Design of Connecting rod

1) Design a connecting rod for an I.C Engine running at 1800 rpm and developing a maximum pressure of 3.15 N/mm^2. The diameter of the piston is 100mm; mass of the reciprocating parts per cylinder 2.25kg, length of connecting rod 380 mm, Stroke of piston 190 mm and compression ratio 6:1. Take a factor of safety of 6 for the design. Take length to diameter ratio for big end bearing as 1.3 and Small end bearing as 2 and the corresponding bearing pressures as 10 N/mm^2 and 15 N/mm^2. The density of material of the rod may be taken as 8000 Kg/m^3 and the allowable stress in the bolts as 60 N/mm^2 and in Cap as 80 N/mm^2. The rod is to be of I-Section for which you can choose your own proportion.

Draw a neat dimensioned sketch showing provision for lubrication. Use Rankine formula for which the numerator constant may be taken as 320 N/mm^2 and the denominator constant 1/7500.

Given data:

$N = 1800$ rpm

$p = 3.15\ N/mm^2$

$D = 100$ mm

$m_R = 2.25$ kg

$L = 380$ mm

Stroke of piston $= 190$ mm

Compression ratio $= 6:1$

FOS $= 6$

$\sigma_c = 320\ N/mm^2$, $a = \frac{1}{7500}$

$\sigma_t = 60\ N/mm^2$

To design

Connecting rod.

Solution:

(i) Dimension of I-Section of Connecting rod

Flange and Web Thickness $= t$

Width of the Section $B = 4t$

Dept or height of Section $H = 5t$

First we will find whether the Section is Satisfactory or not $\left[\frac{I_{xx}}{I_{yy}} = 4\right]$

Now,

area of Section $A = 2(4t \times t) + (3t \times t)$

$$A = 11t^2$$

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

$$= \frac{419}{12} t^4$$

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

$$= \frac{131}{12} t^4$$

$$\frac{I_{xx}}{I_{yy}} = \frac{419}{12} t^4 \times \frac{12}{131 t^4}$$

$$\boxed{\frac{I_{xx}}{I_{yy}} = 3.2}$$

Now let us find the dimension of this I Section.

Since the connecting rod is designed by taking the force on the connecting rod (F_c) equal to the maximum force on the piston (F_L) due to gas pressure

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

$= \frac{\pi}{4} \times 100^2 \times 3.15$

$$\boxed{F_c = F_L = 24740 \text{ N}}$$

Bucking load $W_B = F_c \times F.O.S$

$= 24740 \times 6$

$$\boxed{W_B = 148440 \text{ N}}$$

According to rankine formula

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

$$K_{xx} = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{(419/12) \times t^4}{11t^2}}$$

$$\boxed{K_{xx} = 1.78t}$$

$$W_B = \frac{320 \times 11t^2}{1 + \frac{1}{7500}\left(\frac{380}{1.78t}\right)^2}$$

$$148440 = \frac{3520t^2}{1 + \frac{6.08}{t^2}}$$

~~$148440 + 902515.2t^2 = 3520t^2$~~

$$\left(1 + \frac{6.08}{t^2}\right) 148440 = 3520 t^2$$

$$148440 + \frac{902515.2}{t^2} = 3520t^2$$

$$\frac{148440t^2 + 902515.2}{t^2} = 3520t^2$$

$$3520t^4 = 148440t^2 + 902515.2$$

$$t^4 = \frac{148440t^2 + 902515.2}{3520}$$

$$t^4 = 42.17t^2 + 256.4$$

$$t^4 - 42.17t^2 - 256.4 = 0$$

$$t^2 = 47.56$$

$$t = 6.89$$

$$t = 7\,mm$$

Substitution method

Let $x = t^2$

$x^2 - 42.17x - 256.4 = 0$

$x = 47.56$

$t^2 = 47.56$

Thus the dimension of I Section of connecting rod are

Thickness of flange & web of Section $t = 7mm$

width of Section $= B = 4t = 4 \times 7 = 28$

$B = 28\ mm$

Depth or height of Section $H = 5t = 5 \times 7 = 35$

$H = 35\ mm$

Depth near the Small end

$H_1 = 0.75 H$

$= 0.75 \times 35$

$H_1 = 26.25$ mm

Depth near the big end

$H_2 = 1.1 H$

$= 1.1 \times 35$

$H_2 = 38.5$ mm

Dimension of the Section near Small end

$= H_1 \times B = 26.25 \times 28$

$= 73.5$ mm

Dimension of the Section near big end

$= H_2 \times B = 38.5 \times 28$

$= 1078$ mm

Dimensions of the crank pin or big end bearing

Load on crank pin $= d_c \times l_c \times P_{bc}$

$= d_c \times 1.3 d_c \times 10$ $\quad l_c = 1.3 d_c$

$= 13\, d_c^2$

$F_L = \frac{\pi}{4} d^2 p$

equating the load on the crank pin to the max gas force

$13\, d_c^2 = F_L = \frac{\pi}{4} D^2 p$

$13\, d_c^2 = \frac{\pi}{4} \times 100^2 \times 3.15$

$d_c = 43.6 \simeq 44$

$d_c = 44 \text{ mm}$

$l_c = 1.3\, d_c = 1.3 \times 44$

$l_c = 57.2 \text{ mm}$

Dimension of piston pin or Small end bearing

Load on piston pin $= d_p \times l_p \times P_{bp}$

$= d_p \times 2d_p \times 15$

$= 30\, d_p^2$ $\qquad l_p = 2d_p$

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

Equating the load on piston pin to the max gas force

$30\, d_p^2 = F_L = \frac{\pi}{4} \times 100^2 \times 3.15$

$30\, d_p^2 = \frac{\pi}{4} \times 100^2 \times 3.15$

$d_p = 28.7 \simeq 29$

$d_p = 29\ mm$

$l_p = 2 d_p$

$l_p = 2 \times 29 = 58$

$l_p = 58\ mm$

Size of bolt for securing the big end cap

Force on the bolts

$$F_1 = \left(\frac{\pi}{4}\right) \times d_{cb}^2 \times \sigma_t \times n_b$$

$$= \frac{\pi}{4} \times d_{cb}^2 \times 60 \times 2$$

$$\boxed{F_1 = 94.25\, d_{cb}^2} \rightarrow (1)$$

Inertia force on reciprocating part

$$F_1 = m_R \times \omega^2 \times r \times \left(1 + \frac{r}{l}\right)$$

$$= 2.25 \times \left[\frac{2\pi \times 1800}{60}\right]^2 \times 0.095 \times \left(1 + \frac{0.095}{0.380}\right)$$

$$\boxed{F_1 = 9493\ N} \rightarrow (2)$$

$$(1) = (2)$$

$$94.25\, d_{cb}^2 = 9493$$

$$\boxed{d_{cb} = 10.03\ mm}$$

$$d_b = \frac{d_{cb}}{0.84} = \frac{10.03}{0.84}$$

$$\boxed{d_b = 11.94\ mm}$$

Thickness of big end cap

$$\sigma_b = \frac{M_c}{Z_c}$$

$$M_c = \frac{F_1 \times x}{6}$$

$x = d_c + [2 \times \text{thickness of bearing liner}] + d_b + \text{clearance}$

$= 44 + [2 \times 3] + 29 + 3$

$x = 82 \text{ mm}$

$$M_c = \frac{9490 \times 82}{6}$$

$M_c = 129697 \text{ N·mm}$

$$Z_c = \frac{b_c \times (t_c)^2}{6}$$

$= \frac{29 + (44)^2}{6}$ $= \frac{29\,(t_c^2)}{6}$

$Z_c = 351.7$

$Z_c = 4.83\, t_c^2$

$$\sigma_b = \frac{M_c}{Z_c}$$

$$80 = \frac{129697}{4.83\, t_c^2}$$

$$\boxed{t_c = 18.3 \text{ mm}}$$

Result:

(i) Dimension of I section of connecting rod

$t = 7$ mm

$B = 28$ mm

$H = 35$ mm

$H_1 = 26.25$ mm

$H_2 = 38.5$ mm

(ii) Dimension of crank pin or big end bearing

$d_c = 44$ mm

$l_c = 57.2$ mm

(iii) Dimension of piston pin or small end bearing

$d_p = 29$ mm

$l_p = 58$ mm

(iv) Size of bolt for Securing the big end cap

$d_b = 11.94$ mm

(v) Thickness of big end cap

$t_c = 18.3$ mm