Design of IC Engine Components - Cylinder

Functions of Cylinder

- Primary function is to retain the working fluid such as mixture of air and petrol or air and diesel

- Secondary function is to guide the piston

Requirements of Cylinder Material

- Should be strong enough to withstand high gas pressure
- Should be strong enough to withstand thermal stresses
- Should be hard enough to resist wear due to piston movement
- Should have good surface finish to reduce friction during piston movement
- Should be corrosion resistant

Common Cylinder Materials

a. Grey cast iron (usually)

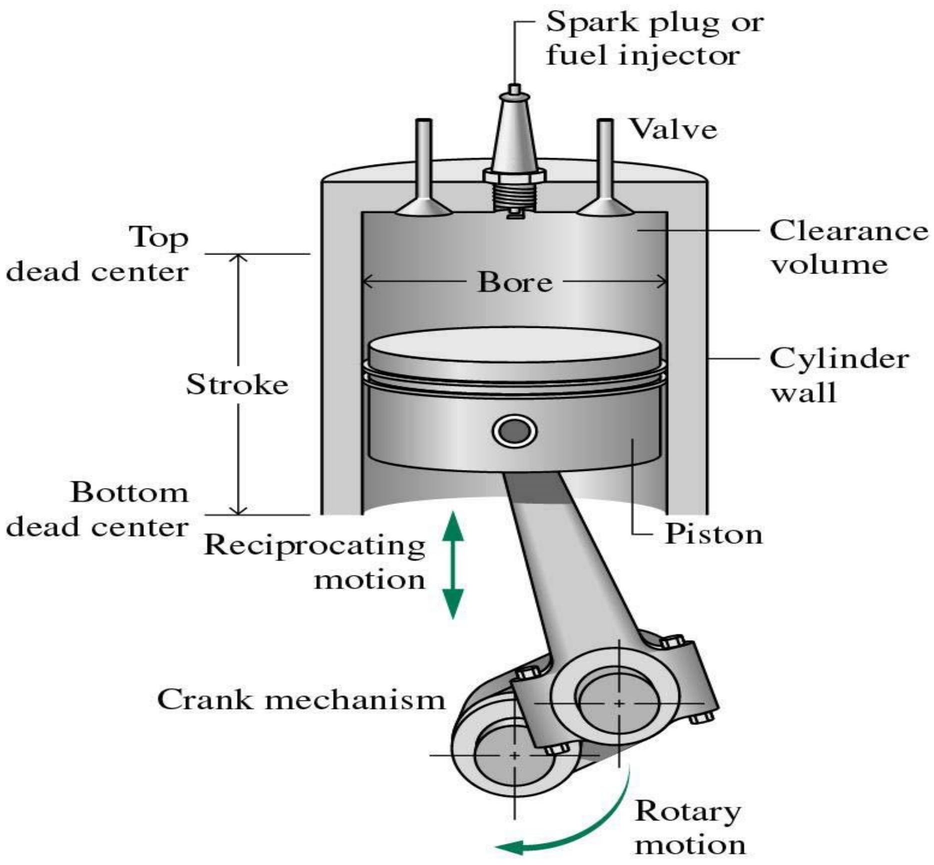
b. Nickel cast iron or Nickel Chromium cast iron for heavy duty applications

c. Cast steels and Aluminium alloys may also be used

Design of Cylinder

Involves assessment of following dimensions:

- Bore of cylinder
- Length of cylinder
- Thickness of cylinder wall
- Thickness of cylinder head
- No. and diameter of cylinder head studs
- Pitch circle diameter of studs



Bore and Length of Cylinder

- Brake power

$$B.P. = \frac{p_{mb}\ L\ A\ n}{60}$$

- Indicated power

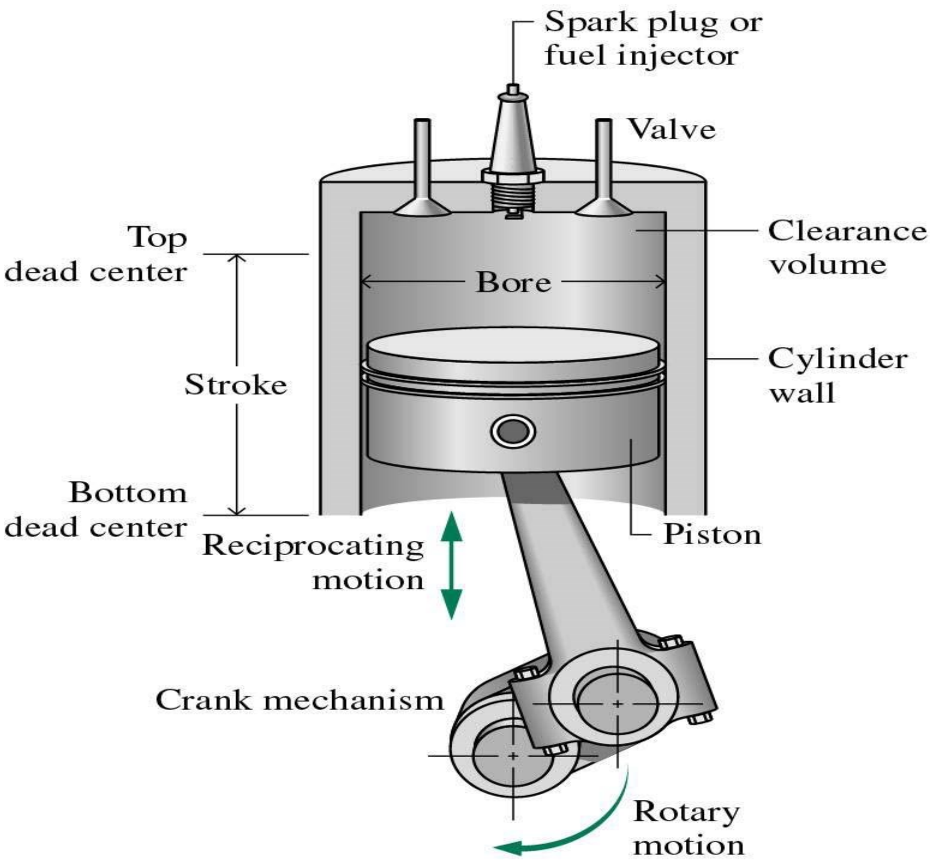
$$I.P. = \frac{p_{m}\ L\ A\ n}{60}$$

- Mechanical efficiency (usually 80 % if not given)

$$\eta_m = \frac{B.P}{I.P}$$

Bore and Length of Cylinder

- Length of stroke is usually 1.5 times bore diameter
- Length of cylinder is more than length of stroke (usually 15%)



Thickness of Cylinder wall

$$t = \frac{p_{max}\ D}{2\ \sigma_c} + C$$

t = thickness of cylinder wall (mm)

p_{max} = maximum gas pressure inside cylinder (10 times indicated mep)

σ_c = permissible circumferential stress for cylinder material (35 to 100 MPa)

D = Bore diameter (mm)

C = re-boring allowance (according to bore diameter from data book)

Thickness of Cylinder head

$$t_h = D\sqrt{\frac{K\,p_{max}}{\sigma_c}}$$

t_h = thickness of cylinder head (mm)

D = Bore diameter (mm)

K = a constant (= 0.162)

p_{max} = maximum gas pressure inside cylinder (10 times indicated mep)

σ_c = permissible circumferential stress for cylinder head material (30 to 50 MPa)

Studs for Cylinder head

- Minimum no. of studs = 0.01 D + 4
- Maximum no. of studs = 0.02 D + 4
- Diameter of studs

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

z = no. of studs

d_c = core diameter of studs (= 0.8 times nominal diameter d)

σ_t = allowable tensile stress for stud material (35 to 70 MPa)

- Pitch circle diameter of studs $D_p = D + 3d$

Design of IC Engine Components - Piston

Functions of Piston

- Transmits force inside the gas cylinder to the crank shaft
- Compresses gas during compression stroke
- Seals the inside portion of the cylinder from the crankcase by means of piston rings
- Takes side thrust resulting from obliquity of connecting rod
- Dissipates large amount of heat from combustion chamber to the cylinder walls

Requirements of Piston Material

- Weight should be as low as possible
- No warping at elevated temperatures
- Low coefficient of thermal expansion
- Thermal conductivity should be high
- Should have good wearing properties
- Should have good resistance to corrosion
- Should have low coefficient of friction for minimum power loss

Common Piston Materials

a. Aluminium

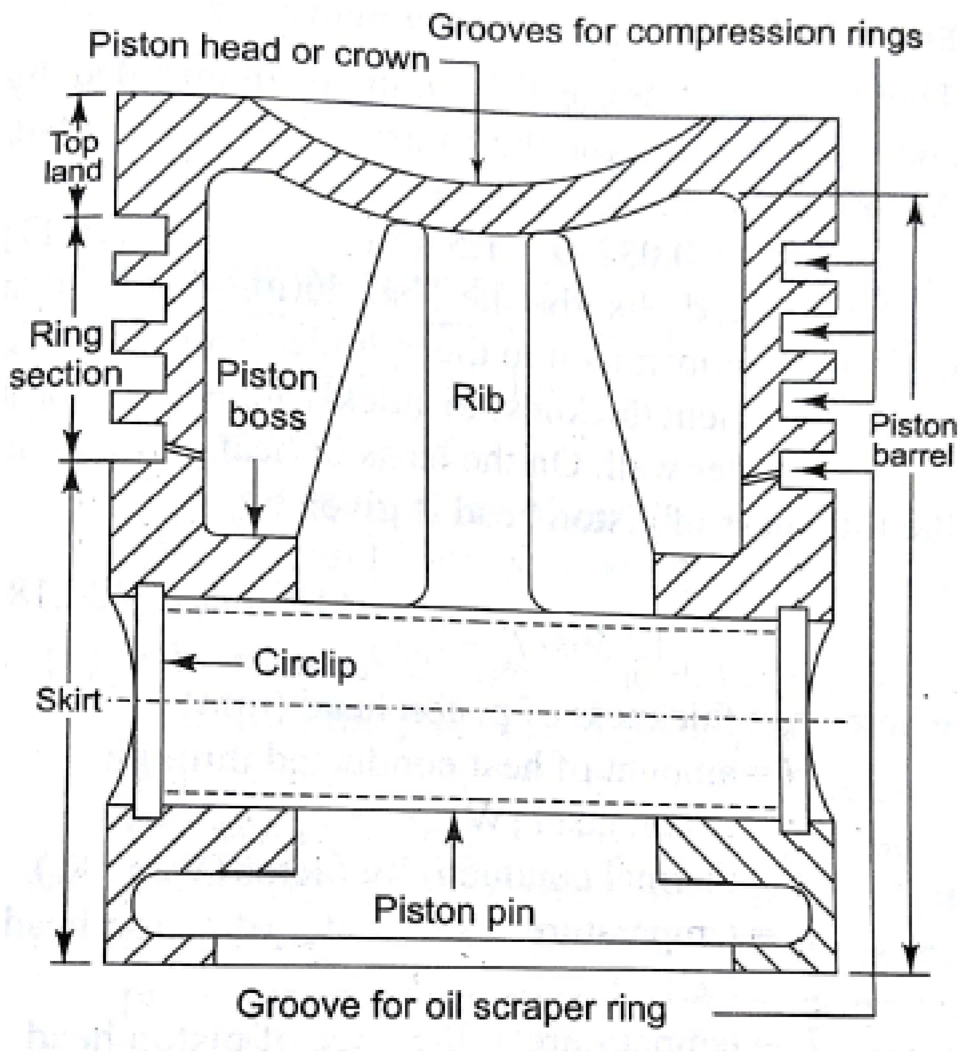
- thermal conductivity thrice as that of cast iron
- density one third that of cast iron (reduced weight)

b. Cast Iron

- higher strength as compared to Aluminium
- relatively more wear strength (than Aluminium)
- approx. half coefficient of thermal expansion

Piston

Piston



Piston head or crown
Grooves for compression rings
Top land
Ring section
Piston boss
Rib
Piston barrel
Circlip
Skirt
Piston pin
Groove for oil scraper ring

Design of Piston

Involves assessment of following dimensions:

- Thickness of piston head (t_h)
- Thickness of Rib (t_r)
- Radial thickness of piston rings (a_1)
- Axial thickness of piston rings (h_1)
- Width of top land
- Thickness of piston barrel at the top end (t_3)
- Thickness of piston barrel at open end (t_4)
- Length of piston skirt
- Total length of piston

Thickness of Piston head

- Strength consideration

$$t_h = D\sqrt{\frac{3\,p_{max}}{16\,\sigma_b}}$$

D = cylinder bore (mm)

p_{max} = maximum gas pressure (4 to 5 MPa)

σ_b = permissible bending stress (35 to 40 MPa for C.I. and 50 to 90 MPa for Al)

Thickness of Piston head

- Heat Dissipation consideration

$$t_h = \left[\frac{H}{12.56\,k\,(T_c - T_e)} \right] \times 10^3$$

H = amount of heat conducted through piston head (W)

k = thermal conductivity factor (46.6 W/m°C for C.I. and 175 W/m°C for Al)

T_c = Temperature at the centre of Piston head

T_e = Temperature at the edge of piston head

$T_c - T_e$ = 220°C for C.I. and 75°C for Al

Thickness of Piston head

- Heat Dissipation consideration

$$H = [\,C \times HCV \times m \times B.P.\,] \times 10^{3}$$

C = ratio of heat absorbed by piston to total heat developed by cylinder (5%)

HCV = higher calorific value (44000 kJ/kg for diesel and 47000 kJ/kg for Petrol)

m = average fuel consumption (0.24 to 0.3 kg/kW/hr)

B.P. = Brake power

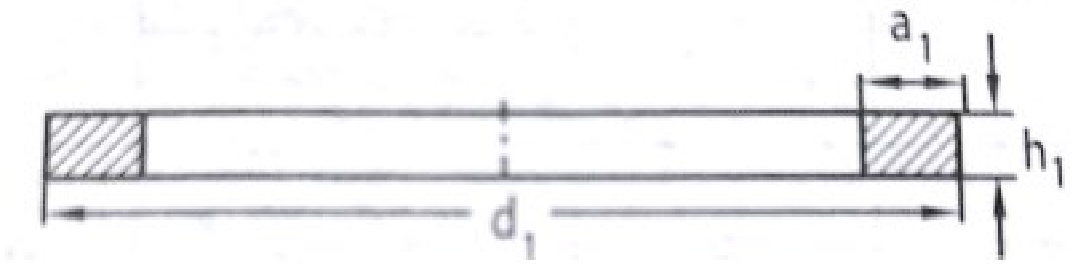
$$B.P. = \frac{p_{mb}\ L\ A\ n}{60} \quad (\text{in kW})$$

Design of Piston

- Thickness of rib = 1/3 to 1/2 (thickness of piston head)

- Radial thickness of piston rings

$$a_1 = d_1 \sqrt{\frac{3\,p_w}{\sigma_t}}$$



d_1 = diameter of cylinder bore (mm)

p_w = allowable pressure (0.025 to 0.042 MPa)

σ_t = permissible tensile stress (85 to 110 MPa)

- Axial width of piston ring $h_1 = 0.7$ to $1.0\ a_1$

Design of Piston (contd.)

- Width of top land = 1.0 to 1.2 t_h
- Width of ring groove = 0.75 to 1.0 h_1
- Thickness of piston barrel at the top end t_3 = 0.03 d + a_1 + 4.9
- Thickness of piston barrel at open end t_4 = 0.25 to 0.35 t_3
- Length of piston skirt 0.65 to 0.8 D
- Total length of piston 1.0 to 1.5 D