Followers: Followers are in direct contact with the cam profile and experience the motion, which may involve sliding or rolling contact.

Cams: Cams do not directly contact the follower but provide the guiding profile that dictates the follower's motion.

3. Types and Shapes:

Followers: Followers come in different types, such as knife-edge, roller, and flat-faced, depending on the application's requirements.

Cams: Cams also come in various types and shapes, including disk, cylindrical, translating, and heart-shaped cams, each suitable for specific motion requirements.

4. Friction:

Followers: The type of follower (e.g., roller follower) can reduce friction between the follower and the cam, leading to smoother operation.

Cams: Cams themselves do not experience significant friction but may affect the friction between the follower and the surface they move on.

5. Precision and Control:

Followers: The choice of follower type can affect the precision and control of the motion. Roller followers, for example, provide smoother and more precise motion.

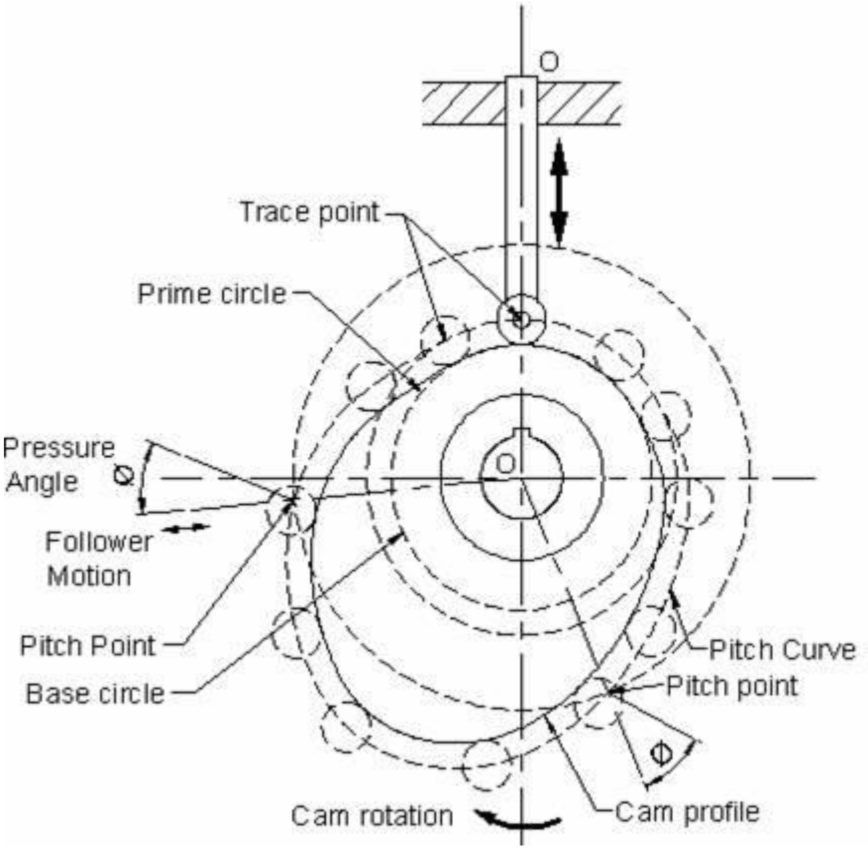
Cams: The cam profile shape and design determine the motion characteristics, allowing for precise control over the follower's movement.

6. Applications:

Followers: Followers are used in various applications, including engines (e.g., valve lifters), manufacturing (e.g., CNC machines), and automation (e.g., robotic arms).

Cams: Cams are employed in mechanisms where controlled and specific motion patterns are required, such as in automated machinery, textile production, and automotive systems (e.g., camshafts).

Certainly, here's an explanation of the key terminology associated with cams:



1. **Cam:** A cam is a mechanical component with an irregularly shaped surface, known as the cam profile, which is designed to impart specific motion or displacement to a follower.

2. **Cam Profile:** The cam profile refers to the contour or shape of the cam's surface. It determines the motion that will be transmitted to the follower as the cam rotates.

3. **Follower:** The follower is a component that makes contact with the cam's surface and follows its contour as the cam rotates. The follower is typically connected to a linkage or another mechanical component to transmit the desired motion.

4. **Base Circle:** The base circle is the smallest circle that can be drawn around the center of the cam. It represents the portion of the cam profile where there is no change in the follower's position or motion.

5. **Pitch Circle:** The pitch circle is an imaginary circle drawn on the cam, usually centered on the camshaft axis. It is used to determine the angular displacement of the cam and is essential for designing and analyzing cam systems.

6. **Prime Circle:** The prime circle is another imaginary circle drawn within the base circle. It represents the smallest circle around which the cam profile rotates without any abrupt changes in the follower's motion.
7. **Dwell:** Dwell refers to the portion of the cam profile where the follower remains stationary or undergoes minimal motion. It often occurs on the base circle of the cam.
8. **Rise:** Rise is the portion of the cam profile where the follower moves upward or away from the camshaft axis, resulting in an increase in follower height.
9. **Dwell Angle:** The dwell angle is the angular portion of the camshaft rotation during which the follower remains stationary. It is measured in degrees.
10. **Return:** The return is the portion of the cam profile where the follower moves downward or back toward the camshaft axis, causing a decrease in follower height.
11. **Lead Angle:** The lead angle is the angle between the line of action (the direction in which the follower moves) and a line perpendicular to the camshaft axis. It determines the direction and timing of the follower's motion.
12. **Pressure Angle:** The pressure angle is the angle between the tangent line to the cam profile at the point of contact with the follower and the radial line from the camshaft center to that point. It affects the force and wear on the follower.
13. **Camshaft:** The camshaft is a rotating shaft that carries one or more cams. It is often used in engines to control valve timing or in machinery to achieve specific motion profiles.

Function of a Piston:

1. **Compression:** During the compression stroke of an engine cycle, the piston moves upward within the cylinder, compressing the air (in diesel engines) or the air-fuel mixture (in gasoline engines). This compression increases the pressure and temperature of the air or mixture, preparing it for combustion.
2. **Ignition and Combustion:** In gasoline engines, the piston plays a role in the combustion process by compressing the air-fuel mixture, which is then ignited by a spark plug. In diesel engines, combustion is initiated by the high compression achieved by the piston.
3. **Expansion:** After ignition, the rapidly expanding gases push the piston down within the cylinder. This downward movement creates the mechanical work that drives the crankshaft, ultimately providing power to move the vehicle or machinery.
4. **Exhaust:** Once the combustion process is complete, the piston moves upward during the exhaust stroke, expelling the exhaust gases from the cylinder.

Design Considerations for a Piston:

1. **Material:** Pistons are typically made from aluminum alloys, cast iron, or steel, depending on the application. Material choice affects factors like weight, thermal conductivity, and durability.
2. **Shape and Size:** Piston design considers factors like bore diameter, stroke length, and cylinder configuration. The piston must fit precisely within the cylinder while maintaining optimal compression ratios and clearances.
3. **Piston Rings:** Piston rings are used to create a seal between the piston and the cylinder wall. These rings prevent gas leakage during compression and combustion and reduce friction between the piston and the cylinder wall.
4. **Skirt and Crown Design:** The piston's skirt and crown (top) design affect its stability and thermal performance. Skirt design can influence friction and engine efficiency, while the crown may have features like valve reliefs for proper valve clearance.
5. **Cooling Features:** In high-performance or heavy-duty engines, pistons may have cooling features like oil galleries or internal cooling channels to dissipate heat generated during combustion.
6. **Weight Reduction:** To improve engine efficiency and reduce reciprocating mass, pistons may incorporate weight-saving features such as lightweight materials, optimized designs, or hollowed-out sections.
7. **Piston Pin (Wrist Pin) Design:** The piston pin connects the piston to the connecting rod. Its design and material affect both the piston's performance and overall engine balance.
8. **Heat Resistance:** Pistons must be designed to withstand high temperatures generated during combustion without deforming or failing.
9. **Balancing:** Ensuring that the piston is balanced helps reduce vibration and engine wear.
10. **Skirt Coating:** Some pistons may have coatings to reduce friction, improve wear resistance, and enhance thermal performance.
11. **Compression Height:** The distance between the centerline of the piston pin bore and the top of the piston crown, known as the compression height, is a critical design parameter that affects engine performance.
12. **Durability and Reliability:** Pistons must be designed to withstand the rigors of engine operation, including high-pressure and high-temperature conditions, for extended periods without failure.

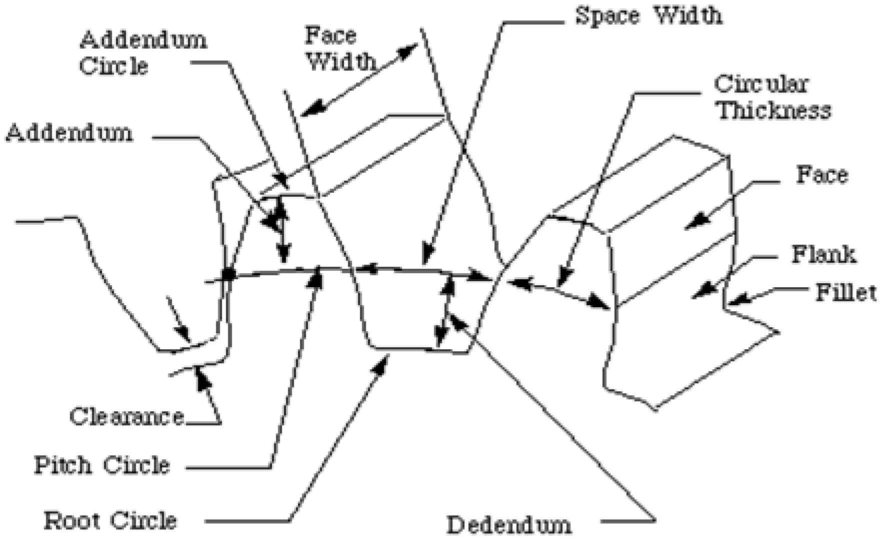
Make use of spur gear terminology and types of gear trains.

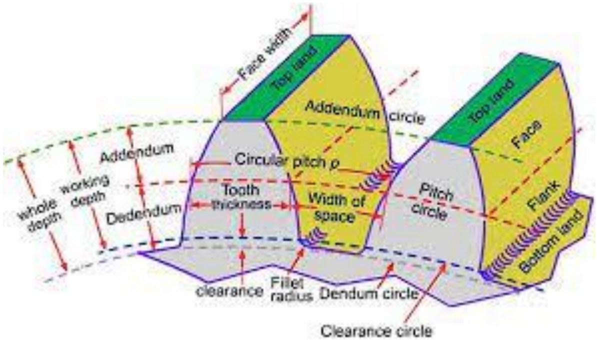
Spur gears are a type of cylindrical gear in which the teeth are cut parallel to the axis of the gear. They are among the most common and simplest types of gears, widely used in various mechanical systems and gear trains. Here, I'll discuss some terminology related to spur gears and mention a few types of gear trains where spur gears are commonly used.

Terminology Related to Spur Gears:

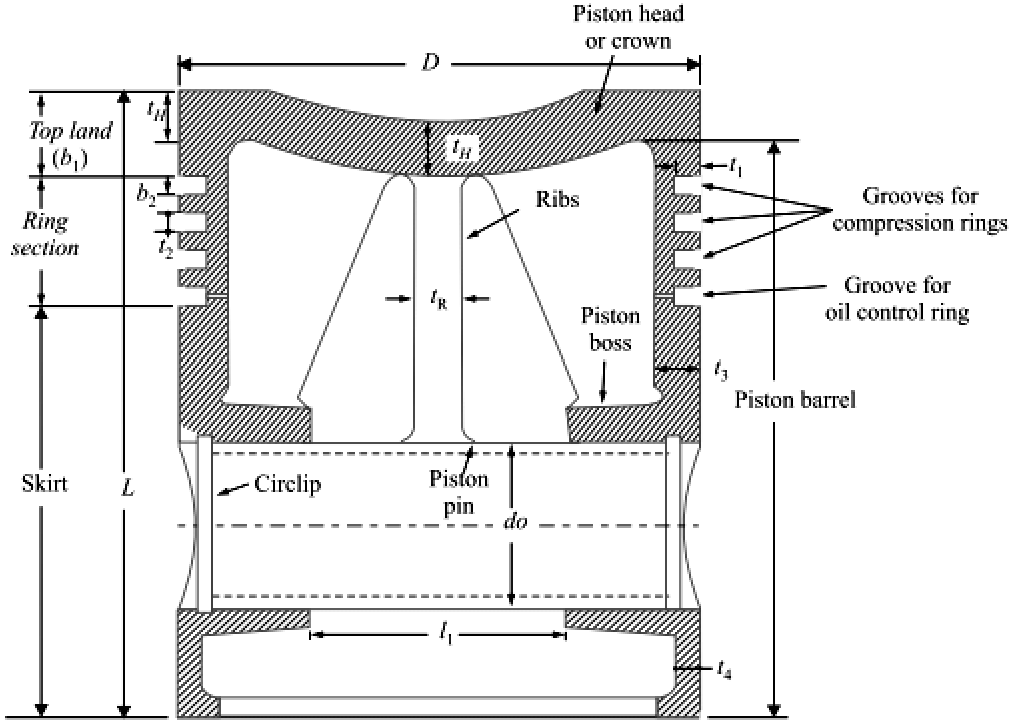
1. **Pitch Circle:** The imaginary circle that passes through the point where the teeth of two meshing gears make contact. The radius of this circle is called the pitch radius.
2. **Pitch Diameter (D):** The diameter of the pitch circle. It is calculated as D = 2 * Pitch Radius.
3. **Number of Teeth (N):** The number of teeth on a gear. It's an essential parameter for gear design and calculations.
4. **Module (m):** A measure of the size of a gear. It is the ratio of the pitch diameter to the number of teeth. Mathematically, m = D / N.
5. **Addendum (a):** The radial distance from the pitch circle to the top of the gear tooth.
6. **Dedendum (b):** The radial distance from the pitch circle to the bottom of the gear tooth.
7. **Pressure Angle (α):** The angle between the tangent to the pitch circle and the line of action of the tooth force. A common pressure angle is 20 degrees.
8. **Center Distance (C):** The distance between the centers of two meshing gears. It affects the gear ratio and determines whether gears are in mesh.

Types of Gear Trains Using Spur Gears:





Piston - function - design considerations for a piston



A piston is a critical component in internal combustion engines, compressors, and various hydraulic systems. Its primary function is to move back and forth within a cylinder to facilitate the intake of air or fuel, compression, ignition (in gasoline engines), and the expulsion of exhaust gases. Here are the main functions and design considerations for a piston:

Function of a Piston:

1. **Compression:** During the compression stroke of an engine cycle, the piston moves upward within the cylinder, compressing the air (in diesel engines) or the air-fuel mixture (in gasoline engines). This compression increases the pressure and temperature of the air or mixture, preparing it for combustion.

2. **Ignition and Combustion:** In gasoline engines, the piston plays a role in the combustion process by compressing the air-fuel mixture, which is then ignited by a spark plug. In diesel engines, combustion is initiated by the high compression achieved by the piston.

3. **Expansion:** After ignition, the rapidly expanding gases push the piston down within the cylinder. This downward movement creates the mechanical work that drives the crankshaft, ultimately providing power to move the vehicle or machinery.

4. **Exhaust:** Once the combustion process is complete, the piston moves upward during the exhaust stroke, expelling the exhaust gases from the cylinder.

Design Considerations for a Piston:

1. **Material:** Pistons are typically made from aluminum alloys, cast iron, or steel, depending on the application. Material choice affects factors like weight, thermal conductivity, and durability.

2. **Shape and Size:** Piston design considers factors like bore diameter, stroke length, and cylinder configuration. The piston must fit precisely within the cylinder while maintaining optimal compression ratios and clearances.

3. **Piston Rings:** Piston rings are used to create a seal between the piston and the cylinder wall. These rings prevent gas leakage during compression and combustion and reduce friction between the piston and the cylinder wall.

4. **Skirt and Crown Design:** The piston's skirt and crown (top) design affect its stability and thermal performance. Skirt design can influence friction and engine efficiency, while the crown may have features like valve reliefs for proper valve clearance.

5. **Cooling Features:** In high-performance or heavy-duty engines, pistons may have cooling features like oil galleries or internal cooling channels to dissipate heat generated during combustion.

6. **Weight Reduction:** To improve engine efficiency and reduce reciprocating mass, pistons may incorporate weight-saving features such as lightweight materials, optimized designs, or hollowed-out sections.

7. **Piston Pin (Wrist Pin) Design:** The piston pin connects the piston to the connecting rod. Its design and material affect both the piston's performance and overall engine balance.

8. **Heat Resistance:** Pistons must be designed to withstand high temperatures generated during combustion without deforming or failing.

9. **Balancing:** Ensuring that the piston is balanced helps reduce vibration and engine wear.

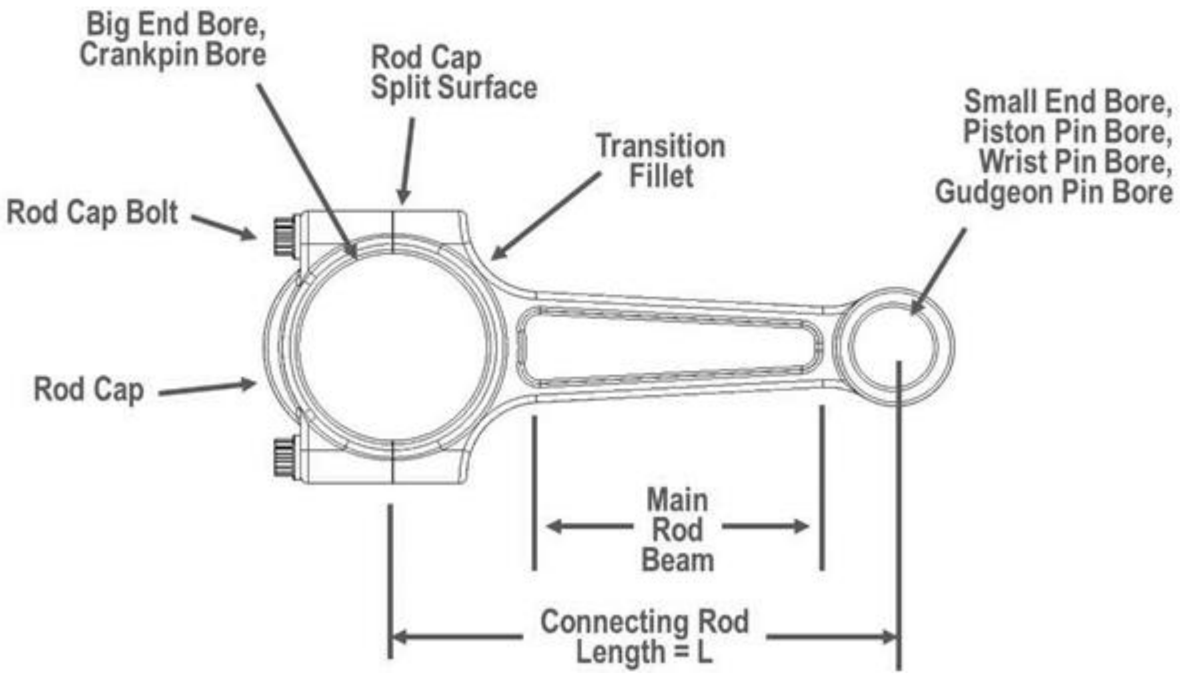
10. **Skirt Coating:** Some pistons may have coatings to reduce friction, improve wear resistance, and enhance thermal performance.

11. **Compression Height:** The distance between the centerline of the piston pin bore and the top of the piston crown, known as the compression height, is a critical design parameter that affects engine performance.

12. **Durability and Reliability:** Pistons must be designed to withstand the rigors of engine operation, including high-pressure and high-temperature conditions, for extended periods without failure.

Overall, piston design is a complex process that involves a careful balance of material selection, geometry, and features to optimize engine performance, efficiency, and durability while minimizing friction and wear. The design considerations may vary depending on the specific engine type and application.

CONNECTING ROD - FUNCTION - FORCES ACTING ON THE CONNECTING ROD



A connecting rod is an essential component in internal combustion engines and other machinery where reciprocating motion is required. Its primary function is to connect the piston to the crankshaft, transferring the reciprocating motion of the piston into rotary motion of the crankshaft. Here's an overview of the function of a connecting rod and the forces acting on it:

Function of a Connecting Rod:

1. **Transmit Reciprocating Motion:** The primary function of a connecting rod is to transmit the reciprocating motion of the piston to the rotary motion of the crankshaft. When the piston moves up and down within the cylinder, the connecting rod converts this linear motion into rotational motion at the crankshaft.
2. **Maintain Alignment:** The connecting rod helps maintain the alignment and synchronization of the piston and crankshaft. It ensures that the piston's movement corresponds accurately to the crankshaft's rotation.
3. **Contribute to Engine Balance:** In multi-cylinder engines, the arrangement of connecting rods and crankshafts is designed to balance the engine's forces and reduce vibrations, providing smoother operation.

Forces Acting on the Connecting Rod:

Several forces act on a connecting rod during its operation within an engine:

1. **Tensile Force:** When the piston moves downward during the power stroke, it exerts a tensile force on the connecting rod. This force tries to elongate the connecting rod.
2. **Compressive Force:** During the compression stroke, the piston moves upward, exerting a compressive force on the connecting rod. This force attempts to shorten the connecting rod.
3. **Bending Loads:** The connecting rod experiences bending loads due to the reciprocating motion of the piston. As the piston changes direction, it applies bending forces to the connecting rod.
4. **Inertia Forces:** Inertia forces result from the mass of the connecting rod and piston. These forces can cause oscillatory movements and vibrations in the connecting rod, which must be managed to prevent excessive wear or damage.
5. **Crankpin Forces:** At the lower end of the connecting rod, the crankpin exerts forces on the connecting rod as it rotates, creating a dynamic load.
6. **Centrifugal Forces:** In high-speed engines, centrifugal forces act on the connecting rod, attempting to pull it away from the center of rotation.

Example 9.1 : *Draw the profile of a cam operating a knife edge follower from the following data :*

(a) Lifts the follower through 40 mm during 60 degrees with SHM.

(b) The follower remains at rest for the next 45 degrees of rotation of the cam.

(c) The follower then descends to its original position during 90 degrees rotation of the cam with SHM.

(d) The follower remains at rest for the remaining part of the revolution.

The least diameter of the cam is 50 mm. **[March 2006]**

Solution :

Given : Lift of follower, = 40 mm

Least diameter of cam = 50 mm

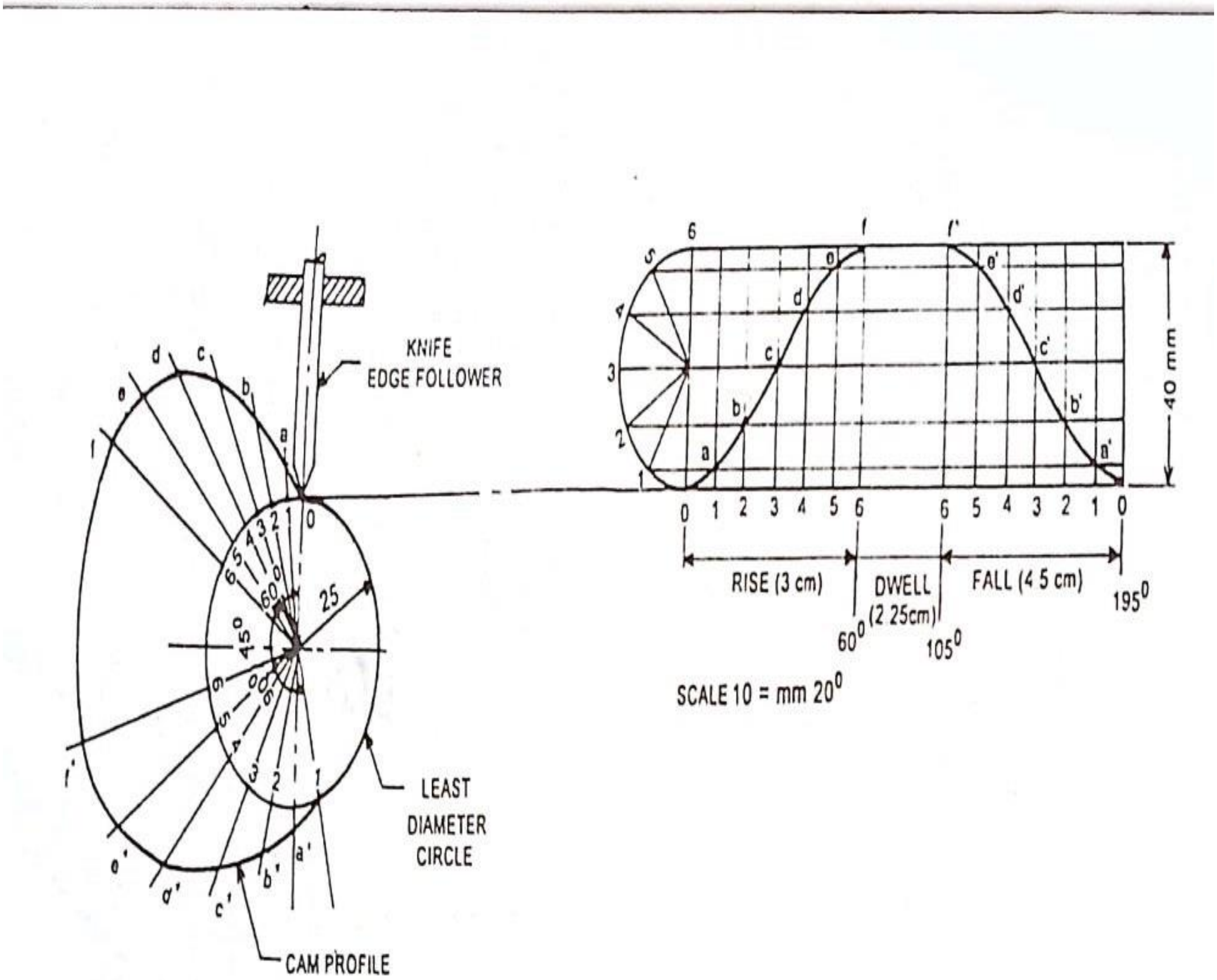
Displacement Diagram :

Draw displacement diagram for SHM of follower as explained in Art 9.6.2. Y–axis represents lift of the follower and X–axis represent angular displacement of cam during rise, dwell and fall

Diagram of Cam Profile :

The following procedure is adopted to draw cam profile.

- With 'O' as centre draw a circle with least radius of 25 mm (i.e least diameter of cam = 50 mm)
- Assume cam rotates in clock-wise direction, mark angular displacement for lift (60^0), dwell (45^0) and descend (90^0)
- Divide angle of lift and descent into same number of equal parts as that are on displacement diagram.
- Obtain the points a, b, c.... and a^1, b^1, c^1... on radial lines such that 1– a, 2 – b, 3 – c .... and 1– a^1, 2 – b^1, 3 – c^1.... correspond to the lift of the follower on respective points.
- Draw the curve passing through all these points (a,b,c.... and a^1, b^1, c^1...) which represents a cam profile.


KNIFE
EDGE FOLLOWER
LEAST
DIAMETER
CIRCLE
CAM PROFILE
25
RISE (3 cm)
DWELL
(2 25cm)
FALL (4 5 cm)
40 mm
60°
105°
195°
SCALE 10 = mm 20°

Example 9.2 : *Draw the profile of a cam to give the following motion to a reciprocating follower with a flat contact of face.*

(a) Out stroke during 120^0 of cam rotation.

(b) Dwell for the next 30^0 of cam rotation.

(c) Return stroke during 120^0 of cam rotation.

(d) Dwell for the remaining 90^0 of the cam rotation.

The stroke of the follower is 30 mm and the minimum radius of the cam is 25 mm. The follower moves with uniform velocity during both out stroke and return stroke. The axis of the follower passes through the axis of the cam shaft.

Solution :

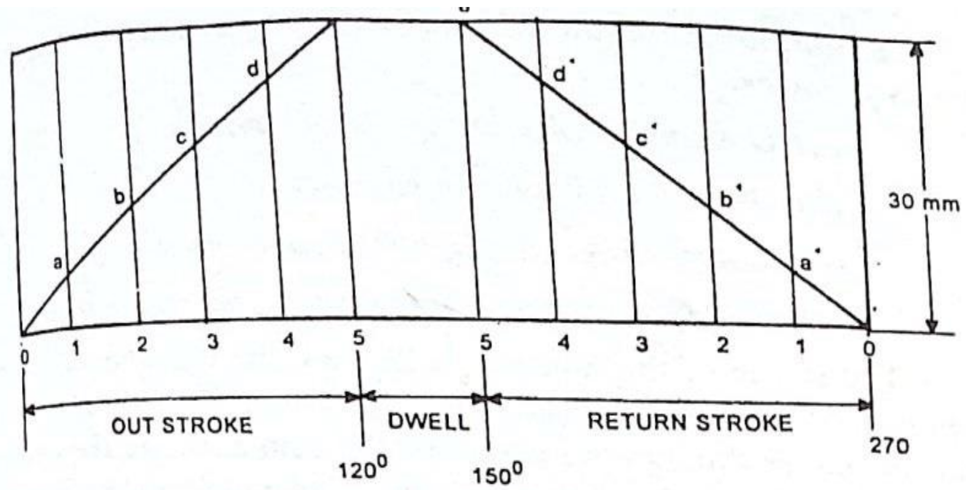
Cam rotation during out stroke	=	120^0
Cam rotation during dwell	=	30^0
Cam rotation during return stroke	=	120^0
Stroke	=	30 mm
Min. radius of cam	=	25 mm

Displacement Diagram :

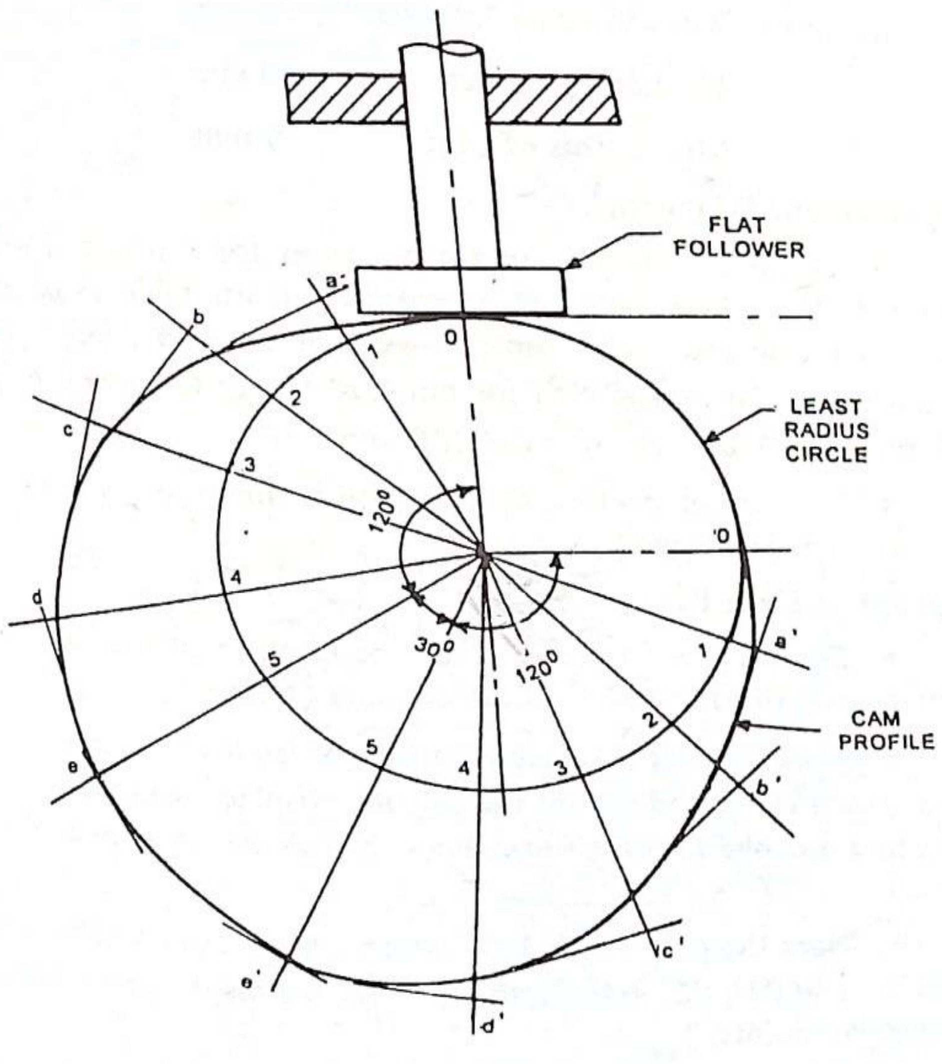
- Draw the displacement diagram for uniform velocity of follower as explained in art 9.6.1. Y–axis represents lift (30 mm) of the follower and X–axis represents angular displacement of the cam (scale 10 mm = 30^0) during out stroke (40 mm = 120^0), dwell (10 mm = 30^0) and return stroke (40 mm = 120^0). Divide out stroke and return stroke into same number of equal divisions, say 5 division.

Diagram of Cam Profile :

- With 'O' as centre draw a circle with 25 mm radius
- Mark angular displacement for out stroke (120^0) dwell (30^0) and return stoke (120^0).
- Divide angle of out stroke and return stroke into same number of equal parts as that are on displacement diagram.
- Obtain the points a, b, c, ... and a^1, b^1, c^1,...... correspond to the displacement of the follower on respective points. Dotted lines indicate the flat face of the follower at the position shown.
- Draw a curve tangent to the face of the follower. This curve represent the profile of the cam.



SCALE 10 mm = 30^0



Example 9.3 : *Draw the cam profile to give the following motion to a roller follower.*

(a) Outward stroke during 60^0 of cam rotation.

(b) Dwell for 15^0 of cam rotation.

(c) Return stroke during 60^0 of cam rotation.

(d) Dwell for the remaining part of cam rotation.

The stroke of the follower is 25 mm; the diameter of the roller is 20 mm; the minimum radius of cam is 40 mm. The line of stroke of the follower passes through the centre of the cam axis and the outward and return strokes takes place with uniform acceleration and retardation .

Solution :

Given : The stroke of follower = 25 mm

Diameter of roller = 20 mm

Min. radius of cam = 40 mm

Displacement Diagram :

- Draw the displacement diagram for uniform acceleration and retardation of the follower as explained in art. 9.6.3. Y–axis represent stroke of the follower (25 mm). X–axis represent angular displacement of cam (scale 10 mm = 20^0) for outward stroke **(30 mm = 60^0)**, dwell (7.5 mm = 15^0) and return stroke (30 mm = 60^0)

- Divide out stroke and return stroke into same number of equal divisions, say 4 division.

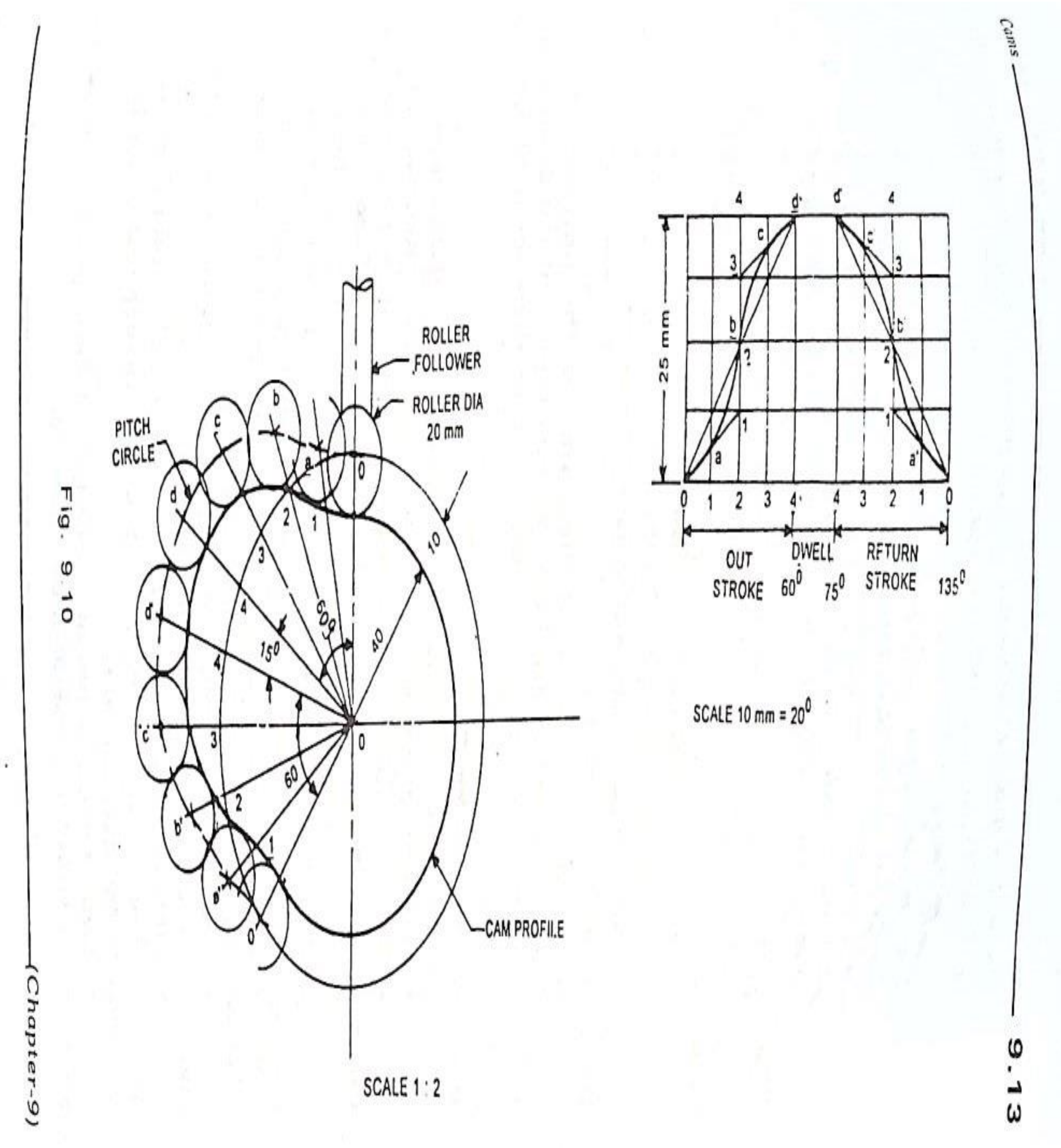
Diagram of Cam Profile :

- Draw a prime circle with centre 'O' and radius equal to the min. radius of cam (40 mm) plus radius of roller (10 mm).

- Mark angular displacement for outstroke (60^0), dwell (15^0) and return stroke (60^0) and divide the angular displacement during outward stroke and instroke into the same number of divisions as in displacement diagram.

- Mark the points a, b, c, ... and a^1, b^1, c^1 ..... on radial. lines 01, 02, 03...... and 01^1, 02^1, 03^1...... to represent the displacement of follower at respective points.

- The profile of the cam is obtained by drawing a curve to touch the successive positions of the roller circumference as shown in Fig. 9.10.



surface to reduce wear.

32.4 Design of a Cylinder

In designing a cylinder for an I. C. engine, it is required to determine the following values :

1. ***Thickness of the cylinder wall.*** The cylinder wall is subjected to gas pressure and the pist side thrust. The gas pressure produces the following two types of stresses :

(*a*) Longitudinal stress, and (*b*) Circumferential stress.

32.8 Piston Head or Crown

The piston head or crown is designed keeping in view the following two main considerations, *i.e.*

1. It should have adequate strength to withstand the straining action due to pressure of explosion inside the engine cylinder, and

2. It should dissipate the heat of combustion to the cylinder walls as quickly as possible.

On the basis of first consideration of straining action, the thickness of the piston head is determined by treating it as a flat circular plate of uniform thickness, fixed at the outer edges and subjected to a uniformly distributed load due to the gas pressure over the entire cross-section.

The thickness of the piston head (t_H), according to Grashoff's formula is given by

$$t_H = \sqrt{\frac{3p.D^2}{16\sigma_t}} \text{ (in mm)} \qquad ...(i)$$

where p = Maximum gas pressure or explosion pressure in N/mm^2,

D = Cylinder bore or outside diameter of the piston in mm, and

σ_t = Permissible bending (tensile) stress for the material of the piston in MPa or N/mm^2. It may be taken as 35 to 40 MPa for grey cast iron, 50 to 90 MPa for nickel cast iron and aluminium alloy and 60 to 100 MPa for forged steel.

On the basis of second consideration of heat transfer, the thickness of the piston head should be such that the heat absorbed by the piston due combustion of fuel is quickly transferred to the cylinder walls. Treating the piston head as a flat ciucular plate, its thickness is given by

$$t_H = \frac{H}{12.56k(T_C - T_E)} \text{ (in mm)} \qquad ...(ii)$$

where H = Heat flowing through the piston head in kJ/s or watts,

k = Heat conductivity factor in W/m/°C. Its value is 46.6 W/m/°C for grey cast iron, 51.25 W/m/°C for steel and 174.75 W/m/°C for aluminium alloys.

T_C = Temperture at the centre of the piston head in °C, and

T_E = Temperature at the edges of the piston head in °C.

The temperature difference ($T_C - T_E$) may be taken as 220°C for cast iron and 75°C for aluminium.

The heat flowing through the positon head (H) may be determined by the following expression, *i.e.*,

$$H = C \times HCV \times m \times B.P. \text{ (in kW)}$$

where C = Constant representing that portion of the heat supplied to the engine which is absorbed by the piston. Its value is usually taken as 0.05.

HCV = Higher calorific value of the fuel in kJ/kg. It may be taken as 45×10^3 kJ/kg for diesel and 47×10^3 kJ/ kg for petrol,

m = Mass of the fuel used in kg per brake power per second, and

$B.P.$ = Brake power of the engine per cylinder

Example 32.2. *Design a cast iron piston for a single acting four stroke engine for the following data:*

Cylinder bore = 100 mm ; Stroke = 125 mm ; Maximum gas pressure = 5 N/mm² ; Indicated mean effective pressure = 0.75 N/mm² ; Mechanical efficiency = 80% ; Fuel consumption = 0.15 kg per brake power per hour ; Higher calorific value of fuel = 42 × 10³ kJ/kg ; Speed = 2000 r.p.m.

Any other data required for the design may be assumed.

Solution. Given : $D = 100$ mm ; $L = 125$ mm $= 0.125$ m ; $p = 5$ N/mm² ; $p_m = 0.75$ N/mm²; $\eta_m = 80\% = 0.8$; $m = 0.15$ kg / BP / h $= 41.7 \times 10^{-6}$ kg / BP / s; $HCV = 42 \times 10^3$ kJ / kg ; $N = 2000$ r.p.m.

The dimensions for various components of the piston are determined as follows :

1. *Piston head or crown*

The thickness of the piston head or crown is determined on the basis of strength as well as on the basis of heat dissipation and the larger of the two values is adopted.

We know that the thickness of piston head on the basis of strength,

$$t_H = \sqrt{\frac{3p.D^2}{16\,\sigma_t}} = \sqrt{\frac{3 \times 5(100)^2}{16 \times 38}} = 15.7 \text{ say } 16 \text{ mm}$$

...(Taking σ_t for cast iron = 38 MPa = 38 N/mm²

Since the engine is a four stroke engine, therefore, the number of working strokes per minute,

$$n = N/2 = 2000/2 = 1000$$

and cross-sectional area of the cylinder,

$$A = \frac{\pi\, D^2}{4} = \frac{\pi\,(100)^2}{4} = 7855 \text{ mm}^2$$

We know that indicated power,

$$IP = \frac{p_m.L.A.n}{60} = \frac{0.75 \times 0.125 \times 7855 \times 1000}{60} = 12\,270 \text{ W}$$
$$= 12.27 \text{ kW}$$

$\therefore$ Brake power, $BP = IP \times \eta_m = 12.27 \times 0.8 = 9.8$ kW ...($\because \eta_m = BP/IP$)

We know that the heat flowing through the piston head,

$$H = C \times HCV \times m \times BP$$
$$= 0.05 \times 42 \times 10^3 \times 41.7 \times 10^{-6} \times 9.8 = 0.86 \text{ kW} = 860 \text{ W}$$

....(Taking $C = 0.05$)

$\therefore$ Thickness of the piston head on the basis of heat dissipation,

$$t_H = \frac{H}{12.56\,k\,(T_C - T_E)} = \frac{860}{12.56 \times 46.6 \times 220} = 0.0067 \text{ m} = 6.7 \text{ mm}$$

...($\because$ For cast iron , $k = 46.6$ W/m/°C, and $T_C - T_E = 220$°C)

Taking the larger of the two values, we shall adopt

$$t_H = 16 \text{ mm } \textbf{Ans.}$$

Since the ratio of L/D is 1.25, therefore a cup in the top of the piston head with a radius equal to 0.7 D (*i.e.* 70 mm) is provided.

2. *Radial ribs*

The radial ribs may be four in number. The thickness of the ribs varies from $t_H/3$ to $t_H/2$.

$\therefore$ Thickness of the ribs, $t_R = 16/3$ to $16/2 = 5.33$ to 8 mm

Let us adopt $t_R = 7$ mm **Ans.**

3. *Piston rings*

Let us assume that there are total four rings (*i.e.* $n_r = 4$) out of which three are compression rings and one is an oil ring.

We know that the radial thickness of the piston rings,

$$t_1 = D\sqrt{\frac{3\,p_w}{\sigma_t}} = 100\sqrt{\frac{3 \times 0.035}{90}} = 3.4 \text{ mm}$$

...(Taking $p_w = 0.035$ N/mm², and $\sigma_t = 90$ MPa)

and axial thickness of the piston rings

$$t_2 = 0.7\,t_1 \text{ to } t_1 = 0.7 \times 3.4 \text{ to } 3.4 \text{ mm} = 2.38 \text{ to } 3.4 \text{ mm}$$

Let us adopt $t_2 = 3$ mm

Example 32.1. *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 / mm² ; Mechanical efficiency = 80 %.

Determine : 1. bore and length of the cylinder ; 2. thickness of the cylinder head ; and 3. size of studs for the cylinder head.

Solution. Given: $B.P. = 5\text{kW} = 5000$ W ; $N = 1200$ r.p.m. or $n = N/2 = 600$; $p_m = 0.35$ N/mm²; $\eta_m = 80\% = 0.8$

1. *Bore and length of cylinder*

Let D = Bore of the cylinder in mm,

A = Cross-sectional area of the cylinder = $\frac{\pi}{4} \times D^2$ mm²

l = Length of the stroke in m.

$= 1.5\ D$ mm $= 1.5\ D / 1000$ m ....(Assume)

We know that the indicated power,

$$I.P = B.P. / \eta_m = 5000 / 0.8 = 6250 \text{ W}$$

We also know that the indicated power ($I.P.$),

$$6250 = \frac{p_m . l . A . n}{60} = \frac{0.35 \times 1.5D \times \pi D^2 \times 600}{60 \times 1000 \times 4} = 4.12 \times 10^{-3}\ D^3$$

...($\because$ For four stroke engine, $n = N/2$)

$\therefore$ $D^3 = 6250 / 4.12 \times 10^{-3} = 1517 \times 10^3$ or $D = 115$ mm **Ans.**

and $l = 1.5\ D = 1.5 \times 115 = 172.5$ mm

Taking a clearance on both sides of the cylinder equal to 15% of the stroke, therefore length of the cylinder,

$$L = 1.15\ l = 1.15 \times 172.5 = 198 \text{ say } 200 \text{ mm } \textbf{Ans.}$$

2. *Thickness of the cylinder head*

Since the maximum pressure (p) in the engine cylinder is taken as 9 to 10 times the mean effective pressure (p_m), therefore let us take

$$p = 9\ p_m = 9 \times 0.35 = 3.15 \text{ N/mm}^2$$

We know that thickness of the cyclinder head,

$$t_h = D\sqrt{\frac{C.p}{\sigma_t}} = 115\sqrt{\frac{0.1 \times 3.15}{42}} = 9.96 \text{ say } 10 \text{ mm } \textbf{Ans.}$$

...(Taking $C = 0.1$ and $\sigma_t = 42$ MPa = 42 N/mm²)

3. *Size of studs for the cylinder head*

Let d = Nominal diameter of the stud in mm,

d_c = Core diameter of the stud in mm. It is usually taken as 0.84 d.

σ_t = Tensile stress for the material of the stud which is usually nickel steel.

n_s = Number of studs.

We know that the force acting on the cylinder head (or on the studs)

$$= \frac{\pi}{4} \times D^2 \times p = \frac{\pi}{4}(115)^2 3.15 = 32\ 702 \text{ N} \quad ...(i)$$

The number of studs (n_s) are usually taken between $0.01\ D + 4$ (*i.e.* $0.01 \times 115 + 4 = 5.15$) and $0.02\ D + 4$ (*i.e.* $0.02 \times 115 + 4 = 6.3$). Let us take $n_s = 6$.

We know that resisting force offered by all the studs

$$= n_s \times \frac{\pi}{4}(d_c)^2\ \sigma_t = 6 \times \frac{\pi}{4}(0.84d)^2\ 65 = 216\ d^2\text{N} \quad ...(ii)$$

...(Taking $\sigma_t = 65$ MPa = 65 N/mm²)

From equations (*i*) and (*ii*),

$$d^2 = 32\ 702 / 216 = 151 \text{ or } d = 12.3 \text{ say } 14 \text{ mm}$$

The pitch circle diameter of the studs (D_p) is taken $D + 3d$.

$$\therefore \qquad D_p = 115 + 3 \times 14 = 157 \text{ mm}$$

We know that pitch of the studs

$$= \frac{\pi \times D_p}{n_s} = \frac{\pi \times 157}{6} = 82.2 \text{ mm}$$

We know that for a leak-proof joint, the pitch of the studs should lie between $19\sqrt{d}$ to $28.5\sqrt{d}$, where d is the nominal diameter of the stud.

$\therefore$ Minimum pitch of the studs

$$= 19\sqrt{d} = 19\sqrt{14} = 71.1 \text{ mm}$$

and maximum pitch of the studs

$$= 28.5\sqrt{d} = 28.5\sqrt{14} = 106.6 \text{ mm}$$

Since the pitch of the studs obtained above (*i.e.* 82.2 mm) lies within 71.1 mm and 106.6 mm, therefore, size of the stud (d) calculated above is satisfactory.

$$\therefore \qquad d = 14 \text{ mm } \textbf{Ans.}$$