Design of Piston

1) Design a cast iron piston for a single acting four stroke engine for the following data.

Cylinder bore = 100 mm

Stroke = 120 mm

Maximum gas pressure = 5 N/mm^2

Indicated mean effective pressure = 0.65 N/mm^2

Fuel consumption = 0.227 Kg/KW-Hr

Speed = 2200 rpm

Assume suitable data.

Given data:

$D = 100$ mm

$L = 120$ mm

$P = 5$ N/mm^2

$P_m = 0.65$ N/mm^2

Fuel consumption = 0.227 kg/kW-Hr

= 6.3106×10^{-5} kg/kW-s

$N = 2200$ rpm

1 kg/h = 0.000278 kg/s

To design:

Piston for four stroke engine

Solution:

(i) Piston Head (or) Crown

On the basis of first consideration of straining action

Thickness of Piston head $[t_H] = \sqrt{\dfrac{3PD^2}{16\sigma_t}}$

$= \sqrt{\dfrac{3 \times 5 \times 100^2}{16 \times 50}}$

$t_H = 13.69$ mm

On the basis of Second consideration of heat transfer

$t_H = \dfrac{H}{12.56\,k\,(T_C - T_E)}$

$H = C \times HCV \times m \times BP$

$H = 0.05 \times 45 \times 10^3 \times 6.3106 \times 10^{-5} \times 8.98 \times 10^3$

$H = 1275$ KW

$t_H = \dfrac{1275 \times 10^3}{12.56 \times 46.6 \times 220}$

$t_H = 9.9$ mm

for Four stroke engine $n = \dfrac{N}{2}$

$B.P = I.P \times \eta_m$

$I.P = \dfrac{P_m L A n}{60}$

$= \dfrac{0.65 \times 120 \times \frac{\pi}{4} \times 100^2 \times \frac{2200}{2}}{60}$

$I.P = 11.23 \times 10^6$ W

Assume $\eta_m = 80\%$

$B.P = 11.23 \times 10^6 \times 0.8$

$= 8.98 \times 10^6$ W

$B.P = 8.98 \times 10^3$ KW

The thickness of piston head $t_H = 13.69$ mm,

Since $t_H > 9$ mm, So no ribs are required

(ii) <u>Piston rings</u>

Radial Thickness of ring $t_1 = D \times \sqrt{\frac{3 P_w}{\sigma_t}}$

$= 100 \times \sqrt{\frac{3 \times 0.04}{110}}$

$$\boxed{t_1 = 3.3 \text{ mm}}$$

Axial Thickness $t_2 = 0.7 t_1$

$= 0.7 \times 3.3$

$$\boxed{t_2 = 2.31 \text{ mm}}$$

Width of the top land

$b_1 = 1.2 t_H = 1.2 \times 13.69$

$$\boxed{b_1 = 16.428 \text{ mm}}$$

Width of the other ring land

$b_2 = 0.75 t_2 = 0.75 \times 2.31$

$$\boxed{b_2 = 1.7325 \text{ mm}}$$

Gap between the free ends of the ring

$G_1 = 3.5 t_1$

$= 3.5 \times 3.3$

$G_1 = 11.55$ mm

Gap when the ring is in the cylinder

$G_2 = 0.002D = 0.002 \times 100$

$G_2 = 0.2$ mm

(iii) Piston Barrel

Maximum thickness of piston barrel (t_3)

$t_3 = 0.03D + t_1 + 4.9$

$= (0.03 \times 100) + 3.3 + 4.9$

$t_3 = 11.2$ mm

Piston wall thickness towards open end

$t_4 = 0.35 t_3 = 0.35 \times 11.2$

$t_4 = 3.584$ mm

(IV) Piston Skirt

Maximum Side thrust on the cylinder due to gas pressure

$$R = \mu \times \left(\frac{\pi}{4}\right) \times D^2 \times P$$

$$R = 0.1 \times \frac{\pi}{4} \times 100^2 \times 5$$

$$\boxed{R = 3927\,N}$$

Consider $P_b = 0.45\,N/mm^2$

$$R = P_b \times D \times l$$

$$3927 = 0.45 \times 100 \times l$$

$$\boxed{l = 87.27\,m}$$

Total length of the piston

$$L = l + (4t_2 + 3b_2) + b_1$$

$$= 87.27 + (4(2.31) + 3(1.7325)) + 16.428$$

$$\boxed{L = 118.14\,mm}$$

(V) Piston pin

~~Load on pin due~~

Length of pin in the bush of Small end of Connecting rod (l_1) $= 0.45 \times D$

$$l_1 = 0.45 \times 100$$

$$\boxed{l_1 = 45 \text{ mm}}$$

Load on pin due to bearing pressure $= P_{b_1} \times d_0 \times l_1$

$= 25 \times d_0 \times 45$

Load on pin due to bearing pressure $= 1125\, d_0$ → (1)

Load on piston due to gas pressure $= \frac{\pi}{4} \times D^2 \times P$

$= \frac{\pi}{4} \times 100^2 \times 5$

Load on piston due to gas pressure $= 39270$ N → (2)

(1) = (2)

$39270 = 1125\, d_0$

$$\boxed{d_0 = 35 \text{ mm}}$$

Inside diameter $d_i = 0.6 \times d_o$

$= 0.6 \times 35$

$d_i = 21$ mm

We know

$$Z = \frac{\pi}{32}\left[\frac{d_o^4 - d_i^4}{d_o}\right]$$

$$= \frac{\pi}{32} \times \left[\frac{35^4 - 21^4}{35}\right]$$

$Z = 3664$ mm^3

$$M = \frac{P \times D}{8}$$

$$P = \frac{\pi}{4} \times D^2 \times p$$

$$= \frac{\pi}{4} \times 100^2 \times 5$$

$$= 39270$$

$$= \frac{39270 \times 100}{8}$$

$M = 490875$ N.mm

$M = Z \times \sigma_b$

$490875 = 3664 \times \sigma_b$

$\sigma_b = 134$ N/mm^2

Since the Value of σ_b is less than 140 N/mm^2

So it is Satisfactory

Result:

(i) Piston head

$t_H = 13.69$ mm

(ii) Piston rings

$t_1 = 3.3$ mm

$t_2 = 2.31$ mm

$b_1 = 16.428$ m

$b_2 = 1.7325$ mm

$G_1 = 11.55$ mm

$G_2 = 0.2$ mm

(iii) Piston barrel

$t_3 = 11.2$ mm

$t_4 = 3.584$ mm

(iv) Piston Skirt

$R = 3927$ N

$l = 87.27$ m

$L = 118.14$ mm

(v) Piston pin:

$l_1 = 45$ mm

$d_o = 35$ mm

$d_i = 21$ mm

$\sigma_b = 134$ N/mm^2