HW-5

Q5) $\frac{L_{95}}{L_{90}} = \left(\frac{\ln(1/R_{95})}{\ln(1/R_{90})}\right)^{1/b}$

$= \left(\frac{\ln(1/0.95)}{\ln(1/0.90)}\right)^{1/1.17}$

$= \left(\frac{0.0513}{0.1054}\right)^{0.5547} \approx 0.54$

$\therefore L_{90} \times 0.54 = L_{95} \Rightarrow 20 \times 10^6 \times 0.54 = L_{95} = 10.8 \times 10^6$

Finding the equivalent Radial Load

$W = \left(\frac{n_1 W_1^3 + n_2 W_2^3 + n_3 W_3^3 + n_4 W_4^3}{n_1 + n_2 + n_3 + n_4}\right)^{1/3}$

$= \left(\frac{0.1n \times 3^3 + 0.2n \times 2^3 + 0.3n \times 1^3 + 0.4n \times 0^3}{0.1n + 0.2n + 0.3n + 0.4n}\right)^{1/3}$

$W = 1.663$ kN

Now, to find dynamic loading

$C = W\left(\frac{L_{90}}{10^6}\right)^{1/k} = 1.663 \times \left(\frac{20 \times 10^6}{10^6}\right)^{1/3}$

$= 4.514$ kN

Now for 95% reliability

~~$C = W \times \left(\frac{L_{95}}{10^6}\right)^{1/k} = 1.663 \times \left(\frac{10.8 \times 10^6}{10^6}\right)^{1/3}$~~

~~$= 3.676$ kN~~

~~$L_{R} = \frac{L_{95}}{0.54}$~~ $L_{90} = \frac{L_{95}}{0.54} \rightarrow \frac{20 \times 10^6}{0.54} = 37.04 \times 10^6$

$\therefore C = W\left(\frac{L_{90}}{10^6}\right)^{1/k} = 1.663 \times \left(\frac{37.04 \times 10^6}{10^6}\right)^{1/3}$

$\boxed{C = 5.54 \text{ kN}}$

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06) $L_{99} = 60 \times N \times L_h = 60 \times 720 \times 24000 = 1036.8 \times 10^6$ rev

Considering life adjustment factors for operating condition & material to be 0.9 and 0.85

$$\frac{L_{99}}{L_{90}} = \left(\frac{\ln(1/R_{99})}{\ln(1/R_{90})}\right)^{1/b} = \left(\frac{\ln(1/0.99)}{\ln(1/0.90)}\right)^{1/1.17} \times 0.9 \times 0.85$$

$$= \left(\frac{0.01005}{0.1054}\right)^{0.8547} \times 0.9 \times 0.85 = 0.1026$$

$$L_{90} = \frac{L_{99}}{0.1026} = \frac{1036.8 \times 10^6}{0.1026} = 10105 \times 10^6 \text{ rev}$$

Now,

$$C = W\left(\frac{L_{90}}{10^6}\right)^{1/k}$$

$$= (1)\left(\frac{10105 \times 10^6}{10^6}\right)^{1/3} \text{ kN}$$

$$\boxed{C = 21.62 \text{ kN}}$$

Q7) $L = 60N\, L_h = 60 \times 15000 \times N = 900000N$ rev

We know basic dynamic equivalent radial load,

$W = X \cdot V \cdot W_R + Y \cdot W_A$

$W = W_R + 1.5 W_A$

For Basic Dynamic load rating,

$C = W \left(\frac{L}{10^6}\right)^{1/k} = (W_R + 1.5 W_A) \left(\frac{9 \times 10^5 N}{10^6}\right)^{1/3}$

We know

$W = [X \cdot V \cdot W_R + Y \cdot W_A] K_S$

It is given that radial load factor = 1 and axial load factor = 1.5 . $V = 1$

$W = (W_R + 1.5 W_A) K_S$

Now, for different operating cycles

$W_1 = (2000 + 1.5 \times 1200) \times 3 = 11400N$

$W_2 = (1500 + 1.5 \times 1000) \times 1.5 = 4500N$

$W_3 = (1000 + 1.5 \times 1500) \times 2 = 6500N$

$W_4 = (1200 + 1.5 \times 2000) \times 1 = 4200N$

Life of bearing in revolutions

$L = 60 N \times L_h = 0.9 \times 10^6 N$ rev

Life of bearing is $1/10^{th}$ of a cycle

$L_1 = \frac{1}{10} \times 0.9 \times 10^6 \times N_1 = 36 \times 10^6$ rev

$L_2 = \frac{1}{10} \times 0.9 \times 10^6 \times 500 = 45 \times 10^6$ rev

$L_3 = \frac{1}{10} \times 0.9 \times 10^6 \times 600 = 108 \times 10^6$ rev

$L_4 = \frac{1}{10} \times 0.9 \times 10^6 \times 800 = 432 \times 10^6$ rev

Now,

$$w = \left(\frac{L_1(w_1)^3 + L_2(w_2)^3 + L_3(w_3)^3 + L_4(w_4)^3}{L_1+L_2+L_3+L_4}\right)^{1/3}$$

$$w = \left(\frac{1.191 \times 10^5 \times 10^{12}}{621 \times 10^6}\right)^{1/3}$$

$w = 5767\ N$

$L = L_1+L_2+L_3+L_4 = 621 \times 10^6$ rev

Now,

$$C = w\left(\frac{L}{10^6}\right)^{1/3} = 5767 \times \left(\frac{621 \times 10^6}{10^6}\right)^{1/3}$$

$C = 5767 \times 8.53 = 49.193$ kN

Using the table in Book, single row deep groove ball bearing no. 215 having $C = 52$ kN is the appropriate one.

Q1) $T_{max} = \frac{\pi}{16} \sigma_y d^3$

$= \frac{\pi}{16} \times 5\,0000000$

$=$ ~~9822~~ 98.2 kNm

$T_{max} = \frac{T}{FoS} =$ 49.1 kNm

$F_s = \tau \times A_s$

$T = F_s \times \frac{d}{2}$

$\therefore T = \tau \times l \times w \times \frac{d}{2}$

$l = \frac{2T}{\tau \times w \times d}$

$\therefore l = \frac{2 \times 49.1 \times 10^6}{42 \times 16 \times 50}$

$l = 2921.43\,mm$

Now, checking for crushing failure criterion

$F_c = \sigma_c A_c$

$T = F_c \times \frac{d}{2}$

$T = \sigma_c \times l \times t \times \frac{d}{2}$

$l = \frac{2T}{\sigma_c t d}$

$\therefore l = \frac{2 \times 49.1 \times 10^6}{70 \times 10 \times 50}$

$l = 2805.14\,mm$

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From shear criterion = 2921.63m
From crushing criterion = 2805.14mm

The shear criterion governs the required length of key

$\therefore \boxed{l = 2922mm}$

Q 2) $T = \frac{\pi}{16} \tau_y d^3$

$T = \frac{\pi}{16} \times 200 \times 256047.875$

$T = 100.68$ kNm

Now $T_{max} = \frac{100.68}{FOS} = \frac{100.68}{2} = 50.34$ kNm

Determining the compressive force acting on the key

$T = F_c \times \frac{d}{2} \Rightarrow F_c = \frac{2T}{d}$

$F_c = \frac{2 \times 50,340 \times 10^3}{63.5} \Rightarrow F_c = 1585,826.77N$

$T = \frac{\pi}{16} \times 200 \times 10^6 \times (0.0635)^3$

$T = 9.964$ kN

$T = \frac{T \cdot k}{d}$ $\left(\begin{array}{l} d = 0.016m \\ k = 1 - 0.5 \times 16/63.5 = 0.745 \end{array} \right)$

$T = \frac{9.964 \times 10^3 \times 0.745}{0.016}$

$T = 7.427 \cdot L^{-1}$

As $\tau \le 0.4\times10^6$

$C \ge \frac{T}{\tau}$

$C \ge \frac{19.966\times10^3}{0.4\times10^6}$

$C \approx 24.9mm$

Q3) $T_{shaft} = \frac{\pi}{16} \times 355\times10^6 \times (30\times10^{-3})^3 = 1870.5N$

$= 1.870kN$

$T_{shaft} = T_{sun}$

$1870 = l\omega \frac{d}{2} \times \left(\frac{\sigma}{2\times3}\right)$

$1870 = l\omega \times \left(\frac{30}{1000\times2}\right) \times \left(\frac{650\times10^6}{2\cdot6}\right)$

$l\omega = 0.00115$

$l = \frac{0.00115}{0.03/4}$

$\boxed{l = 153.3mm}$