Design of piston

① piston Head (or) Crown

ⓐ Basis of strength

$$\boxed{t_{H_1} = \sqrt{\frac{3PD^2}{16\sigma_t}}}$$

[For CI $\sigma = 38$ mpa (or) N/mm²]

P = max gas press

D = Bore diameter

ⓑ Basis of Heat dissipation

$$\boxed{t_H = \frac{H}{12.56K(T_c - T_E)}}$$

$K = 46.4\ W/m°c$

$T_c - T_E = 220°c$

$BP = \frac{2\pi NT}{60}$

$BP = IP \times \eta_m$ $\quad IP = \frac{P_m LAn}{60}$

$n = \frac{N}{2}$

$$\boxed{H = C \times HCV \times M \times BP}$$

$C = 0.04$

45×10^3 kJ/kg for diesel

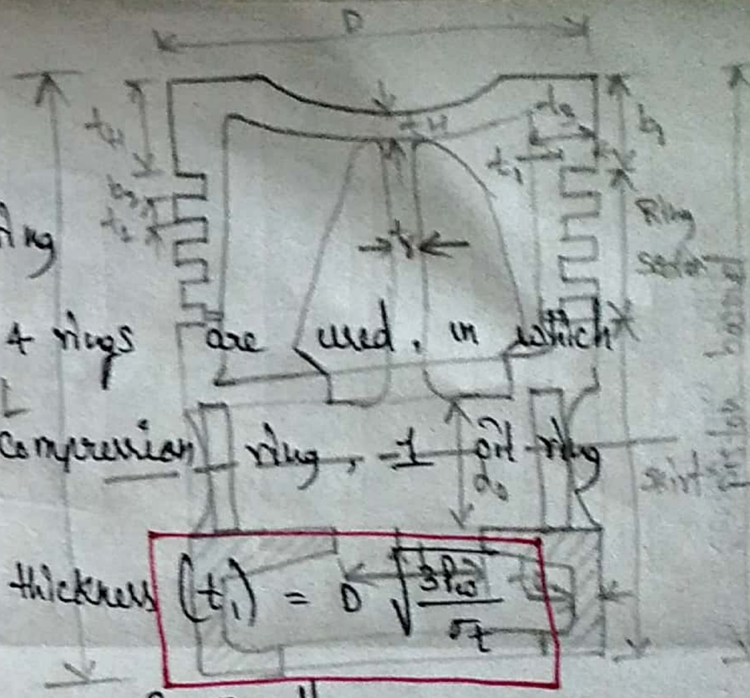
47×10^3 kJ/kg for petrol

ⓒ Radial Ribs

If $t_H > 6$ mm then radial ribs → thickness $t_H/3$ to $t_H/2$

If L/D ratio is upto 1.5 then cup shape → radius $0.7 \times D$

② piston ring



usually 4 rings are used, in which

3 compression ring, 1 oil ring

$$\boxed{\text{Radial thickness } (t_1) = D\sqrt{\frac{3P_w}{\sigma_t}}}$$

P_w = wall pressure = 0.035 N/mm²

σ_t = 70 mpa tensile stress

axial ~~stress~~ thickness $(t_2) = 0.7t_1$ to t_1

$$\boxed{t_2 = \frac{D}{10\,n_r}}$$

should be $< t_2$

3. piston barrel

$b = t_1$ to 0.4

max thickness $\boxed{(t_3) = 0.03D + t_1 + 4.9 \text{ mm}}$

piston wall thickness towards the open end

$\boxed{t_4 = 0.25t_3 \text{ to } 0.35t_3}$

$b_1 = t_H$ to $1.2t_H$

$b_2 = 0.75t_2$ to t

$G_1 = 3.5t_1$ to $4t_1$

$G_2 = 0.002D$ to $0.004D$

4. Piston Skirts

max side thrust due to gas = side thrust due to piston barrel

$$\boxed{R = \mu \times \frac{\pi D^2}{4} \times P = P_b \times D \times l}$$

$b_1 = t_1$ to $1.2t_H$

$b_2 = 0.75$ to t_2

Total length of piston

$$\boxed{L = l + (4t_2 + 3b_2) + b_1}$$

5 piston pin

load on pin due to bearing pressure = max load on the piston due to gas pressure

$$\boxed{P_{b_1} \times d_o \times l_1 = \frac{\pi}{4} D^2 \times P}$$

$P_{b_1} = 25 \text{ N/mm}^2$

d_o = outside dia

l_1 = length of pin in bush $= 0.45 d_o$

Inside dia $(d_i) = 0.6 \times d_o$

Now to check internal bearing stress

$\sigma_b = 140$ mpa

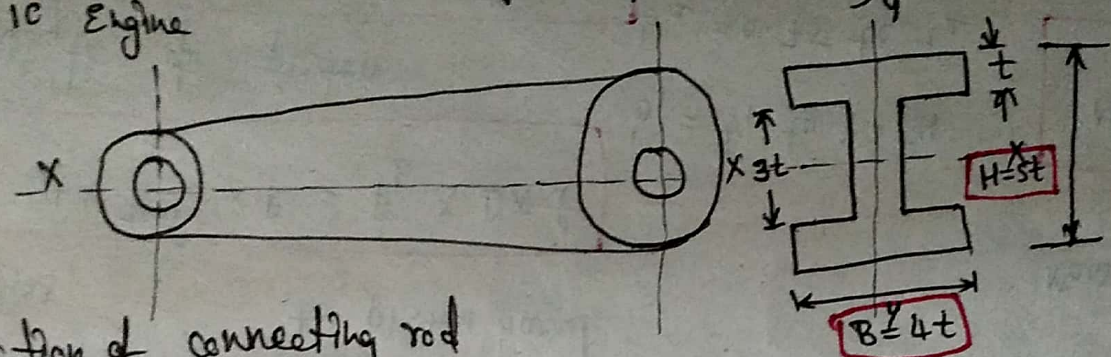
$$\boxed{M = \frac{PD}{8} = \frac{\pi}{32}\left[\frac{d_o^4 - d_i^4}{d_o}\right] \times \sigma_b}$$

$\sigma_b < 140$

Design of Connecting Rod

3 main parts in IC Engine

→ piston.
→ connecting rod.
→ crank shaft.



① Cross section of connecting rod

Buckling load (W_B)

* Rankine formula

$$\boxed{W_B = \frac{\sigma_c A}{1 + a\left(\frac{L}{K_{xx}}\right)^2}}$$

Here W_B about X-axis

$$\boxed{W_{BX} = \frac{\sigma_c A}{1 + a\left(\frac{L}{K_{xx}}\right)^2}}$$

about Y-axis

$$\boxed{W_{BY} = \frac{\sigma_c A}{1 + a\left(\frac{L}{2K_{yy}}\right)^2}}$$

Both ends hinged $L = l$

Both ends hinged $L = \frac{l}{2}$

moment of inertia about X-axis

$$\boxed{I_{xx} = \frac{1}{12}\left[4t\left(5t^3\right) - 3t\left(3t\right)^3\right] = \frac{419}{12}t^4}$$

moment of inertia about Y-axis

$$\boxed{I_{yy} = \frac{1}{12}\left[2 \times \frac{1}{12} t \times (4t)^3 + \frac{1}{12}(3t)\, t^3\right] = \frac{131}{12}t^4}$$

So ∴ $\boxed{\frac{I_{xx}}{I_{yy}} = \frac{419}{12} \times \frac{12}{131} = 3.2}$

so $\boxed{I_{xx} = 3 (or) 3.5\, I_{yy}}$

minor (or) major dia of bolts

$$\boxed{d_b = \frac{d_{cb}}{0.84}}$$

② Dimension of crank pin at big end & piston pin at small pin
(gudgeon pin) (wrist pin)

→ the max load carried by both pins is the max force

F_c max gas force

$$\boxed{F_c = \frac{\pi D^2}{4} \times P} \quad — ①$$

→ Load on crank pin = projected area × bearing pressure

$$\boxed{= d_c \cdot l_c \cdot P_{bc}} \quad — ②$$

$$\boxed{l_c = 1.25 d_c \text{ to } 1.5 d_c}$$

Load on the piston pin

$$\boxed{= d_p \cdot l_p \cdot P_{bc}} \quad — ③$$

$$\boxed{l_p = 1.5 d_p \text{ to } 2 d_p}$$

① = ② $d_c \; l_c$

① = ② $d_p \; l_p$

③ Size of bolts for securing big end cap :-

→ Bolts & cap are subjected to tensile force which corresponds to inertia force of reciprocating part

$$\boxed{F_I = m_R \cdot \omega^2 \cdot r \left(\cos\theta + \frac{\cos 2\theta}{\mu_r}\right)}$$

Now $\theta = 0$ angle of inclination

$$\boxed{F_I = m_R \, \omega^2 \cdot r \cdot \left(1 + \frac{r}{l}\right)} \quad — ①$$

m_R = mass of reciprocating part (kg)

ω = angular speed rad/s

r = radius of crank

d_{cb} = core dia

n_b = no. of bolts.

and Force on the bolts

$$\boxed{F_b = \frac{\pi}{4} (d_{cb})^2 \times n_b \times \sigma_t} \quad — ②$$

by ① = ②

$$\boxed{F_I = \frac{\pi}{4} (d_{cb})^2 \sigma_t \times n_b}$$